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Environmental Solutions

HANDBOOK
XA00131
REVISION A

EXO NitraLED™

EXO NitraLED Handbook

NITRATE MONITORING, ENLIGHTENED.

YSI
a xylem brand

EXO NitraLED™

The information contained in this manual is subject to change without notice.

Effort has been made to make the information in this manual complete, accurate, and current.

The manufacturer shall not be held responsible for errors or omissions in this manual.

Consult ***YSI.com*** *for the most up-to-date version of this manual.*

Thank you for purchasing the **EXO NitraLED**™ UV Nitrate Sensor. This document is a complete guide to the sensor operation and best practices.

EXO NitraLED is an optical nitrate sensor designed for long-term, low-drift monitoring. Built-in corrections for Natural Organic Matter (NOM) and Turbidity minimize interferences in freshwater environments. The NitraLED sensor can integrate with any EXO Sonde.

Safety Information

EXO NitraLED emits UV-B/C radiation within the optical cell. Personal protective equipment (PPE) for UV light, including safety glasses and gloves, should be worn when interfacing with a powered sensor.

The manufacturer is not responsible for any damages due to misapplication or misuse of this product including, without limitation, direct, incidental and consequential damages, and disclaims such damages to the full extent permitted under applicable law. The user is solely responsible to identify critical application risks and install appropriate mechanisms to protect processes during a possible equipment malfunction.

Please read this entire manual before unpacking, setting up, or operating this equipment. Pay attention to all precautionary statements. Failure to do so could result in serious injury to the operator or damage to the equipment.

Technical Support

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Check out our comprehensive collection of how-to videos covering all aspects of EXO.

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Quick Reference of NitraLED Sensor Application

For clarity and consistency, this section serves as a summary of recommended uses for the NitraLED sensor. To fully understand best practices and sensor applications, please read the entire document.

i. Site Type

The NitraLED sensor is recommended for freshwater systems only. Brackish and marine environments with high salinity can have ions and chemical species in the water column that interfere with sensor performance at the optical measurement wavelengths (Section 3.5).

ii. Sampling Application

The NitraLED sensor is best suited for extended deployments, due to the need for Site-Specific Corrections and its ability to maintain stable calibrations. The sensor may be applicable for spot sampling, but sensor performance can be hindered if Site-Specific Corrections are not performed for each sampled site, which can be laborious. If all spot-sampled sites have very low interfering conditions (low turbidity and low Natural Organic Matter (NOM)), then the sensor performance may be satisfactory for spot sampling without Site-Specific Corrections (Section 6.1).

iii. Turbidity

The NitraLED is well-suited for deployment at sites with low sediment conditions, or turbidity levels less than 15 FNU. In low turbidity conditions, a Site-Specific Correction may not be required to improve data. Site examples are source water, oligotrophic lakes, or high-elevation streams. The NitraLED is also recommended at sites with turbidity levels between 15 and 200 FNU, though a Site-Specific Correction may be required for optimal data. The sensor may experience performance issues at sites with turbidity above 200 FNU, due to the optical interference. These may include wastewater, sites with extreme algal blooms, high stormflow events, and post-fire runoff (Section 3.3).

iv. Natural Organic Matter (NOM)

The NitraLED is recommended for deployment at sites with average or low Natural Organic Matter (NOM). However, sensor performance is affected by the species of NOM present and how it varies from factory-calibrated standard conditions. A Site-Specific Correction is often required to achieve high-quality data and offset NOM interference. The sensor may not be recommended at sites with very high NOM, such as wetlands, bogs, peatlands, and areas of increased organic degradation, as the level of interference may be too high to offset using corrections (Section 3.4).

v. Site Conditions

The NitraLED performs best when site conditions are homogenous, regarding stable flow rates such as during baseflow, the deployment is free of obstructions such as algae mats, woody debris, eddies, and trash, the water quality is consistent, and the water column is well-mixed. Heterogeneity in the water column can cause unpredictability and noise in the nitrate data as the sensor continuously corrects for defined interferences (Section 3.7).

Because Site-Specific Corrections are static coefficients applied to the internal algorithm, the sensor can target conditions at which the corrections were applied only. For example, if corrections were applied using baseflow samples, the sensor may over- or under-correct during stormflow, as the interfering species of turbidity and NOM can change during events and seasonality. To monitor event-related flow, it is best to perform a Site-Specific Correction during an event to create applicable correction coefficients.

vi. Maintenance

It is important to have a firm understanding of the NitraLED sensing technology to successfully optimize deployments and troubleshoot data (Section 3.0). The NitraLED requires regular calibration with NitraLED Standards (Section 1.4). Optical drift in LED sensors over time is natural and can be corrected with regular user calibrations.

Site-Specific Corrections are frequently necessary to improve sensor performance to correct for optical interferences present at the site. Troubleshooting during the correction calibration process may be necessary to minimize contamination, limit bubble formation on the sensor lens, and overall achieve accurate coefficients (Section 5.4). Regular site maintenance will ensure the sensor performance remains consistent and reliable. For best practice, an EXO Central Wiper should be installed alongside the NitraLED to limit fouling (Section 4.0).

vii. Total Absorbance

The total optical absorbance at a site should be less than 2.0 Absorbance Units (AU) at 235 nm. This limit is ideal for the accuracy specs of the NitraLED. Optical absorbance can be determined by benchtop spectrophotometer. Total absorbance over 2.0 AU will likely result in unreliable data, as this exceeds the signal headroom of the sensor at the measurement wavelengths (Section 3.7).

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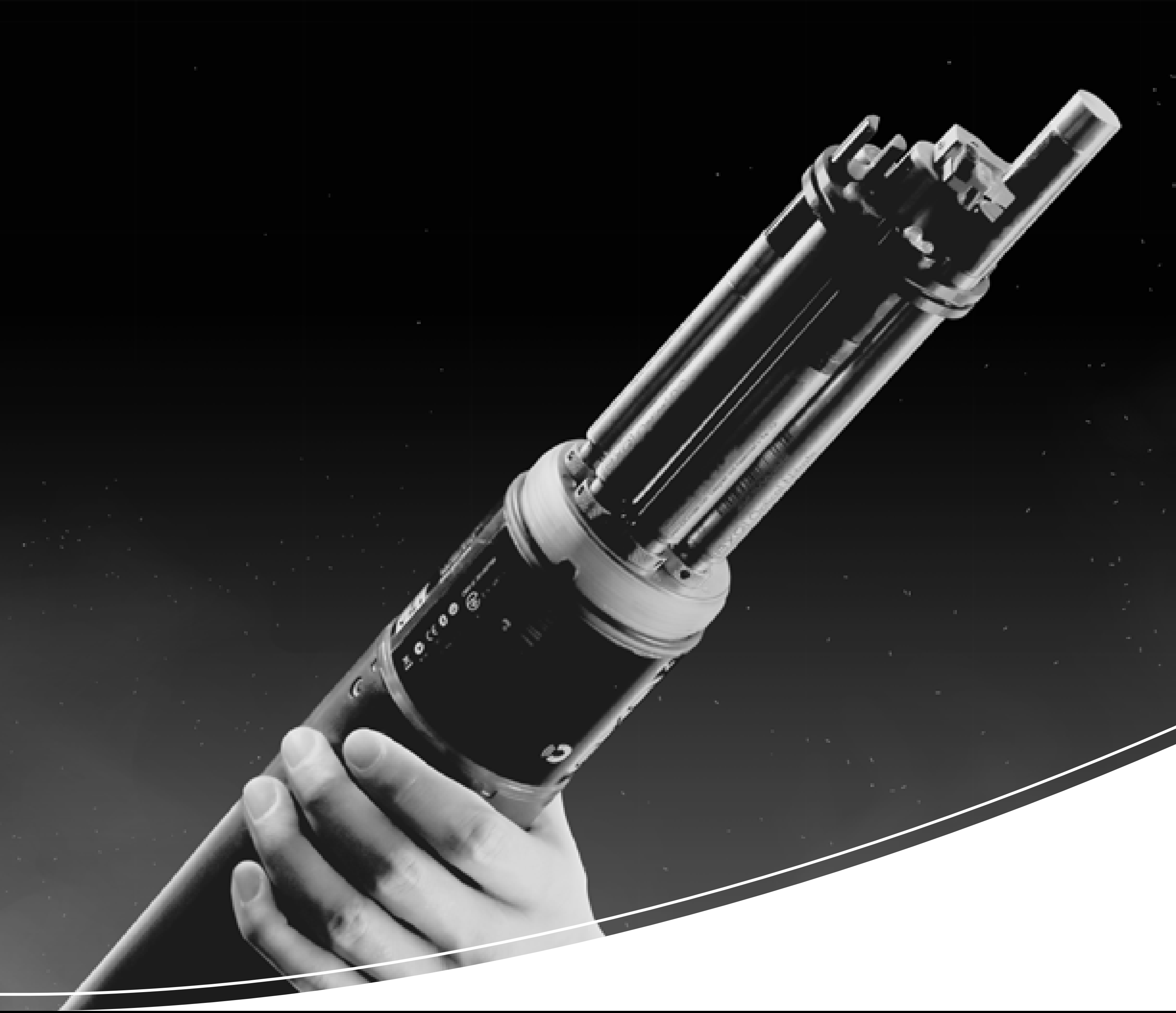


Section 1
Required Equipment

1.1 EXO Multiparameter Sonde

The **EXO Sonde** provides the power, data storage, and connection point required for NitraLED use. While the NitraLED can be used with any EXO sonde, we recommend the EXO2 or EXO3 for long-term deployments, or the EXO2^{S} or EXO3^{S} if external power can be supplied.

Selection Guide

	EXO1	EXO1^{S}	EXO1^{S} with depth	EXO2	EXO2^{S}	EXO3	EXO3^{S}
Sensor Ports	4	4	4	7 (6 Sensors + 1 Central Wiper)	7 (6 Sensors + 1 Central Wiper)	5 (4 Sensors + 1 Central Wiper)	5 (4 Sensors + 1 Central Wiper)
Battery Power	2 D-cell batteries	External power required	External power required	4 D-cell batteries	External power required	2 D-cell batteries	External power required
Battery Life	90 days*	–	–	90 days*	–	60 days*	–
External Power	9 - 16 V	9 - 16 V	9 - 16 V	9 - 16 V	9 - 16 V	9 - 16 V	9 - 16 V
Central Wiper	–	–	–	✓	✓	✓	✓
Auxiliary Port	–	–	–	✓	✓	–	–
Diameter	4.70 cm (1.85 in)	4.70 cm (1.85 in)	4.70 cm (1.85 in)	7.62 cm (3.00 in)	7.62 cm (3.00 in)	7.62 cm (3.00 in)	7.62 cm (3.00 in)
Length with guard	64.53 cm (25.40 in)	44.77 cm (17.63 in)	46.41 cm (18.27 in)	70.52 cm (27.76 in)	42.87 cm (16.88 in)	58.61 cm (23.07 in)	42.87 cm (16.88 in)
Weight without sensor payload	1.42 kg (3.13 lbs)	0.48 kg (1.06 lbs)	0.56 kg (1.24 lbs)	3.60 kg (7.94 lbs)	1.06 kg (2.34 lbs)	2.00 kg (4.41 lbs)	1.06 kg (2.34 lbs)

*Based on a full sensor payload and a 15-minute logging interval; actual battery life will depend on the number of sensors and measurement frequency.

EXO Sonde Specifications*	
Memory	>1,000,000 logged readings, 512 MB total memory
Software	Kor Software for Windows; Kor Mobile for Android
Communications	
Computer Interface	YSIP via USB Signal Output Adapter (SOA) and Bluetooth
Output Options	All: RS-232 & SDI-12 via DCP-SOA Modbus & RS-485 via Modbus-SOA EXO3 & EXO3^{S}: SDI-12 Native Output
Temperature	
Operating	-5 to 50 °C (23-122 °F)
Storage	-20 to 80 °C (-4 to 176 °F)
Depth Rating	0 to 250 m (0 to 820 ft)
Sampling Rate	Up to 4 Hz (0.25 seconds)
Sensor Options	Conductivity/Temperature, Depth, Dissolved Oxygen, fDOM, ISE Ammonium, ISE Chloride, ISE Nitrate, pH, pH/ORP, Rhodamine, Total Algae (PC or PE), Turbidity, UV Nitrate
Warranty	3 years

*Specifications indicate typical performance and are subject to change.

1.2 EXO Turbidity Sensor

The **EXO Turbidity sensor** is designed to measure water cloudiness directly in the water. The NitraLED uses the value from the Turbidity sensor for reference. Sediment attenuation has a significant effect on any field nitrate measurement, so it is important to account for the amount and also the type. The Turbidity sensor is essential for NitraLED to account for interferences caused by suspended particles. EXO NitraLED should be deployed in conditions where the turbidity is less than **200 FNU/NTU**.

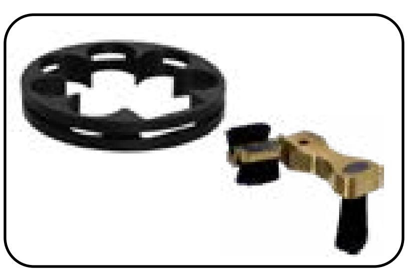
1.3 EXO Conductivity & Temperature Sensor

Temperature and conductance are two critical parameters that impact virtually all water quality measurements. It is extremely important to include a **Conductivity/Temperature (C/T) sensor** in your EXO payload, as most sensors require temperature compensation. YSI offers two versions of this sensor: a Standard C/T sensor and a Wiped C/T sensor with an open cell to enable anti-fouling with the EXO Central Wiper. The Wiped C/T is recommended for long-term deployments on an EXO2 or EXO3 Sonde.

1.4 EXO NitraLED Calibration Standards

The NitraLED is user-calibrated. Degassed, ultrapure (Type 1) water should be used for the first point at 0 mg/L NO_3^--N. **NitraLED-specific calibration standard solutions** are available in concentrations of 5 and 10 mg/L NO_3^--N versions. These standards are filtered to remove optical interferences that may be present in other calibration standards, such as those used for calibrating ion-selective electrodes, and are recommended for use. Users can purchase these standards online at YSI.com.

1.5 Anti-Fouling Accessories



The **EXO Alignment Ring** fits around the EXO sensor payload to minimize movement while the NitraLED Wiper Brush cleans the sensor faces. The Alignment Ring is held tightly in place by an o-ring that makes contact with the sensors. A **NitraLED-specific wiper** effectively cleans all sensor faces with its two-arm design.

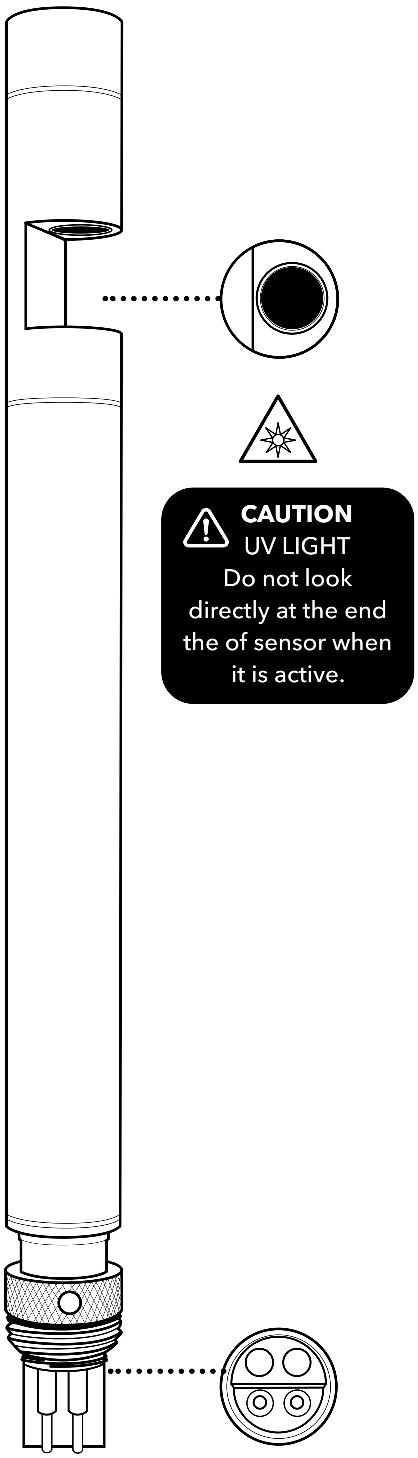
1.6 Ordering Information

Part Number	Item	Description
608090	EXO NitraLED Kit	For use with EXO2/EXO3; includes NitraLED Sensor, Alignment Ring, and Wiper Brush
608040	EXO NitraLED UV Nitrate Sensor	Optical Nitrate Sensor only, no accessories needed for EXO1
599501-XX	EXO1 Sonde	4 ports, internal battery, onboard memory
599502-XX	EXO2 Sonde	7 ports, internal battery, onboard memory, Central Wiper compatible
599503-XX	EXO3 Sonde	5 ports, internal battery, onboard memory, Central Wiper compatible, SDI12 output
577501-XX	EXO1^S Sonde	4 ports, onboard memory, batteryless
577502-XX	EXO2^S Sonde	7 ports, onboard memory, batteryless, Central Wiper compatible
577503-XX	EXO3^S Sonde	5 ports, onboard memory, batteryless, Central Wiper compatible, SDI12 output
599101-01	EXO Turbidity Sensor	Optical turbidity sensor
599870	EXO Conductivity and Temperature Sensor	Standard conductivity-temperature combined sensor
599827	EXO Wiped Conductivity and Temperature Sensor	Central Wiper compatible
608072	NitraLED Calibration Standard, 5 mg/L	Optical nitrate calibration solution
608073	NitraLED Calibration Standard, 10 mg/L	Optical nitrate calibration solution
608080	EXO2/EXO3 Alignment Ring	Accessory to stabilize sensors during wiping
608085	EXO NitraLED Wiper Brush	Custom wiper brush head for optimal NitraLED cleaning

Section 2
Specifications

2.1 NitraLED Sensor Specifications

The EXO NitraLED UV Nitrate Sensor measures nitrate as nitrogen while compensating for interferences from organic matter in freshwater environments. EXO's NitraLED range and accuracy specifications are based on nitrate-nitrogen standards prepared by diluting pure nitrate-nitrogen with Type I water under laboratory temperatures and conditions.



608040

Specifications

Units Measured	NO_3^-N (Nitrate-N) in mg/L
Light Source	UV LED (x2)
Nominal Wavelengths	235nm, 275 nm
Pathlength	10 mm
Measurement Range	0 to 30 mg/L-N
Minimum Detection Limit[1]	0.01 mg/L-N
Accuracy[1] 0 to ≤10 mg/L	± 0.1 mg/L-N or 5% of reading, w.i.g. (within 2°C) ± 0.4 mg/L-N or 5% of reading, w.i.g. (full temp range)
>10 to 30 mg/L	± 7% of reading
Response[2]	T95<30 sec
Resolution	0.01 mg/L-N
Drift/Stability	≤ 0.2 mg/L-N
Repeatability/ Precision[1]	≤ 2% Coefficient of Variation (CV)
Dimensions	21.3 cm L x 1.5 cm Dia
Weight	0.07 kg
Sensor Type	Optical, absorbance

[1] The specifications listed apply to analytes comprised of nitrate in pure water only and absent of all other absorbing species.

[2] Assumes a 30-day deployment with a 15-minute logging interval, and does NOT account for drift due to fouling.

2.2 Additional Specifications

Operating Medium	Fresh water
Operating Temperature	+5 to +35°C
Storage Temperature	-20 to +80°C
Depth Rating	250 m
Warranty	2 years
Compatibility	EXO

Section 3
Theory of Operation

3.1 Principles of Absorbance

UV-nitrate sensors have not supplanted traditional analytical methods such as ion-chromatography for quantitative analysis, but have become common practice as an invaluable screening method due to their inherent advantages of being chemical-free and field deployable. Traditional UV photometers use lamps such as xenon, mercury or deuterium which suffer from high power requirements and remain bulky and expensive. However, recent advances in UV-LED technology have made possible truly miniature UV sources which do not suffer the shortcomings of traditional lamps.

The YSI EXO NitraLED sensor detects nitrate using the basic principle of optical absorbance. All optical technologies must contend with turbidity interference, which occurs due to the scattering of light caused by suspended particles. Sensors that rely on the UV ranges of light will experience Natural Organic Matter (NOM) interference due to absorbance.

The NitraLED employs a UV-LED (center wavelength 235 nm) to generate UV-C optical radiation transmitted across an optical gap of 10 mm where the transmitted optical signal is collected by a UV-enhanced photodiode. The signal is converted to absorbance and follows Beer's Law in the following equation:

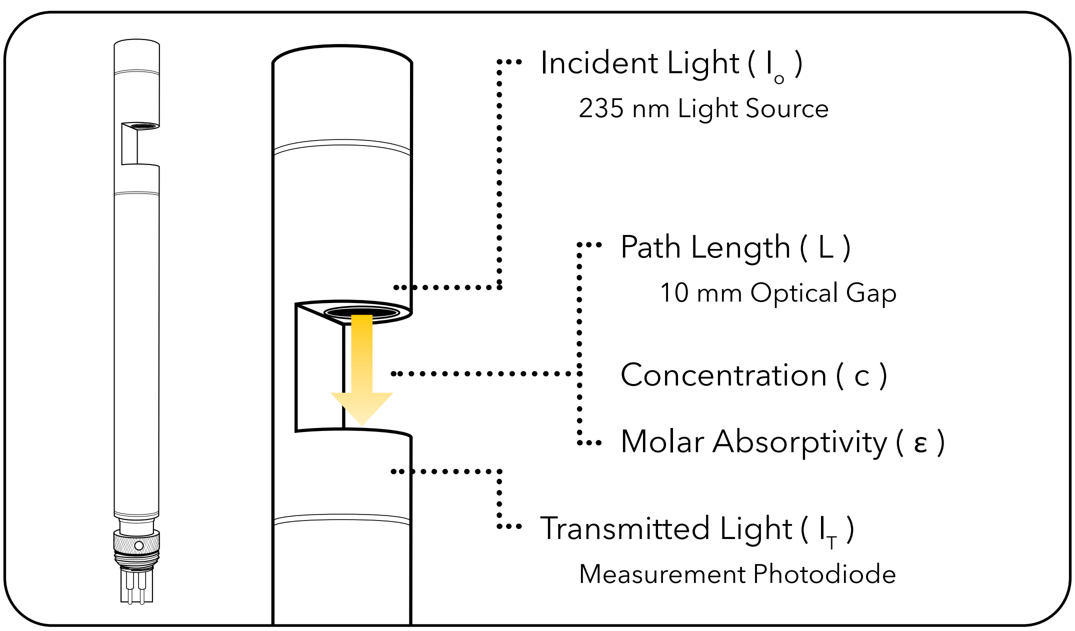
$$A = -\log\left(\frac{I_t}{I_o}\right)$$

where **A** is absorbance in Absorbance Units (AU), I_t is the intensity of light transmitted through the sample, and I_o is the intensity of light as it originates from the sensor.

Concentration, c, is calculated through the Beer-Lambert Law:

$$c = \text{Absorbance} / \varepsilon L$$

where **ε** is absorptivity and **L** is the optical path length.



The concentration of nitrate ions, NO_3^- mg/L, is proportional to the optical absorbance of the UV-C radiation. It is important to note, however, that the UV method presented by YSI does not distinguish between nitrate NO_3^- and nitrite, NO_2^-, owing to similar UV absorption properties and we therefore denote the combined species, NO_3-N (nitrate as nitrogen). However, in natural waters, nitrate is typically the most prevalent species.

The mg/L NO_3^-N concentration of NO_3^-N has a linear relationship to the absorbance of UV radiation and obeys the Beer-Lambert law, but the linearity holds true only for spectrally narrow UV-sources. For spectrally broad UV-LED sources, like those contained in the NitraLED, some degree of non-linearity will be present in the sensor's response due to the polychromatic effect and can become severe for extremely high concentrations of NO_3^-N. To eliminate this non-linearity, the sensor is factory-calibrated at multiple nitrate concentrations and the data fit to a third-order regression.

3.2 Interferences from Non-Intended Attenuating Species

Interference from other non-intended attenuating species needs to be accounted for in any UV absorbance measurement. For YSI's NitraLED, interference correction is loosely-adapted from a Standard Method for measuring nitrate in wastewater. As indicated in the method, use of this screening method is primarily intended for uncontaminated natural waters and potable water supplies where Natural Organic Matter (NOM) and turbidity are understood to be the primary sources of optical interference.

A very simplified equation for how the NitraLED sensor computes absorbance of nitrate based on the total absorbance at 235 nm recorded by the sensor is:

$$A_{235} = A_{NO3\text{-}N} + A_{Turb235} + A_{NOM235}$$

The effects of interferences are determined using a similarly simplified equation at the 275 nm wavelength:

$$A_{275} = A_{Turb275} + A_{NOM275}$$

The absorbance at 235 nm is determined using Beer's Law and then the attenuation due to turbidity, which will have been converted to AU, and absorbance from NOM, estimated from 275 nm, are subtracted. The ANO_3^-N thus calculated will be used in a regression equation that is based upon the factory linearization and then two-point user calibration.

This regression defines the relationship between absorbance and nitrate concentration. It is imperative in the calculation of this regression that the nitrate standards used during calibration have no absorbance from any particulate matter or organic compounds. As stated earlier, this is among the reasons that it is recommended to purchase the standards from YSI.

3.3 Correcting for Turbidity Attenuation

Turbidity can have a significant effect on absorbance measurements, as it can scatter the light on its path from the LED to the detector. The number, size, and shape of particles can all influence the level of light attenuation. Turbidity is handled by leveraging the EXO Turbidity sensor. This sensor must always be used alongside the NitraLED sensor. As seen in Figure 1 below, the relationship between the "absorbance" of 235 nm light and Turbidity FNU is fairly linear. However, the slope of that relationship varies with different sources of turbidity.

The default absorbance correction programmed inside the NitraLED sensor is based on Kaolin (example in figure). This was chosen because it very nearly approximates the average of all the samples YSI worked with. Some of the samples (Miami River and Canoe Club) in Figure 1 were in fact collected from natural waters, while the others (Bentonite, Arizona Test Dust, Diatomaceous Earth, Kaolin, and Elliot Silt Loam) were purchased. It was verified that the samples were nitrate-free in the case of the purchased standards, and field samples were corrected for nitrate when it was present. The graph shows only the 235 nm wavelength correlations, but a similar linearity was observed for Kaolin at 275 nm.

When a user chooses the default turbidity coefficients in Kor software, the relationship between Kaolin and absorbance is applied to the raw signals within the sensor. An average set of Kaolin interference correction coefficients are used based on extensive testing; all of the Kaolin tests conducted are not depicted in Figure 1.

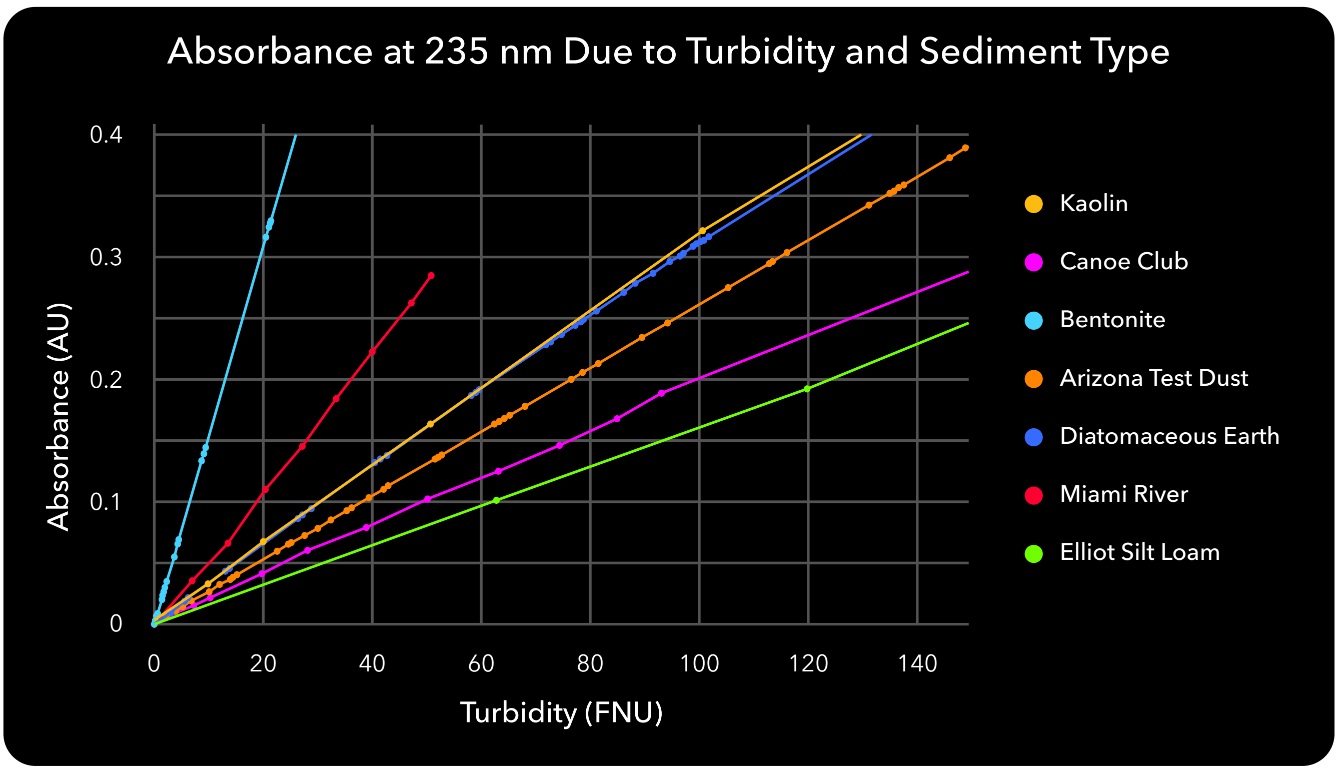


Figure 1: *The absorbance measured by the NitraLED sensor will vary depending on the sediment type and the amount of that sediment in the water sample.*

A user may instead choose to do a Site-Specific Correction. Figure 1 demonstrates that at higher FNU, the difference between samples grows. If users work with higher FNU waters, they may not find these differences acceptable for their study objectives.

For example, the turbidity at a site could be 120 FNU and the absorbance measured by an optical tool (spectrophotometer, NitraLED, etc.) is found to be 0.19 AU. The slope of the equation with site-specific turbidity is 0.00158 AU/FNU. By comparison, the slope of Kaolin is 0.0028 AU/FNU. Therefore we see that depending on the sediment type, the difference between the default absorbance correction and a Site-Specific Correction can have a significant effect on the NitraLED's calculation of nitrate.

When one uses the Site-Specific Correction, NitraLED builds a new turbidity regression equation internally, which will override the use of the default relationship for processing the raw signals in the sensor. During the Site-Specific Correction process, an absorbance value is collected before and after the sample is filtered using a 0.45 µm filter. This difference in AU is expected to be due to particles that were removed by the filter (i.e. turbidity). This method is described in the EXO User's Manual (Rev K and later).

Note that while these measurements of turbidity were made, NitraLED was also collecting measurements using the 275 nm LED. Conveniently then, the corresponding absorbance at each wavelength is determined and subtracted from the total absorbance measured by each sensor. We are now able to narrow down absorbance from NOM and nitrate. The equations from the previous section then become:

$$A_{235} - A_{Turb235} = A_{NO3\text{-}N} + A_{NOM235}$$

$$A_{275} - A_{Turb275} = A_{NOM275}$$

The absorbance of NOM is now known at the 275 nm wavelength but that number is not equal to the absorbance of NOM at 235 nm, which is determined as described below.

3.4 Correcting for NOM

To address interference from Natural Organic Matter (NOM), the NitraLED contains an additional 275 nm LED that is introduced into the transmission beam path. Like other NOx species absorbing at 235 nm, NOM is not the only thing in natural waters that can absorb 275 nm light. But within certain ranges, and especially with user-provided inputs about the environment, the 275 nm LED can facilitate NOM corrections to in-situ measurements. The efficacy of the correction depends upon the nature of the NOM. The basis of the correction is that both nitrate and NOM absorb at 235 nm, but only NOM will absorb at 275 nm. This information is used to perform an internal, subtractive correction.

The correction of NOM from the 275 nm wavelength to an absorbance of NOM at the 235 nm wavelength is loosely adapted from a Standard Method for measuring nitrate in wastewater. The NOM correction factor is equal to the following:

$$\text{NOM factor} = A_{235} / A_{275}$$

The NitraLED sensor has a default NOM coefficient programmed internally but for the most accurate calculation, it is recommended to perform a Site-Specific Correction. In the Site-Specific Correction procedure, the user can make minor adjustments to the above ratio. As this number is adjusted, the output of the sensor is adjusted, and tweaks to the NOM coefficients should be made until the output is equal to the known nitrate concentration. Recall that this nitrate concentration will have been made with an independent measurement.

Once the NOM factor is determined, the absorbance of NOM at the 235 nm wavelength is determined following rearrangement of the equation above:

$$A_{NOM235} = \text{NOM factor} * A_{275}$$

This calculated NOM at 235 nm is used in the equation below to determined absorbance measured by NitraLED that is attributable to nitrate:

$$A_{NO3\text{-}N} = A_{235} - A_{Turb235} - A_{NOM235}$$

Once the absorbance of nitrate has been calculated, it is then inserted into the regression equation stored in the sensor during the two-point calibration process to determine the final estimated concentration of nitrate in the measured sample.

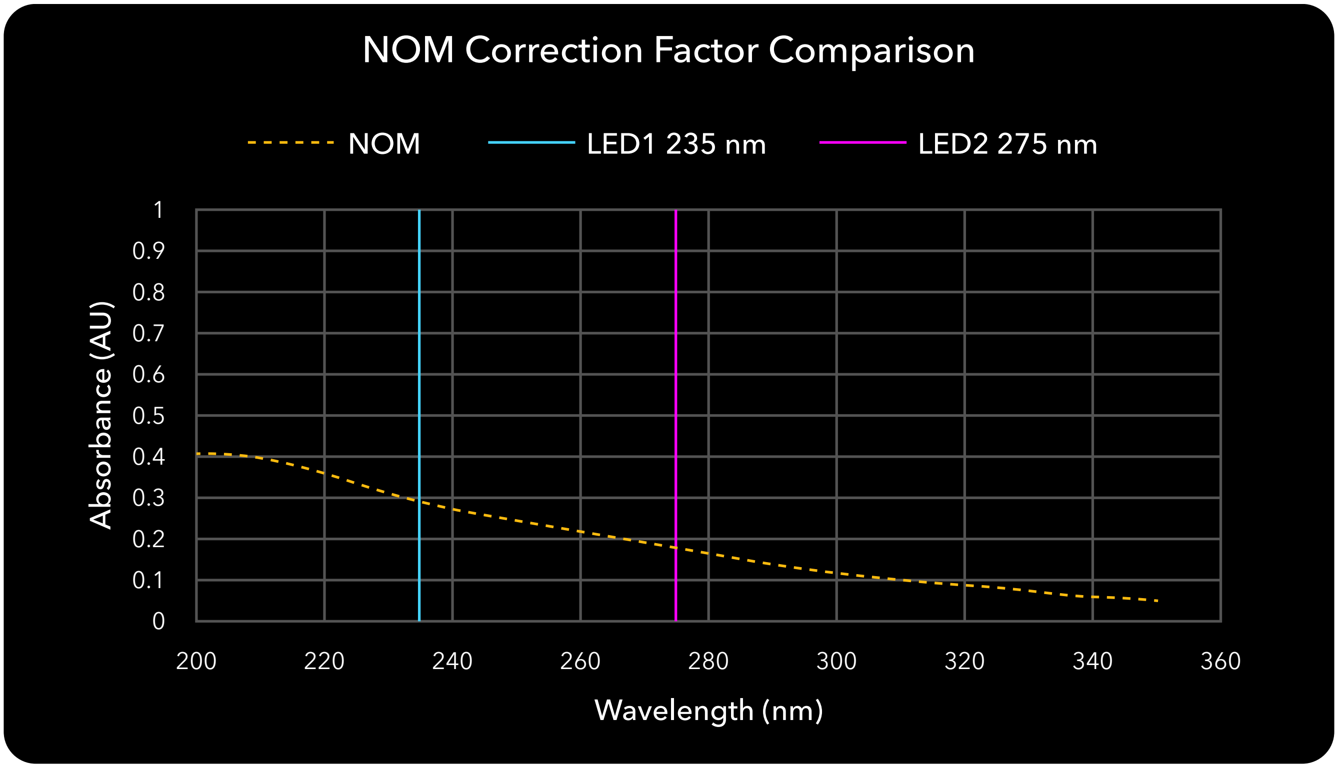


Figure 2: *The NOM correction factor is equal to the absorbance of NOM at 235 nm divided by the absorbance of NOM at 275 nm. The absorbance of NOM measured by each wavelength can vary by site.*

3.5 Other Attenuating Species Not Covered in Interference Correction

There are other constituents that absorb in the UV region of the spectrum (e.g. Cl^-, Br^-, HS^-, I^-, $S_2O_3^{2-}$) which are known to be a problem in brackish and coastal waters. For other interfering species, those that are not specifically called out in the Standard Method are not addressed for this freshwater-version of the sensor.

Though reported literature values vary significantly for the respective concentrations and absorbances of these seawater constituents, a more pragmatic assessment reveals that users can expect false nitrate readings as high as ~ 0.5 mg/L. For example, YSI deployed sensors into full concentrations (measured salinity of ~ 33 PSU) of Instant Ocean® and Gulf of Maine seawater samples which resulted in false nitrate readings of 0.48 mg/L and 0.28 mg/L respectively. Therefore, users should be aware of these unaccounted-for interferences if the sensor is to be deployed in saltwater, brackish waters or even in freshwater systems prone to seawater incursions.

For those users who have additional knowledge of the constituent components within a particular water body prone to seawater incursion, please reference the following possible interferences including but not limited to:

Seawater Component (typical seawater concentrations)		False Nitrate-N (mg/L)
Sodium Chloride: 32 ppt (NaCl)	→	0.080
Iodide: 0.1 ppm (I^-)	→	0.300
Bromide: 65 ppm (Br^-)	→	0.020
Bisulfide: (0-16 µM (HS^-), typical is unknown)	→	(0-6.000)

For example, if all of the above constituents were found within the waterbody with the quoted (high-end) concentrations, then the sensor would read a false nitrate-N value of 6.4 mg/L. Furthermore, the user would expect such false nitrate readings to scale down proportionally with the amount of seawater locally present, eventually reading negligible false positive(s) in pure freshwater conditions. Since the user may expect varying false nitrate readings from the NitraLED due to interfering factors found in saltwater, **YSI does not recommend use of the NitraLED in brackish or marine environments**. There is no defined upper limit of salinity that can be present in a sample that will allow for proper function of the NitraLED because environmental factors and concentrations of interfering constituents will vary by site.

3.6 Site-Specific Correction Overview

In addition to the standard calibration procedure, this sensor allows a user to correct the internal default coefficients that correct for the effects of turbidity and Natural Organic Matter (NOM) for the particular site of interest. The surrogates that YSI used to determine the defaults for the sensor were Kaolin for turbidity and Suwannee NOM for NOM.

The Site-Specific Correction (SSC) procedure is a simple 4-step process with a 5th step that shows the new coefficients that have now been programmed in the sensor. Please review Section 5.4 for step-by-step instructions on SSC. This procedure can be performed in Kor software or the Kor Mobile App; the correction functionality is not available in the handheld. The data from the final (5th) step is saved as a calibration record for the NitraLED sensor.

In order to complete the SSC procedure, at least two liters of water will need to be collected. One liter will be used for the raw water step and one liter will be filtered for the two filtered steps.

When collecting the water samples, all attempts should be made to avoid stirring up bed sediment, as this can cause inaccuracies in the correction procedure which can lead to errors in data upon deployment.

It is also important to collect the sample water as close to the deployment location as possible. For example, if the sensor will be deployed on a buoy, the sample should be collected from near the buoy as opposed to along the bank.

A nitrate reading from an external source should also be collected as part of the initial preparation. This reading could be from a variety of sources, but be aware that the error in the NitraLED Site-Specific Correction procedure is going to be greater than or equal to that of the comparison sensor.

YSI recommends collecting a reading with either a calibrated benchtop photometer or from an EPA-approved laboratory method. However, the use of ion selective electrodes and colorimeters are still acceptable.

If a sample is to be sent to the lab for analysis, keeping the two liters of sample water in a dark bottle in the refrigerator at less than 4°C is ideal for preservation and the sample can be stored this way for one month with very little change in nitrate levels. Collect water sample as near to the deployment location as possible, and during conditions that represent the type of data that is desired (baseflow or stormflow events).

One caveat to this is in extremely biologically active environments – preservation with sulfuric acid to a pH less than two standard units may be necessary to stop the biological activity and alteration of nitrate values. If sulfuric acid is added to the sample, there will be no effects on the NitraLED sensor because sulfuric acid absorbs light at a different wavelength than the two LED's inside the sensor.

In order to prevent bubbles from accumulating on the sensor faces of the NitraLED and Turbidity sensors, it is recommended to soak the sensors (ideally overnight) in a beaker of degassed DI water.

Finally, the Turbidity sensor that is used during this procedure must be the same sensor that the NitraLED sensor was calibrated with and must also be the same sensor that the sonde will be deployed with. Any changes to the Turbidity sensor will skew results. Please review Section 5.4 for step-by-step instructions on SSC.

3.7 Sensor Limitations

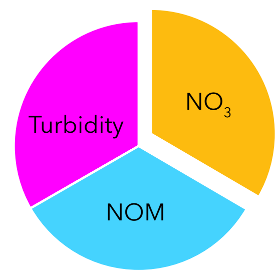
Consequences of Inaccurate SSC Coefficients

The NitraLED sensor measures optical absorbance at 235 nm where interference correction is performed for Natural Organic Matter (NOM) and turbidity. Correction can be performed using either the factory-derived coefficients or user-defined coefficients created during a Site-Specific Correction (SSC). If the user applies coefficients from an SSC performed during specific water quality conditions, the coefficients will be appropriate for those conditions. The SSC coefficients, once determined, enter as fixed constants in YSI's correction algorithm. However, in real-world scenarios, NOM-type and turbidity-type are known to change seasonally over time, and this is especially true during the onset of event conditions that are disparate from baseflow. If site conditions change significantly, the previously obtained SSC coefficients are no longer valid, resulting in nitrate error.

Interference Corrections (graphical depiction)

Corrections amount to an accurate accounting of the absorbance contributions as depicted in the pie chart below.

These contributions add up to the total absorbance at 235 nm. The section most relevant for the NitraLED is the absorbance attributable to nitrate. The SSC coefficients are used to subtract out interfering sections of the pie, leaving behind the desired nitrate absorbance. However, what happens to the correction if the SSC coefficients are inaccurate or change over time? The result—a misappropriation of absorbance, leading to error in the nitrate reading.

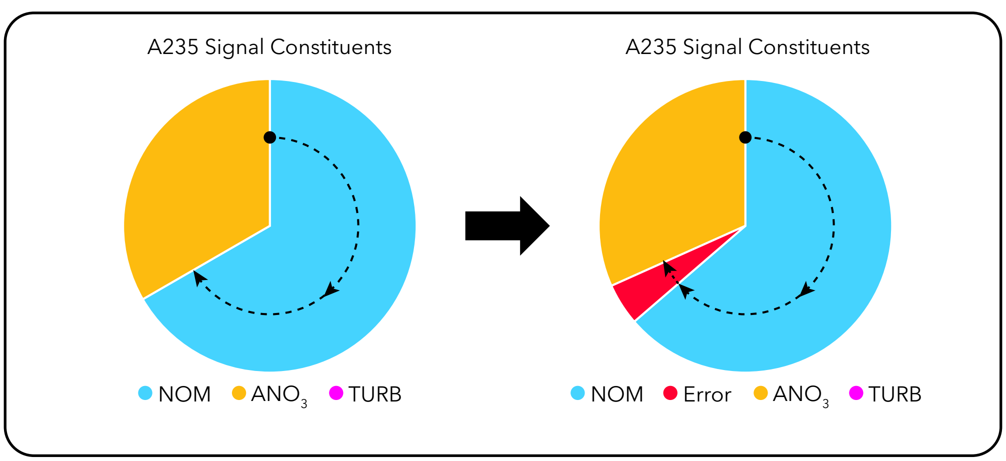


$$A_{235} = A_{NO3} + A_{NOM235} + A_{Turb235}$$

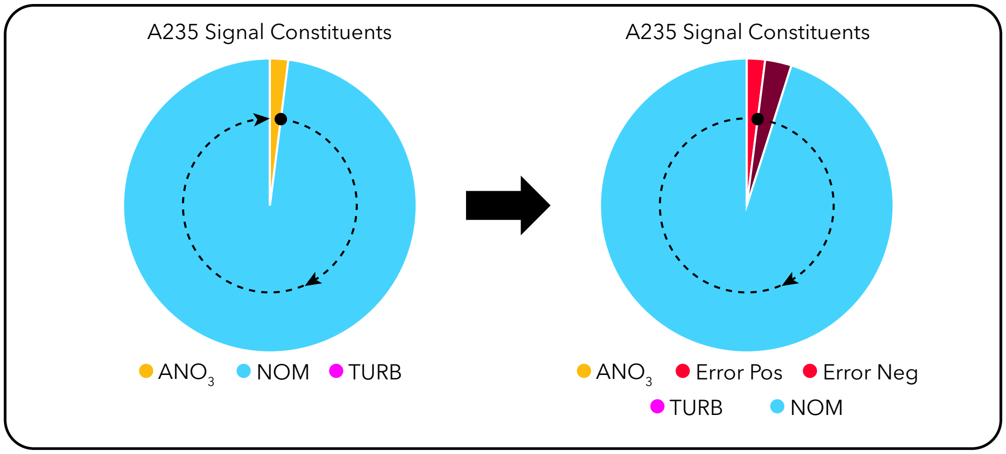
measured total absorbance	Nitrate absorbance	NOM absorbance	Turbidity absorbance

Simple Example (negligible turbidity, moderate NOM)

To more effectively illustrate this concept, consider a simplified field scenario of negligibly low turbidity, but with moderate NOM and nitrate.



The graphic above (left) depicts interference correction with the appropriate SSC coefficients whereas the graphic on the (right) depicts the resulting nitrate error due to a +5% overestimate in the magnitude of the NOM coefficient. In this case, the nitrate is underestimated due to an overcorrection for NOM. For scenarios in which the absorbance due to nitrate is a large percentage of the total (33% for the above example), such an error might not be so obvious. However, let's consider a scenario in which the nitrate absorbance comprises a relatively small percentage of the total (2% in the below example).



In this case, with the same +5% overestimate for the NOM coefficient, the nitrate estimate is now consumed by the error resulting in negative NitraLED readings.

Generalized Example
In real-world scenarios, the situation is more complicated. In the most general case, the magnitude and sign of any NitraLED error have a dependence on the following three quantities:

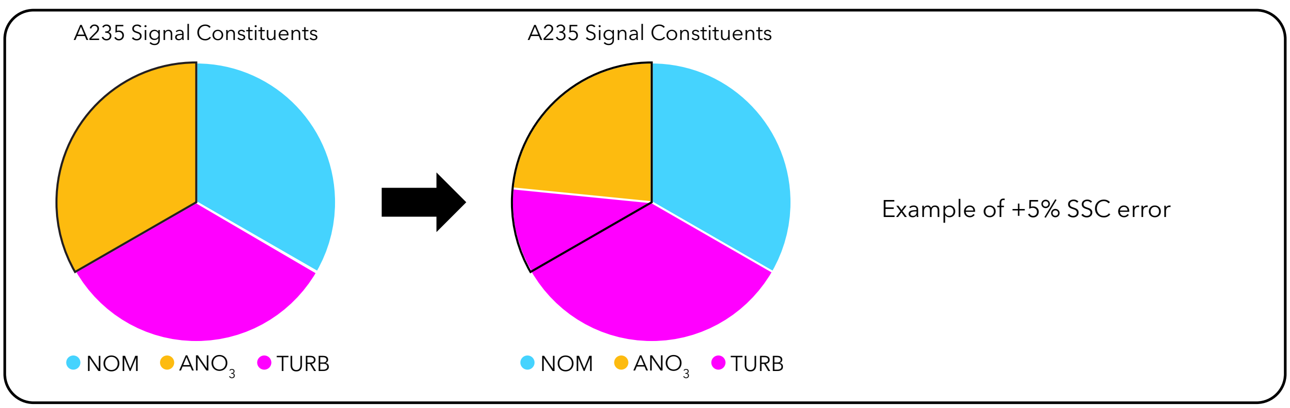
1. Magnitude and sign of the SSC coefficient errors
2. Magnitude of SSC coefficients
3. Concentration of interfering constituents, NOM and turbidity

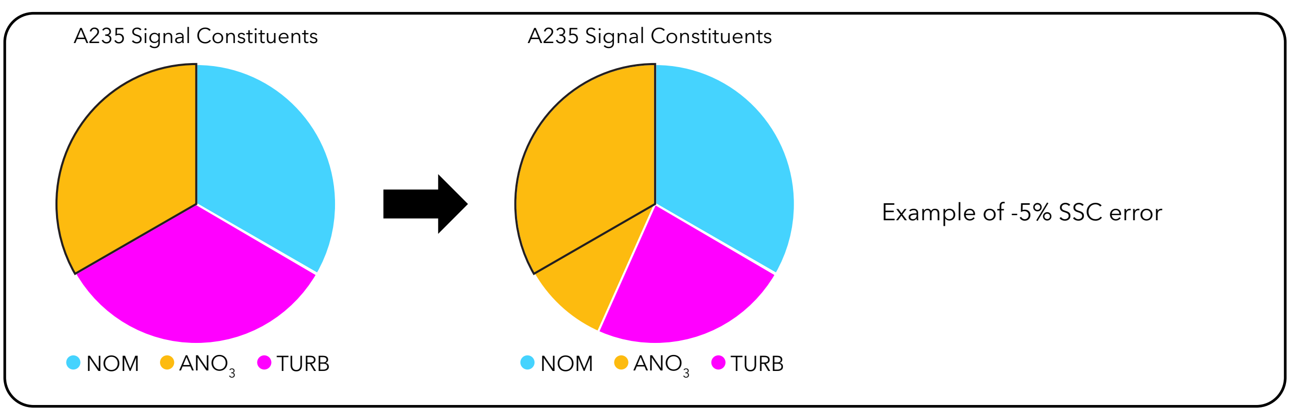
Given knowledge of the above quantities, one could calculate nitrate absorbance error directly using:

$$\Delta A_{NO3} = -\Delta\alpha_{NOM} A_{275} - (\Delta\alpha_{NOM}\, \alpha_{275} + \alpha_{NOM}\, \Delta\alpha_{275} + \Delta\alpha_{235})Turb$$

where **Δ** indicates error, or uncertainty.

The two graphics below help to visualize two key examples of the effect of error:





With a positive 5% error in the SSC coefficients, the effect of turbidity and NOM interference is overestimated, resulting in an underestimation of nitrate. With a negative 5% error in the SSC coefficients, nitrate is overestimated.

There are a few key concepts to consider regarding the calculation of error in nitrate absorbance:

- Multiple scenarios can produce the same nitrate error. There is no unique set of percent error of SSC coefficients that produce a specific nitrate error.
- The resulting nitrate error is proportional to the concentration of the interfering species. This implies that low interfering conditions, environments with low turbidity and NOM, can afford higher percent error of SSC coefficients; and conversely, high interfering conditions, environments with high turbidity and NOM, cannot afford high percent error, as this will result in significant error in nitrate.
- Reversing the sign of the percent error of the SSC coefficients results in a near-equal but opposite sign on the corresponding nitrate error.

It is important to obtain SSC coefficients that are as site-representative as possible to reduce nitrate error, especially when NOM and turbidity levels are expected to be high. Conversely, it is only when the interfering constituents are exceptionally low, that the final nitrate correction can afford large uncertainty in the SSC coefficients.

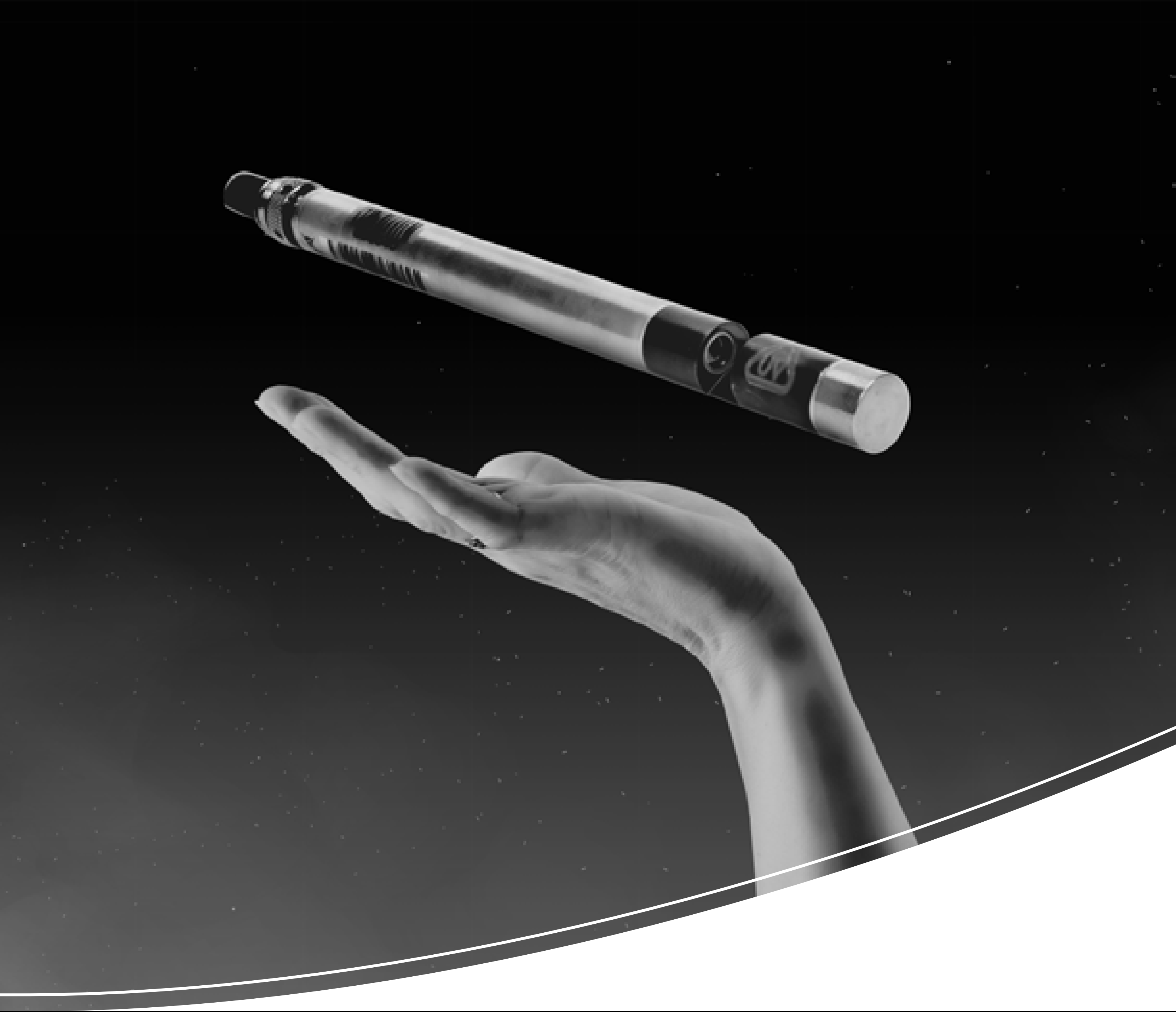
Other Limitations

Absorbance Range

As a reminder, nitrate accuracy specifications apply to nitrate in pure DI water only. However, for best field results, YSI recommends using the NitraLED in waters whose optical absorbance at 235 nm (A235) is < 1.2 AU (absorbance units). Beyond 1.2 AU, the efficacy of SSC will begin to diminish since the transmitted signal across the optical gap quickly approaches the sensor noise floor corresponding to ~ (1.8-2.0 AU). In other words, the largest the total absorbance at 235 nm can safely be is 1.2 AU. The largest the total absorbance can absolutely be is (1.8 – 2.0 AU).

Equilibrium vs. Nonequilibrium Conditions

The NitraLED sensor operates most effectively in media that is at equilibrium, meaning conditions are stable and water quality is homogenous. If the sample is not well-mixed (i.e. due to debris, eddy flows, algae clumps), the NitraLED and Turbidity sensors could experience different turbidities with respect to each other, resulting in error and noisy data. For this reason, it is important to perform an SSC during equilibrium conditions.



Section 4
Sensor Installation Guide

4.1 Before You Start

Watch the detailed how-to video:

EXO University
YSI.com/E XO-University

These instructions are relevant for NitraLED installation on EXO2 and EXO3 Sondes.

The NitraLED Sensor is compatible with EXO1; however, the Alignment Ring and Wiper Brush are not compatible, nor required, for NitraLED use on EXO1.

NOTE: For those with the EXO1 Sonde, it is important to understand the limitations of unattended monitoring without a wiper. Data can be impacted by fouling or even a bubble on the sensor lens, so YSI recommends EXO1 use ONLY under low fouling conditions and short-term deployments or for spot sampling applications (Section 6.1).

Caution

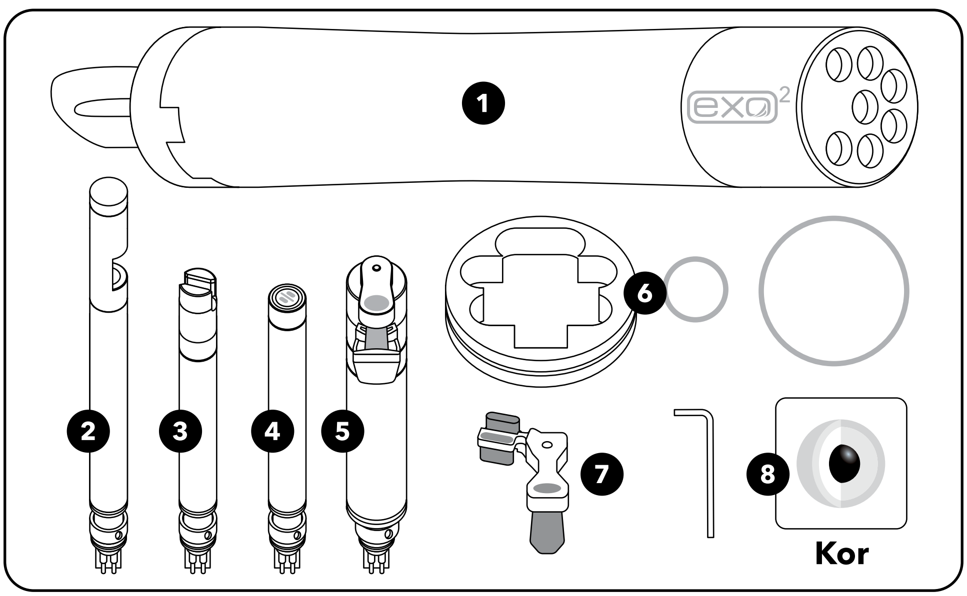
EXO NitraLED emits UV-B/C radiation within the optical cell. Personal protective equipment (PPE) for UV light, including safety glasses and gloves, should be worn when interfacing with a powered sensor. Do not look directly or touch in the window when the sensor is powered.

What Do You Need?

In addition to this list, please see Section 1.6 for part numbers and ordering information. You will also need the 1/20" (.050) and 1/16" hex keys that accompany the standard and NitraLED wiper brushes.

1. EXO2 or EXO3 Sonde
2. EXO NitraLED Sensor
3. EXO C/T Sensor (Wiped recommended)
4. EXO Turbidity Sensor
5. EXO Central Wiper
6. EXO2/EXO3 Alignment Ring
7. EXO NitraLED Wiper Brush
8. Kor Software*

*Make sure Kor Software is up-to-date and firmware has been updated for the sonde, wiper, and Turbidity sensor. The minimum requirements are as follows: KorEXO: 2.3.10, EXO Sonde: 1.0.84, NitraLED Sensor: 1.0.58, Turbidity Sensor: 3.0.4, Central Wiper: 3.0.11, Handheld: 1.0.63



Before Installation

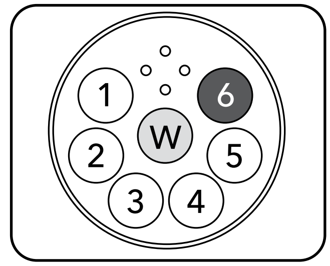
Make sure software and firmware are updated to the latest versions.

Make sure at least the EXO Wiper, Conductivity/Temperature (C/T), Turbidity, and NitraLED Sensors are installed as follows below

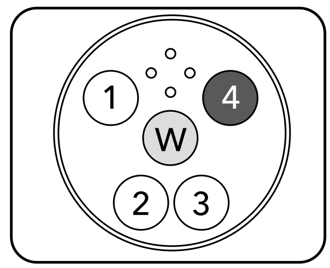
- The **NitraLED sensor** is unique in that it must be installed in a specific port on the EXO2 and EXO3:
    - **EXO2**: Port 6
    - **EXO3**: Port 4
- The **Conductivity/Temperature sensor** must be installed:
    - **EXO2**: Port 3 or Port 4
    - **EXO3**: Port 2 or Port 3

    This is to ensure the Conductivity/Temperature channel is opposite the brush guard of the wiper.
- The **Turbidity sensor** must be installed. Do not install Turbidity in a port that will be obstructed by the wiper brush. The photodetector requires a minimum path length, from the sensor face to the bottom of the sensor guard, for optimal sensing.

NOTE: For EXO2 configurations with NitraLED, Port 5 should be reserved for one of the following sensors: pH, pH/ORP, ODO, or any of the Ion Selective Electrodes (ISEs). These sensors are not impaired by the Wiper Arm of the NitraLED Brush parked above Port 5.



EXO2 port configuration



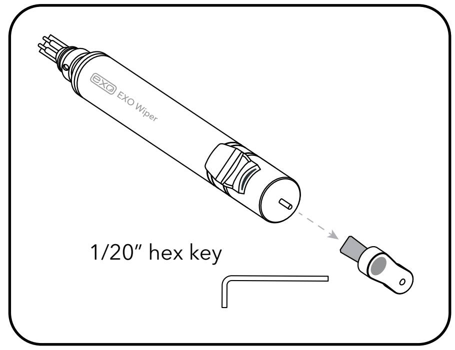
EXO3 port configuration

4.2 EXO Wiper Installation

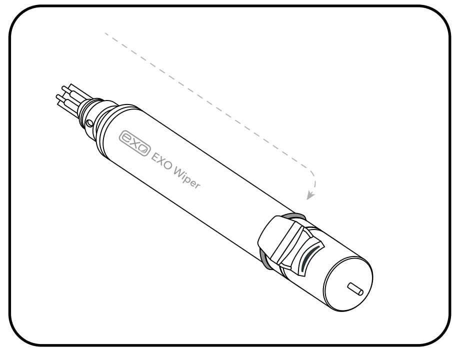
Watch the detailed how-to video:

EXO University
YSI.com/E XO-University

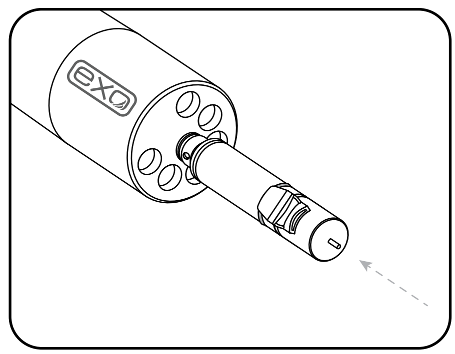
1. Remove old wiper brush by loosening the set screw with a 1/20" (.050) hex key. Clean any residue from wiper shaft.



2. Roll the new o-ring up the wiper probe until it seats under the wiper brush guard.

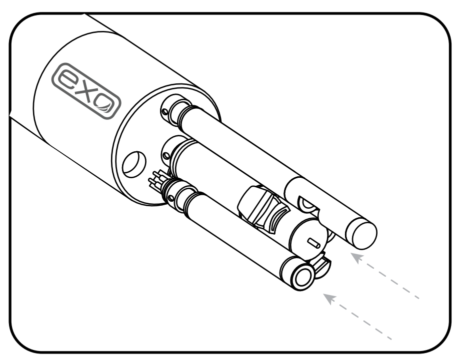


3. Install the Central Wiper on to the sonde bulkhead.



4. Install the remaining sensors.

   NitraLED must be installed:
   EXO2: Port 6
   EXO3: Port 4



⚠ Do NOT leave any ports empty. Port plugs must be inserted into any port that does not have a sensor.

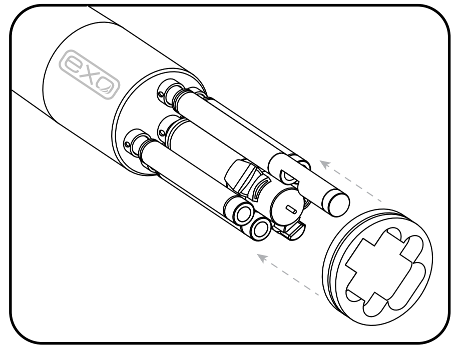
4.3 EXO Alignment Ring Installation

Watch the detailed how-to video:

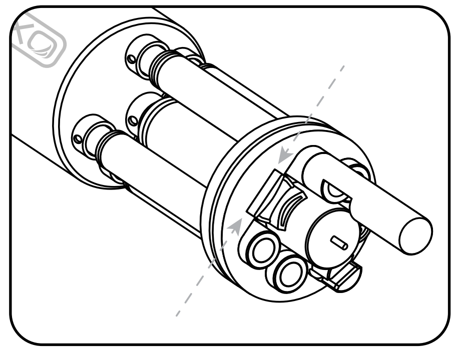
EXO University
YSI.com/E XO-University

1. Slide the Alignment Ring over the sensors. Make sure an o-ring is not already inside the Alignment Ring.

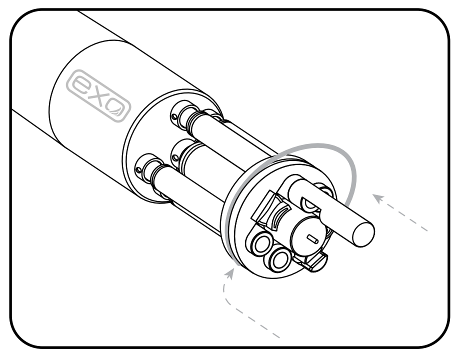
   NOTE: The top of the Alignment Ring should line up with the seam on the brush guard, approximately 0.5 cm below the optical sensor faces.

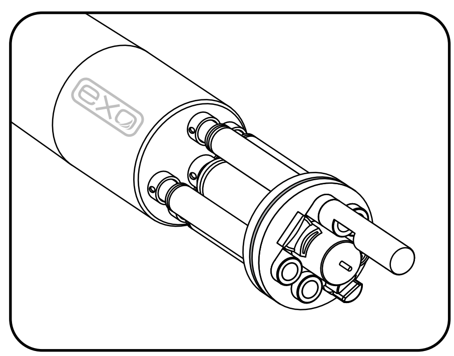


2. While holding the Ring in place, carefully pull the larger o-ring over the sensors and fit into the groove.



3. Once the o-ring is fully seated around the Alignment Ring, installation is complete.





4.4 EXO NitraLED Wiper Brush Installation

Watch the detailed how-to video:

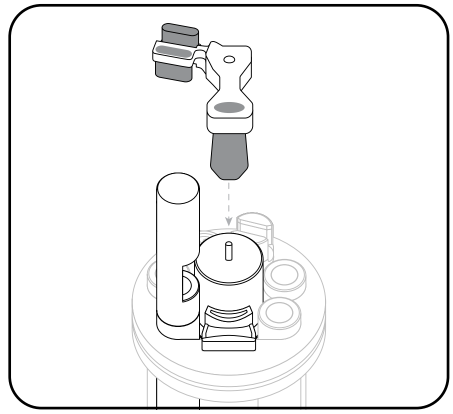
EXO University
YSI.com/E XO-University

NOTE: The old wiper brush must first be removed using a 1/20" (.050) hex key, following above instructions.

1. The wiper shaft has a "D" shape and is sometimes referred to as the D shaft. The wiper brush fits on the D shaft only one way.

   Slide the Brush onto the D shaft until fully seated.

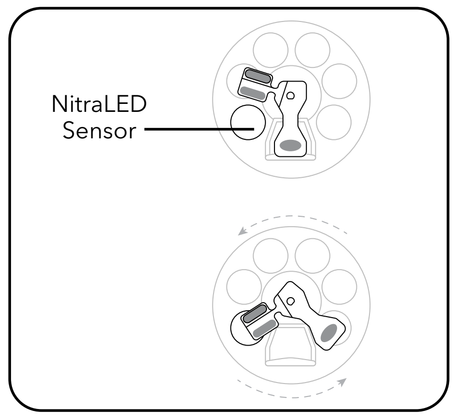
⚠ **DO NOT tighten the screw yet.**



Slide Brush down until fully seated on top of the Central Wiper

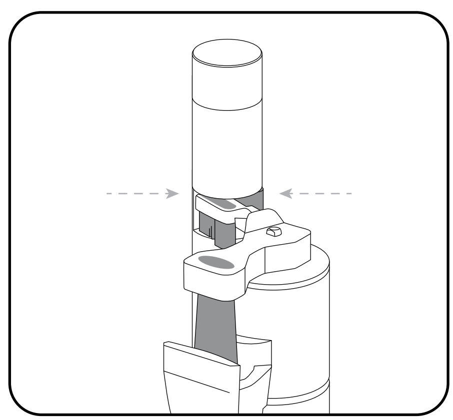
2. Manually rotate the Brush counter-clockwise until the Wiper Arm is seated within the sensing window of the NitraLED Sensor.

   NOTE: Be careful not to use too much force while rotating the brush by hand.



(Top view) Center Wiper Arm within NitraLED Sensor window

⚠ Make sure the Wiper Arm is fully contained within the NitraLED sensing window.

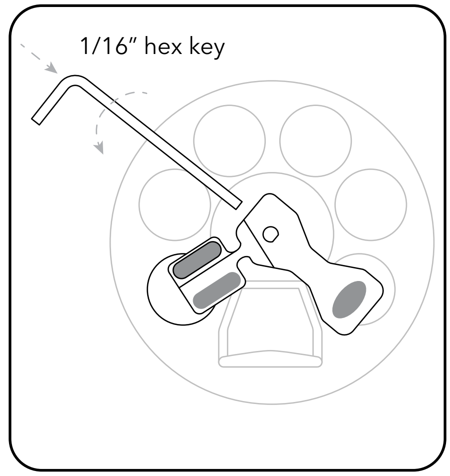


Other elements hidden to focus on the Brush and sensing window

3 In this position, tighten the set screw on the Wiper Brush using the 1/16” hex key.

There may be some resistance as the screw is designed not to back out easily.

After tightening, gently rock the brush to ensure a snug fit against the D shaft and tighten more if necessary.



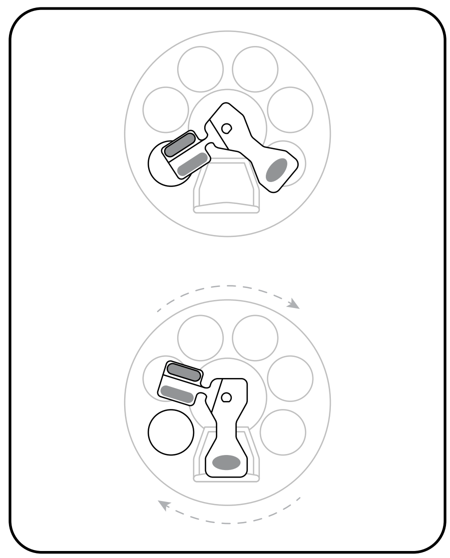
Tighten screw on back of Brush while centered in Nitrate window.

4 After the screw is tightened, manually rotate the Brush back to its home position.

NOTE: Be careful not to use too much force while rotating the brush by hand.

The main brush should be centered within the brush guard, while the Wiper Arm should be over port 5 of the EXO2 or the blank of the EXO3.

NOTE: For EXO2 configurations with NitraLED, Port 5 should be reserved for one of the following sensors: pH, pH/ORP, ODO, or any of the Ion Selective Electrodes (ISEs). These sensors are not impaired by the Wiper Arm of the NitraLED Brush parked above Port 5



Rotate back so the main brush is over the guard.

NOTE: After installing the NitraLED Wiper Brush, users must switch the **Wipe Mode** to **NitraLED** using Kor Software.

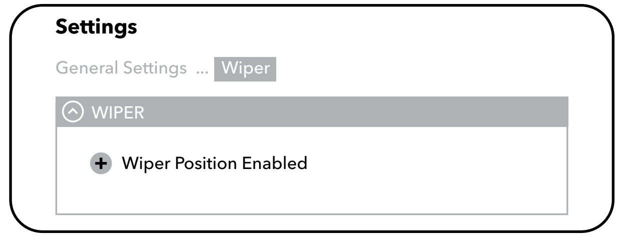
4.5 Update Wiper Settings

Watch the detailed how-to video:

EXO University
YSI.com/E XO-University

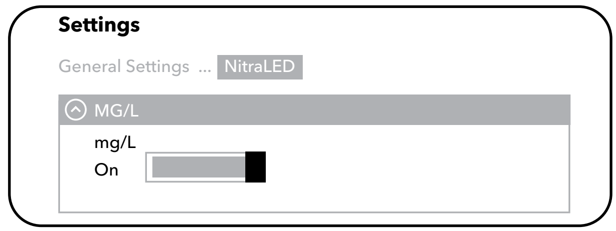
1. In Kor Software, make sure the Wiper Position is on.

   Go to **File > Settings** and select **Wiper** to enable **Wiper Position**.

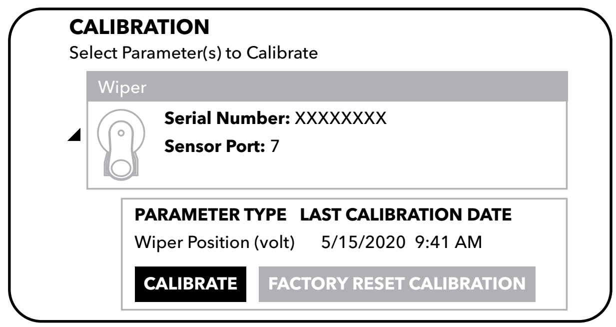


2. Also, make sure NitraLED is enabled.

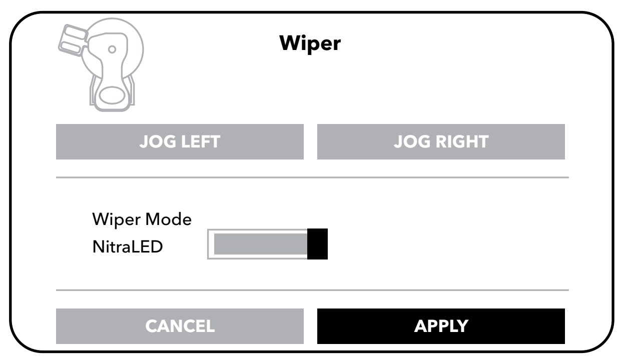
   Go to **File > Settings** and select **NitraLED** to enable **mg/L**.



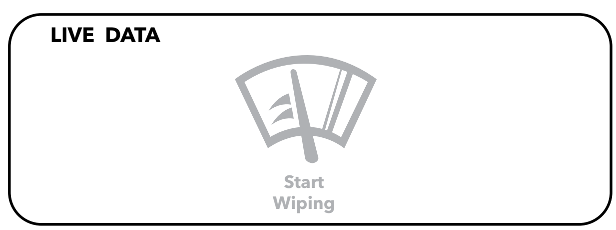
3. Go to the **Calibration** menu and select **Wiper**; then select **Calibrate**.



4. Enable the **NitraLED Wiper** mode and then click **Apply**.

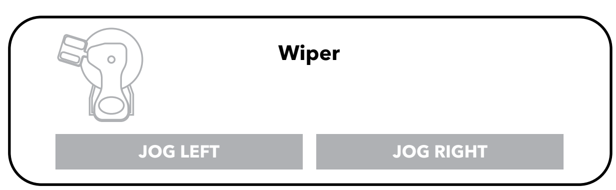


5. Go to **Live Data** and select **Start Wiping** to verify that the wiper brush effectively sweeps through the NitraLED sensor window and parks in its home position.



6. If the brush is off center after the wipe cycle, it will be necessary to adjust the seating location by selecting **Wiper** in the **Calibration** menu and selecting **Jog Left** or **Jog Right**.

   Use the Jog controls to adjust the home position, ensuring that the main brush is centered within the brush guard and the Wiper Arm is not obstructing the entire sensing window.



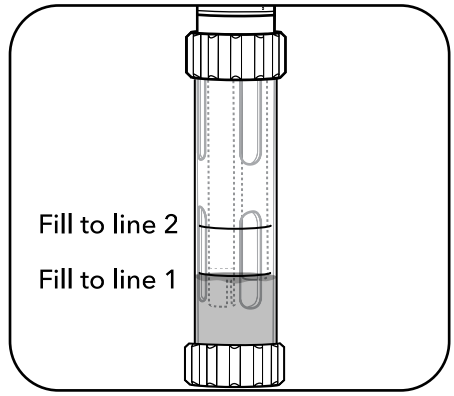
Section 5
Calibration & Site Correction

5.1 General Calibration Set-Up

EXO sensors (except temperature) require periodic calibration to assure high performance. Two to three rinses with standard are recommended. Discard the rinse standard, then refill the calibration cup with fresh calibration standard. Alternatively, rinse the sensors, calibration cup, and sensor guard with deionized water and dry with a lint-free cloth between standards.

Fill the cup to make certain that the sensor is submerged in standard. Begin with clean, dry probes and sensor guard installed on the EXO sonde. Install the clean calibration guard over the probe(s), and then immerse the probe(s) in the standard and tighten the calibration cup onto the EXO sonde.

The basic calibration description can be found in EXO User Manual, Section 4.2.



5.2 NitraLED 2-point Calibration

Watch the detailed how-to video:

EXO University
YSI.com/E XO-University

Before calibrating, be certain that the sensing window is clean.

Caution

EXO NitraLED emits UV-B/C radiation within the optical cell. Personal protective equipment (PPE) for UV light, including safety glasses and gloves, should be worn when interfacing with a powered sensor. Do not look directly or touch in the window when the sensor is powered.

An EXO Turbidity sensor and Conductivity/Temperature sensor must be installed during calibration, site correction, deployment of the EXO NitraLED sensor. YSI recommends calibrating the Turbidity sensor just before calibrating NitraLED. For best results, users should deploy EXO NitraLED with the same Turbidity sensor with which it was calibrated.

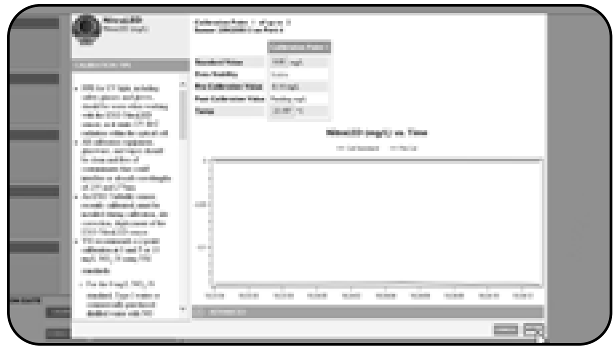
YSI recommends a 2-point calibration at 0 and 5 or 10 mg/L NO3-N using YSI NitraLED standards:

Item No.	Description
608072	5 mg/L NO_3^-N standard
608073	10 mg/L NO_3^-N standard

The standard for Calibration Point #2 should be selected based on which is closer to the expected measurement value. While other standards may be used, such solutions may have interfering species that could result in a calibration that is not optimal for the EXO NitraLED sensor.

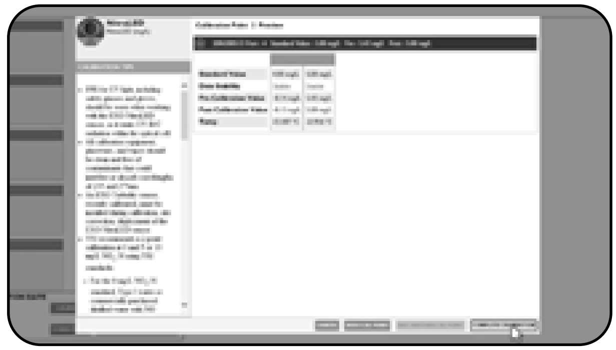
Calibration Point #1 at 0 mg/L:

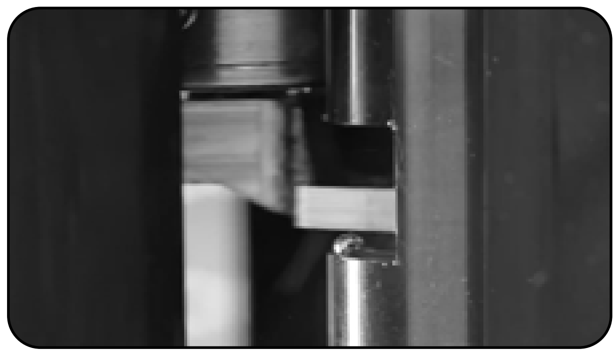
Place the sonde into a clean calibration cup containing degassed Type 1 distilled water with no added minerals. The software or handheld will show a graph while the sensor is stabilizing. Make sure the "Standard Value" is equal to zero (0). When the Data Stability indicates "Stable," click "Apply" in the software or "Accept Calibration" on the handheld. In the software, select "Add Another Cal Point" and proceed to Step 2.



Calibration Point #2 at user preferred concentration (in mg/L):

Place the sonde into a clean calibration cup containing the standard solution. Make sure the "Standard Value" is equal to the concentration of the solution. When the Data Stability indicates "Stable", click "Apply" in the software or "Accept Calibration" on the handheld. Finally, select "Complete Calibration" [software] or "Finish Calibration" [handheld] and proceed to the calibration review screen. From here users can view the Calibration Report or select "Exit" to return to the main calibration menu.





Calibration Tips:

- Consider having a spare, clean sensor guard and calibration cup for use during calibrations to minimize contamination of standards.
- A sensor guard must be installed during calibration to limit the effects of reflective surfaces (such as white stir plates) on the sensor optics.
- While other calibration standard solutions may be used, these standards may have interfering species that will result in a calibration that is not optimal for the EXO NitraLED sensor. NitraLED-specific nitrate standards are filtered for optical interferences, and should be used for best practices. Please see Section 1.4.
- Allow standards to temperature acclimate before calibration. This can minimize bubbles during calibration, especially when the standards are cold and need to warm.
- Unstable measurements in standards are likely due to bubbles in either the solution, or one or more of the EXO sensors' measurement areas.
- Soaking the sensors in degassed Type I water for 1 hour prior to calibration was found to minimize bubble formation on the sensing lens during calibration.
- Errors in a zero-nitrate calibration may appear as negative readings within a dataset.
- Always inspect optics for fingerprints and oils from handling which will impact calibration.
- Use Type I water and lint-free wipes to clean the sensors between calibration points.
- Removal of the Central Wiper, or using a wiper brush reserved only for calibration, can significantly reduce the risk of contaminating the sensitive calibration standard with dirt or other absorbing species from the brush.

5.3 SmartQC and Troubleshooting Tips

The SmartQC Score for NitraLED is based on a gain factor and an offset factor. Both of these values may change as the sensor and the optics age.

Guidance on interpretation of the SmartQC Score for this sensor is as follows:

Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.

Yellow: The sensor gain or offset is near the threshold of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and complete a recalibration.
    a. For calibration point 1, the 0 mg/L NO_3^--N standard, use Type I water or commercially purchased distilled water with NO minerals added. DO NOT USE commercially purchased Reverse Osmosis, Deionized, or Distilled Water with Minerals added.
    b. For calibration point 2, use YSI NitraLED calibration standards 5 mg/L NO_3^--N [Item# 608072] or 10 mg/L NO_3^--N [Item# 608073] for best results. These standards are free of the interfering species that would result in a less than optimal calibration.
    c. Allow standards to temperature acclimate before calibration. This can minimize bubbles during calibration, especially when the standards are cold and need to warm.
2. Ensure that the standard value was entered correctly.
3. Ensure that the sensor is free of contamination. Refer to Section 7.0 for additional information on how to properly clean the sensor in order to avoid damage.
4. Remove the central wiper brush and thoroughly clean the brush guard. Contaminants can reside within the bristles of the wiper brush and the small gaps of the plastic brush guard. If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.
5. Watch for bubbles settling on the Turbidity and NitraLED sensor faces during all steps of the calibration.

Red: The sensor gain or offset are outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

5.4 Site-Specific Correction

Watch the detailed how-to video:

EXO University
YSI.com/E XO-University

The NitraLED sensor detects nitrate using the basic principle of optical absorbance. All optical technologies must contend with turbidity interference, which occurs due to the scattering of light caused by suspended particles. Sensors that rely on the UV ranges of light will experience NOM interference due to absorbance.

The NitraLED sensor uses a second LED to compensate for interferences from organic matter. Additionally, the EXO Turbidity sensor (which is required for use) readings are used to correct for turbidity interference. These corrections are class-based using common species for both turbidity and NOM.

Users may achieve better results with NitraLED by performing an optional Site-Specific Correction (SSC) using Kor Software. This process will fine-tune the NitraLED sensor to compensate for the specific interferences present at the monitoring location. It is best to perform an SSC during stable environmental conditions. Please review Section 3.6 for more information.

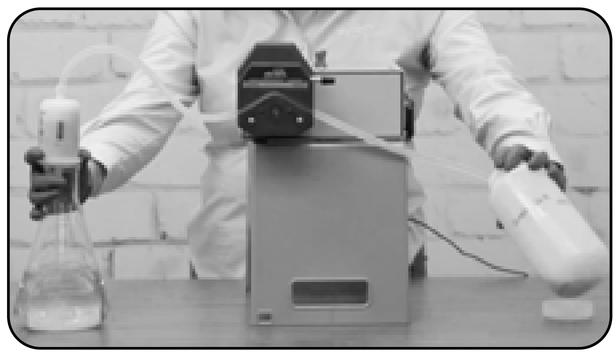
Collect a Sample and Determine the Nitrate Value

Obtain a grab sample from the intended deployment site. At least 2 liters is recommended to complete the process.

Determine the nitrate of the sample in mg/L NO_3^--N using an independent and approved method. YSI recommends using a standard method for determining nitrate concentration. Note that the error associated with the method used for the reference value applies to the final calibration of NitraLED.

Filter the Raw Sample

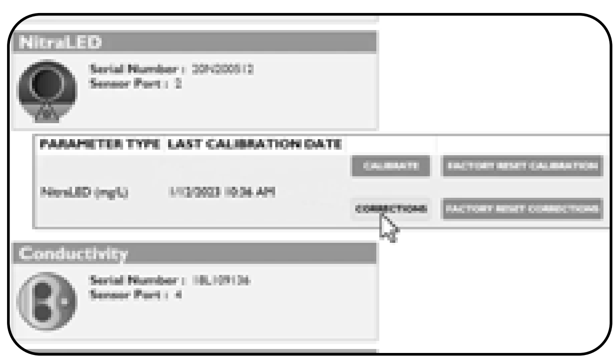
Filter the site sample using a 0.45 µm filter. A vacuum pump or peristaltic pump can be used to expedite this process. 800 mL to 1 L of sample water should be filtered. Filtering before starting the SSC will allow the user to more quickly switch from raw to filtered sample. Make sure the turbidity of the filtered sample is <1 FNU. If it is not, filter the sample again with a new 0.45 µm filter.



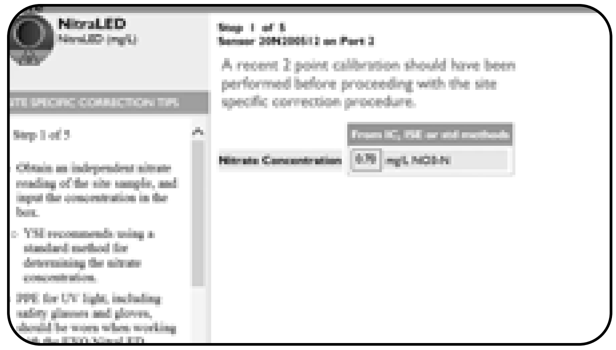
Perform SSC Using Kor Software

NOTE: Both the EXO Turbidity and NitraLED sensors should have been recently calibrated before proceeding with the Site-Specific Correction.

1. Connect the sonde to Kor Software. Navigate to the Calibration menu and select NitraLED; then select **Corrections**. You can also choose to move directly into the SSC following 2-point calibration of NitraLED.



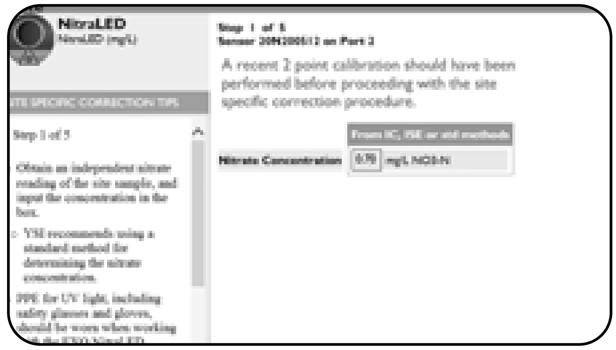
2. Enter the nitrate value in mg/L of the site sample that was determined by independent methods and click **Next** to continue.



3. Set up the stir plate under a ring stand or other device that will hold the EXO during this procedure. Place a 1 L beaker on the stir plate and fill to approximately 800 mL with raw sample water. Place the stir bar in the sample water. Turn the stir plate on to a speed slightly higher than that of the site environment that keeps all sediments suspended as they would be in the natural water body.

   NOTE: YSI recommends removing the wiper brush from the central wiper, if one is installed, during this procedure. The EXO needs to have the sonde guard installed in order to ensure proper spacing for the Turbidity sensor and also to prevent any reflected light from affecting the readings of either the turbidity or NitraLED sensor.

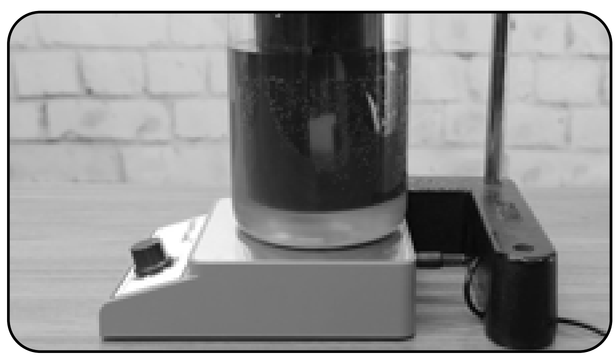
   Place the sonde into the beaker of raw water and hold in place with the ring stand clamp. Verify that the entire colored part of the NitraLED sensor and the Turbidity sensor are submerged.



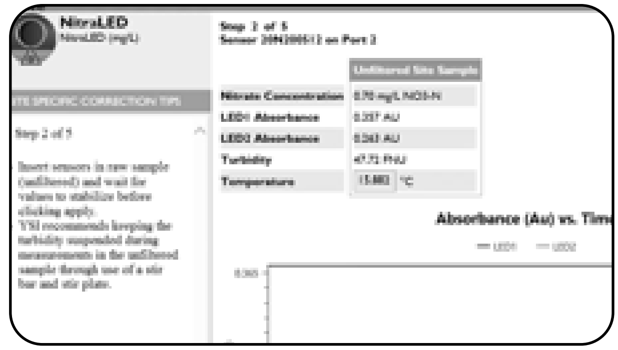
4. With the probe guard installed, insert the EXO sensors in the raw sample and wait for readings to stabilize. Because this raw sample may have significant debris, readings might be continuously moving; however, the values should plateau over time.

   NOTE: While the sensor LED values are stabilizing, verify that there are no bubbles accumulating on the sensor faces of the NitraLED or turbidity sensors. Be sure to watch the turbidity values for stabilization as well. If turbidity continually rises over time, this is most likely due to bubbles accumulating on the sensor face. Even the smallest bubbles can have an impact on sensor readings; if there are bubbles, remove the sonde from the water briefly and reinstall.

   If the user observes the turbidity constantly decreasing, this could be a sign to increase the stir speed. Also verify that there are no sediments settled on the lens surfaces. If needed, wipe the sensor face with a lint free cloth and quickly reinsert into the sample water.



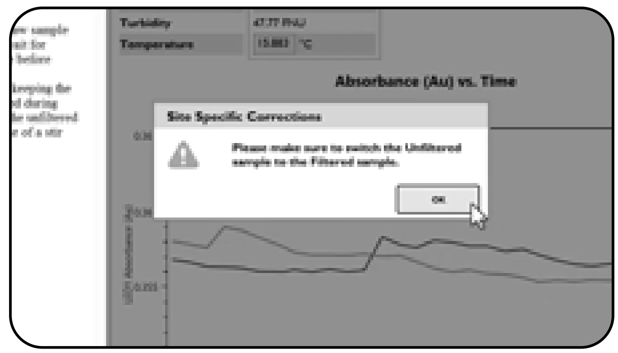
5 Check the turbidity value. At this stage, users can choose to correct for turbidity based on the raw sample reading or use the default, class-based Kaolin turbidity coefficients which are pre-programmed in every EXO NitraLED sensor. YSI typically recommends applying corrections based on the raw site sample if turbidity values are greater than 15 FNU. Please review Section 3.3.



If this option is selected from the Step 2 screen, the user will be directed to Step 4 after a measurement has been taken in the raw sample water. The software will then indicate that the sensor should be placed into the filtered water sample

NOTE: The default class-based coefficients may not represent the species of turbidity or NOM for the user's site. Thus even at low turbidity, (less than 15 FNU), the best results may be achieved by performing the full Site-Specific Correction.

6 Once the turbidity and absorbance values have stabilized (this can take up to 5-10 minutes), click **Apply**. The correction procedure will then proceed to Step 3 and the software will indicate that the sensor should be placed into the filtered water sample.



7 After applying the site-specific or default turbidity correction, remove the sonde from the raw sample, rinse with Type I water, and dry with lint free wipes before moving to the next step. Take care not to carry over any turbidity from the unfiltered into the filtered sample.

8 Next, Place the stir bar in the sample water. Turn the stir plate on again to keep the sample properly mixed. Place the EXO sensors in the filtered sample.

a. If users chose to apply the site-specific turbidity correction, they will now need to apply a filtered NOM correction after readings stabilize.

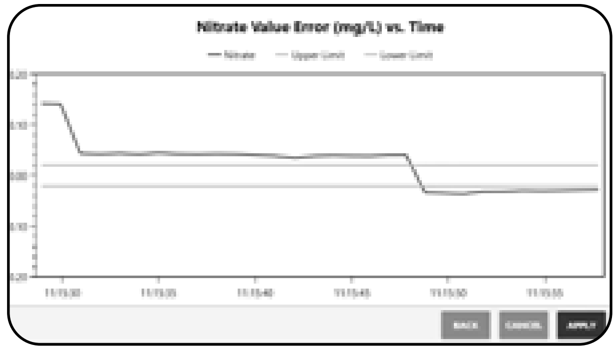
b. If users chose to apply the default turbidity correction, they will skip to the NOM coefficient adjustment.

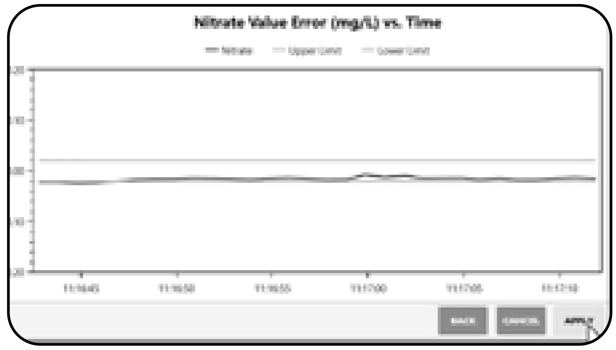
NOTE: When the sensors are in the filtered water, observe the turbidity reading. The filtered sample water should ideally have turbidity less than 1.0 FNU. If the turbidity of the filtered sample is higher than this, stabilization may take a slightly longer period of time and additional error may be introduced, so filtering a second time through a smaller pore size filter would be beneficial to the process.

9 Once the absorbance values are stabilized, click **Apply**. This process should not take as long in filtered water as it may have in the raw water sample.

10 The sensors should remain in the filtered sample for this step. Continue to ensure that there are no bubbles accumulating on the sensor faces during this step.

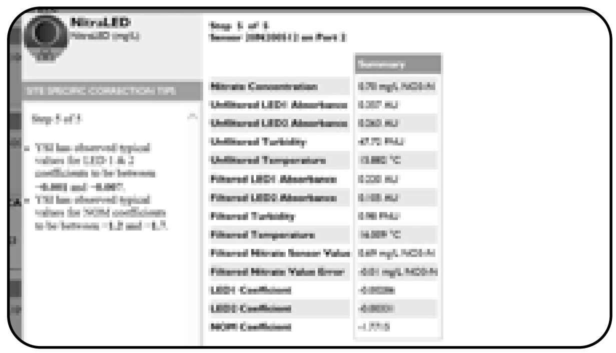
In this step, the software calculates a NOM coefficient to minimize nitrate error. The user can make adjustments to the NOM coefficient as needed. By manually typing a value into the editable field, the user can make adjustments to the nitrate value and error in the upper half of the box. In the bottom half of the box, the user will see two orange error bar lines. While watching the numbers in the upper half of the box, the lower half should be watched for stability. When the blue line is stable within the orange lines, click **Apply**.





11 Finally, users will be presented with a site correction summary page where all of the values may be reviewed before completing the process. These values are saved as a Calibration Report separately from the two-point standards calibration in Kor. There is guidance in Kor software as to what typical value ranges for the LED and NOM coefficients are:

- YSI has observed typical values for LED 1 & 2 coefficients to be between −0.001 and −0.007.
- YSI has observed typical values for NOM coefficients to be between −1.2 and −1.7.



NOTE: Your coefficient values may not fall exactly within this range, but your SSC results may still be acceptable. These ranges are based on YSI testing, and may not represent all possible cases. Some variation can be expected given different environmental conditions.

Close the table when finished viewing the calibration results.

Once the process is complete, the EXO NitraLED sensor will be ready for deployment.

NOTE: The new coefficients applied during the SSC will be retained to the sensor indefinitely and will apply to all following measurements. To remove SSC coefficients from the sensor, first reset the NitraLED back to Factory Settings in the Calibration menu. This will apply the factory default coefficients to the sensor's algorithm. Then perform the two-point nitrate calibration before use.

Section 6
Deployment

6.1 Deployment

Once properly calibrated and prepared according to the above instructions, deploying the NitraLED sensor is as simple as plugging it into the correct port in your EXO sonde (see Before Installation) and using it with your existing site setup and Turbidity sensor. The NitraLED is applicable for either spot sampling (see Section 6.2 below) or long-term monitoring. The NitraLED can be used in many applications, such as flow-through setups using the EXO Flow Cell, Harmful Algal Bloom monitoring, and source water nutrient monitoring, and more.

You can deploy sondes with EXO NitraLED in standard EXO flow cell systems. No changes to the existing site infrastructure are required.

If you are setting up a new deployment with the NitraLED, keep the sensor specifications and limitations in mind (See Sections 2.1, 3.7). The ideal site would have well-mixed, homogenous flow, avoiding eddies, excessive algae mats, debris packs, and other sources of increased turbidity or optical blockages. Avoid environments with salinity greater than 2.5 PSU, as a benchmark.

Please refer to the EXO User Manual Section 3.7 for more information on how to program EXO deployments using Kor Software.

6.2 Spot Sampling

Though the NitraLED sensor was designed and intended for continuous long-term monitoring applications, it can be used for spot sampling. The tradeoff for portability is that the best possible data requires a Site-Specific Correction (SSC); however, it can be laborious to perform an SSC for every site you plan to sample. The alternative is to not perform an SSC; however, without an SSC, the NitraLED relies on the default turbidity and NOM coefficients, resulting in an additional error in the readings.

Under the right conditions, the user may choose to forego the SSC and sample sites using the default coefficients. This can be suitable for sites with low turbidity and NOM interference. In these cases, the default corrections may be sufficient for the sensor. We recommend comparing site data with applied default coefficients versus SSC coefficients to determine if the variance is acceptable to user standards.

It may be more appropriate to use spot-sampled NitraLED data for trend analyses, rather than to determine the absolute concentration of nitrate. Grab samples may be the most reliable method to determine nitrate concentrations at your site.

Section 7

Maintenance & Storage

7.1 Maintenance and Storage

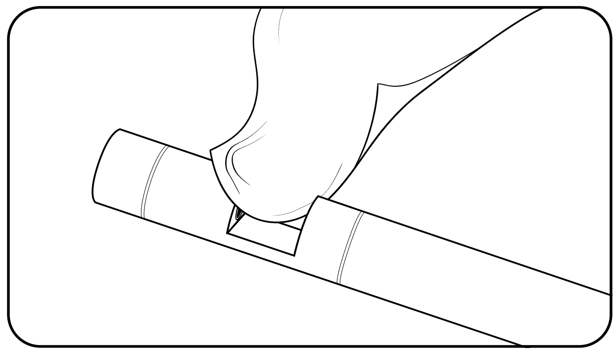
Optical sensors require less maintenance than other sensors. Long-term storage is applicable for long periods of inactivity (over winter, end of monitoring season, etc.). Short-term storage is applicable if the sonde will be used at a regular interval (daily, weekly, biweekly, etc.).

Caution

EXO NitraLED emits UV-B/C radiation within the optical cell. Personal protective equipment (PPE) for UV light, including safety glasses and gloves, should be worn when interfacing with a powered sensor. Do not look directly or touch in the window when the sensor is powered.

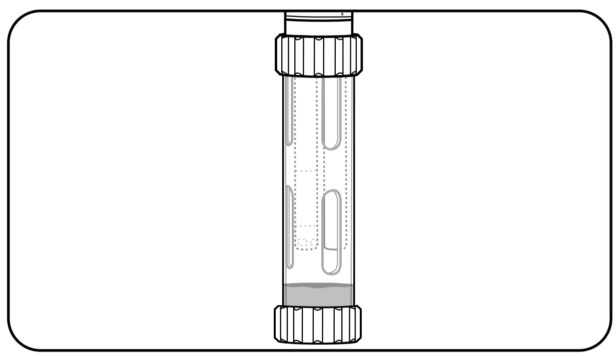
Clean sensing windows

Users should periodically inspect the optical windows and wipe the surfaces clean with a non-abrasive, lint-free cloth if necessary. As much as possible, prevent scratches and damage to the sensing window.



Long- and short-term storage

Users can either remove the sensor or leave it installed in the sonde for long- and short-term storage. If left installed on the sonde, follow guidelines for sonde storage. If users remove the sensor from the sonde, it may be stored in dry air in the shipping cap (to protect against physical damage).



Section 8
NitraLED FAQs

8.1 Technology

Q: Do I need an fDOM sensor to make EXO NitraLED work?

The fDOM sensor is unnecessary in the computation of nitrate when using the NitraLED sensor. Natural Organic Matter (NOM) breaks down into a category called Dissolved Organic Matter (DOM), which is then further categorized into Colored Dissolved Organic Matter (CDOM) and fluorescent Dissolved Organic Matter (fDOM). While it seems that fDOM and NOM should be relatable because fDOM is a subset of NOM, this is not the case. As the species in a water sample changes, so does the percentage of fDOM that makes up NOM. Also, merely knowing the fluorescence does not mean that we automatically know the species' absorbance characteristics. There are too many variables to consider, and relying on the absorbance from the NitraLED LED's and calculating NOM from those provides a more accurate measure of nitrate.

Q: Will my results be similar to the values I get when I collect manual grab samples for lab analysis?

First, laboratory analysis is still highly relevant and should not be replaced entirely from your monitoring program. Second, the NitraLED sensor's values should be comparable if you apply a Site-Specific Correction. However, please note that certain situations may cause the sensor to drift from the Site-Specific Correction coefficients (such as sediment composition change, seasonality, amount of algae/plant life, etc.). It is crucial to review Site-Specific Corrections if you notice significant drift between laboratory and continuous data.

Q: Is EXO NitraLED equivalent or supplemental to the more expensive nitrate analyzers I have now?

This sensor will report values similar to the continuous analyzers that you may have deployed in the field. For the most accurate data, you'll need to perform a Site-Specific Correction to account for any effects of turbidity or NOM on the nitrate reading.

Q: How does the UV LED technology in EXO NitraLED compare to an ion-selective electrode, colorimeter, photometer, or spectrophotometer?

Ion-selective electrodes (ISE's) are typically not intended for long-term deployment due to the significant drift over short periods. Other instruments, such as a colorimeter or photometer, are not designed for long-term deployment. They are typically used for discrete measurements and rely on reagents to determine a value. Spectrophotometers are typically lab instruments, but some have been designed for long-term deployment to monitor nitrate. These spectrophotometers are extremely expensive, have large power budgets, and are incredibly complex to install and maintain.

Q: If no Site-Specific Correction is applied to NitraLED, what are the impacts on data accuracy?

The data will trend relatively well, but will not be as aligned with any grab samples collected and may not give the full picture of nitrate fluctuations at the site. You may see more noise in the data or negative values due to overcorrection when using the default coefficients.

Q: Are there instructional videos available online that show how to use the EXO NitraLED Sensor?

Instructional videos can be found at YSI.com, as part of the EXO University series. They cover the sensor and accessory installation, routine calibration, and Site-Specific Correction.

8.2 Compatibility

Q: Is this sensor compatible with any other technology platforms besides EXO Sondes? Maybe a 6-Series Sonde or the ProDSS Handheld Meter?

EXO NitraLED is only available for the EXO Monitoring Platform. YSI designed the sensor for continuous deployment, and currently, EXO Sondes are the only instruments we offer for continuous environmental monitoring.

Q: Can I run a sonde deployment off internal batteries, or does an EXO Sonde with NitraLED require an external power source?

You can deploy an EXO sonde with NitraLED using internal batteries alone. You can also choose to power the instrument externally. External power is often supplied by connecting the instrument to a solar-powered system.

Q: Will EXO NitraLED require excessive power like other UV nitrate sensors?

No! Our new sensor requires the same amount of power that other EXO sensors do. It does not call for an external battery or power source for a single sensor, unlike many available options on the market today.

Q: Do I need a data logger to capture my EXO NitraLED data?

The EXO sonde platform allows for a user to log data internally and also gives the ability to connect to an external data logger if desired. When deploying the sonde, internal data logging is always an option. Even if the data logger loses power, as long as the sonde has batteries installed, it will still log data. Data saved onto the sonde can be easily downloaded via Kor Software and copied into any data record.

Q: Can the nitrate readings from EXO NitraLED be transmitted via SDI-12 or other external means?

Yes! The EXO sonde can be connected to a data logger and transmit data via SDI-12, RS-232, or Modbus. You can find additional information about EXO connectivity in the EXO User Manual.

8.3 Ordering

Q: How expensive is the EXO NitraLED Sensor compared to other solutions for in-situ nitrate monitoring?

The price of NitraLED is a fraction of the cost of other field spectrophotometers or wet chemistry analyzers. YSI engineers designed EXO NitraLED for field use, whereas other companies have retrofitted laboratory instruments for the field. This product development strategy adds a tremendous amount of cost to their equipment and restricts the number of scientists that can afford to collect continuous nutrient data. Before NitraLED, an environmental monitoring program could afford to monitor nitrate at a few select locations. Now, you can afford to monitor nitrate, at scale, throughout your entire watershed!

Q: How do I request a quote for an EXO NitraLED Sensor?

Visit YSI.com/NitraLED and fill out the Request a Quote form with your contact information. Your local YSI representative will follow-up to discuss the sensor and provide pricing information.

8.4 Setup and Maintenance

Q: Will I still get nitrate readings if I don't have an EXO Turbidity sensor installed in my sonde?

You must use an EXO Turbidity sensor along with EXO NitraLED to maintain the specified accuracy of the sensor. Turbidity compensation is a critical part of collecting quality nitrate data. Kor software will not allow calibration of the NitraLED without an installed and calibrated Turbidity sensor.

Q: How long does it take to calibrate EXO NitraLED?

The two-point calibration does not take long to complete. Our engineers added Auto-stabilization functionality into Kor Software, so you'll know as soon as the sensor has stabilized in standard, and the calibration process can continue to subsequent steps.

Q: What calibration solutions are necessary to calibrate EXO NitraLED?

The standard calibration for the NitraLED sensor is a two-point calibration. The first point requires Type I water, or deionized water (0 mg/L). Distilled water with no added minerals is a substitute for Type I water, but there must be no interfering species in the water. The second calibration point is determined by the user depending on expected site conditions. YSI offers two solutions for this second calibration point: 5 mg/L and 10 mg/L NO3-N. Be sure to use the NitraLED nitrate standards, as these are free of optical interferences.

Q: Can I use the nitrate standards used with EXO ISE Sensors?

The NitraLED sensor requires a particular standard made with nitrate diluted into pure water. The ISE sensor's nitrate standards have an added salt to increase the standard's conductance to allow the ISE to stabilize faster. The addition of this salt could cause interference with the NitraLED sensor calibration, so we recommend using the specific NitraLED standard.

Q: What is the shelf life of the NitraLED calibration standards?

The NitraLED calibration standards have a shelf life of one year unopened.

Q: What type of solutions can I use for the NitraLED 0 mg/L-N calibration?

YSI recommends using Type I water for the 0 mg/L-N calibration point. Distilled water may also be used, however, make sure there are no minerals added.

Q: Where can I find MSDS sheets for NitraLED calibration standards?

You can find the MSDS sheet for our 5 mg/L NO3-N standard here and our 10 mg/L NO3-N standard here.

Q: How long can the EXO NitraLED Sensor be deployed in the field before another calibration is necessary?

Calibration intervals are dependent on factors such as the deployment setup and environmental conditions the sensor is exposed to. This sensor is an optical sensor, so it has a high level of stability. If deploying at a 15-minute interval, we expect a 30-day deployment to have 0.2 mg/L-N of drift or less typically.

Q: Can you calibrate multiple EXO NitraLED Sensors with EXO's concurrent calibration feature?

No, you cannot calibrate more than one NitraLED Sensor at a time. The NitraLED must be calibrated alongside the specific Turbidity sensor it will be deployed with in the field.

Q: Do I need a third-party nitrate sensor to calibrate EXO NitraLED?

For the calibration in standards, an external nitrate sensor is unnecessary. However, step one of the Site-Specific Correction requires that a user input the actual value of nitrate in the water body. This value can be recorded from an ion-selective electrode, photometer, or colorimeter. An ISE or laboratory-style photometer will provide the best data for the initial site-specific calibration value. Please see Section 5.4.

Q: I do not have an external nitrate sensor, but I send samples to the lab. Can I preserve my samples, wait for the lab results to come back, and then perform the Site-Specific Correction for EXO NitraLED?

Yes, as long as the sample is adequately preserved, there should be no issue. Proper preservation calls for holding the sample chilled at or below 4°C. Ensure that around 2 L of the sample is reserved for th Site-Specific Correction procedure. Our testing indicates that nitrate in properly preserved samples changed very minimally over the course of a month. Hence, a sample held for even a month can still allow for a proper Site-Specific Correction. Please see Section 5.4.

Q: Once I perform a Site-Specific Correction, will my NitraLED sensor read the same in standards?

Yes, once the Site-Specific Correction is performed, the sensor should still read 0 mg/L-N in Type I water and 5 mg/L-N or 10 mg/L-N in the corresponding standards.

Q: How often do I need to perform a Site-Specific Correction with EXO NitraLED?

There is no definitive answer to this question because many factors affect the need for Site-Specific Corrections. For example, as algae grow in a reservoir, additional Natural Organic Matter (NOM) in the water will influence the sensor during summer months. However, as the algae die off in cooler temperatures, and the water at the top of the reservoir in the measuring location becomes clearer and free of NOM, the Site-Specific Correction may need to be completed again.

Seasonality will likely affect the frequency of Site-Specific Corrections, as alluded to in the example above, and also because some seasons are more likely to see increased runoff from storm events. When the sediment type changes at a monitoring location, we also recommend performing additional Site-Specific Corrections. For example, if summer baseflow conditions at a site are extremely low, and the sediment type is sand, this will give different values than elevated baseflow conditions where the sediment type is clay. Experimentation is needed to determine how often these corrections need to occur at each site.
Please see Section 3.6.

Q: What's the average lifespan of an EXO NitraLED Sensor?

A long time! Like our other optical sensors, the NitraLED sensor is designed to last for an extended time in the field. At YSI, we test each sensor before shipping it to ensure the highest quality standards. We also offer a 2-year warranty on this sensor to protect your investment.

Q: Are there any changes to Kor Software related to EXO NitraLED?

There are several changes to Kor software from previous versions. The first, of course, is the addition of the NitraLED sensor to the recognized sensors list. When you connect a NitraLED sensor to an EXO sonde, the sensor will appear in the Calibration and Instrument & Settings tabs. When navigating to File > Settings, the NitraLED sensor will also appear as an option in the menu. In the Calibration menu for the NitraLED sensor, there are two options now available. There is one option for the calibration in standards and another option for the Site-Specific Correction.

The software update also includes an update to the Central Wiper that allows a user to designate between Nitrate Mode and Normal Mode. To change the wiper mode, navigate to the Calibration menu, select the wiper, select Calibrate, and choose Normal or Nitrate. Please make sure you have installed the latest version of Kor Software available on YSI.com.

Q: Is the small wiper brush for the EXO NitraLED sensor as effective as the big wiper brush for the other sensors?

The new wiper brush has been tested in heavy fouling environments for efficacy and is as effective in cleaning the sensors as the old wiper brush. The short arm wiper brush intended to wipe the nitrate sensor has bristles on the top and bottom of the arm to wipe the photodiode lens and the LED lens effectively.

Q: Will the wiper affect the sensor adjacent to the NitraLED sensor?

YSI recommends installing a non-optical sensor in the port adjacent to the NitraLED sensor. The NitraLED wiper arm will park on top of this adjacent sensor and impact any optical readings. Sensors such as the pH, pH/ORP, other ISE's, or the optical dissolved oxygen sensor will not be affected by the new wiper brush positioning. Please see Section 4.1.

Q: Are there special storage requirements for the EXO NitraLED Sensor?

Like other optical sensors, this sensor can be stored completely dry. However, we recommend saving the sleeves used in shipping to protect the sensor faces and the pins during any storage period. The sensor can also remain installed on a sonde when placed into storage. Please see Section 7.0.

Q: Once I set my EXO Sonde up for use with NitraLED, can I use it without the new sensor?

Of course! You can use the sonde without the NitraLED by merely removing the sensor and recalibrating the Central Wiper to wipe in "Normal" mode instead of "NitraLED" mode.

Q: If I uninstall NitraLED, can I put other sensors in that sensor port?

Yes! The NitraLED sensor is just like any other EXO sensor, and having it installed does not change the sonde's inner workings. If you remove the NitraLED sensor and install any other sensor, the new sensor will be recognized. That new parameter will be reported in place of nitrate.

Q: What are the minimum software and firmware versions needed to use NitraLED?

The minimum requirements are as follows: KorEXO: 2.3.10, EXO Sonde: 1.0.84, NitraLED Sensor: 1.0.58, Turbidity sensor: 3.0.4, Central Wiper: 3.0.11, Handheld: 1.0.63

8.5 Sensor Applications

Q: Why will EXO NitraLED not work in saltwater?

There are too many other species in saltwater that interfere with the nitrate absorbance. For example, iodide and bisulfide absorb in the wavelength that we measure at, which could heavily impact nitrate readings. Please see Section 3.5.

Q: What is the max salinity value the sensor will operate in?

There is no definite answer because there could be many interfering species in the water. A safe bet would be to avoid areas with salinity greater than 2.5 PSU. Please see Section 3.5.

Q: Can I use EXO NitraLED Sensors for spot sampling?

The sensor can be used for spot sampling. However, you'll need to decide whether it is worth performing the Site-Specific Correction at each location or just performing a comparison using the sensor calibrated in standards. Please see Section 6.2.

Q: Can EXO NitraLED be used in groundwater applications?

Most groundwater applications call for a sonde with a diameter no greater than 2". If the NitraLED sensor is installed on an EXO1 Sonde with a Conductivity/Temperature Sensor and a Turbidity sensor, the sonde will monitor nitrate in a groundwater well. Please note there is no wiper option on the EXO1 system, so data could be impacted by bubbles left on the sensor faces if there is a great amount of aeration in the well. In this case, it may be best to use an EXO2 or EXO3 with a Central Wiper using a flow cell setup. Please see Section 4.1.

Q: What water quality parameters would you recommend for monitoring Harmful Algal Blooms (HABs)?

For HAB monitoring, we would recommend the EXO2 Sonde equipped with Conductivity/Temperature, pH, Optical Dissolved Oxygen, Turbidity, Total Algae Phycocyanin, and Nitrate (NitraLED), using the Central Wiper for anti-fouling purposes. Please visit YSI.com/HABs for more information.

8.6 Health and Safety

Q: Will the UV light from EXO NitraLED harm me in any way?

The UV light emitted from the NitraLED sensor is in the UV-B and UV-C spectrum and can cause irreversible damage to the body if care isn't taken. When uninstalled and independent from an EXO sonde, the sensor is harmless. However, when the sensor is installed and a power source is available (such as internal batteries), it activates and emits light. Do not look directly into the sensor light pathway or put any body part in the light pathway. Also, be aware that harmful UV light can be reflected if any reflective material is placed in the sensor path. If the light pathway requires cleaning, wear nitrile gloves to prevent the UV-B and UV-C light from coming into contact with the skin. You can find more information on our UV Safety page.

Q: Are the calibration standards for EXO NitraLED safe?

There is no known harm from the calibration standard coming into contact with the skin. MSDS information is provided with the standard for reference if it is splashed into the eyes or ingested.

You can find the MSDS sheet for our 5 mg/L NO3-N standard here and our 10 mg/L NO3-N standard here.

9.0 Contact Us

Please reach out to YSI Technical Support at 1+ (937) 767-7241 if you have questions or need more guidance for your EXO sonde or NitraLED sensor. We can offer live guidance during business hours, or you can email us at info@ysi.com for follow-up within 24-48 hours.

Telephone: 800 897 4151 (USA)

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Fax: +1 937 767 9353 (orders)

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10.0 References

"Standard Methods for the Examination of Water and Wastewater," Nitrate, UV Screening DOC316.53. part 4500-NO3–B

"Direct Ultraviolet Spectrophotometric Determination of Total Sulfide and Iodide in Natural Waters," Elizabeth A. Guenther, Kenneth S. Johnson, and Kenneth H. Coale, Analytical Chemistry 2001 73 (14), 3481-3487

"New YSI NitraLED UV Nitrate Sensor Put to the Test in Ohio," YSI, a Xylem brand. 2022. Application Note XA00208.

Xylem |'zīləm|

1) The tissue in plants that brings water upward from the roots;

2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

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