Water Lens™

Technical Overview
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1. Intro

Waters typically encountered in the oil & gas industry contain very high concentrations of compounds that can damage equipment and the structure of geological formations, as well as causing fluid compatibility issues. These issues can dramatically increase costs and reduce the expected recoveries from a well. To combat this, Water Lens, LLC has developed a field test kit for the quantification of important components in produced waters and waters used in both upstream and downstream segments. This test kit is portable, economical, and capable of lab-quality results in minutes (instead of days). By monitoring water quality during various processes, an operator will be able to optimize water chemistry and maintain compatible fluids, which will limit damage and increase recovery rates in oil and gas operations. Additionally, water treatment/recycling companies can determine the effective treatment levels needed to achieve a given water quality and verify the results onsite, in minutes.

The Water Lens test kit utilizes several independent detection motifs in a 96 well plate format. Each chemistry is loaded into an 8-well strip (12 strips to a plate), each of which contain a colorimetric dye (and other constituents) sensitive to the presence of the component being measured. The tests have all been carefully formulated to be compatible with high TDS and TSS produced waters from the oil and gas industry. The colorimetric response is then related back to a calibration curve to calculate the concentration of the parameter present in the sample. The chemistry in the tests have been freeze dried for stabilization, which provides for a long shelf life, even in harsh environments.

With this information, a number of actions can be taken by the operator to either improve or tolerate water chemistry. Our test kit is designed to be used by workers who are largely unfamiliar with water chemistry. The obtained water chemistry is referenced to a matrix containing the chemical tolerances of compounds commonly used by the oil and gas industry. In the case of highly specific or proprietary compounds not present in the matrix, a worker familiar with the chemistries involved is able to manually enter in new tolerances to the matrix to improve applicability to their particular operation.

Based on these tolerances, our software can give critical information for optimizing water use. First, it can quickly identify if the compounds in use are incompatible with the water

chemistry. This is indicated by a clear flagging of the compounds so that the worker can report to a supervisor to take appropriate action. Second, the software can identify that certain other compounds (which accomplish the same goals as the compounds in use) will better-tolerate the observed water chemistry. These compounds may then be substituted in to reduce cost and/or improve results.

Our customer feedback to date has been overwhelmingly positive. Compared with alternative field kits, customers have noted our kit is much easier to use and gives much faster and more accurate results. We are not aware of any other field kit which can give the parameter concentrations that we give easier, faster or more accurately than we can.

2. Operating Principles

The Water Lens test kit operates on the principle of colorimetric absorption by photosensitive dyes. When the dyes bind to their respective analytes, the photometric spectrum of the dyes change. These changes are read by monitoring the absorbance of light at specific wavelengths as light passes through the sample. The absorbance characteristics are read by a colorimeter, and the data generated is used to calculate the concentration of the particular analyte in the sample the proprietary Water Lens software.

The test kit itself is in the form factor of a 96-well plate. The plate is filled with freeze dried dye/reagent mixtures which dissolve when the sample is introduced. The 96-well plate format is ubiquitous in the medical and diagnostic community, and a number of different colorimeters are designed specifically to be compatible with them. The current kit interfaces with a Tecan Infinite F50 96-well plate reader. Though the kit can easily be translated to be compatible with any reader, this reader was chosen for its ruggedness, simplicity, and reliability. The reader itself is managed by Magellan analysis software. This software is used only to gather the raw absorbance data; no calculations for concentrations are done by Magellan.

No binding motif has perfect specificity for its intended analyte. As such, the dyes/sensors used in the Water Lens kit to bind their target analytes are subject to various interferences. However, if the interferences are well characterized and their concentrations are known, then the accuracy of a result generated in their presence can be greatly increased using correction factors. By testing for multiple agents and using proprietary machine-learning algorithms, the Water Lens kit can simultaneously gather absorbance data from a dye/sensor and the most common significant interferences for that particular sensor. This enables the system to correct

for interferences and give an accurate result without ever reporting an incorrect value that requires adjustment by the user.

The raw data from the plate reader is used to calculate concentrations using the Water Lens proprietary analysis software. Our software correlates the absorbance data to an analyte concentration by referencing the calibration curves, which we generate in our lab. **Figure 1** shows an example of such a calibration curve. The calibration curves are generated using at least 12 calibration points with 8 replicates per point. Our limits of detection (LOD) are determined using this software as well. Traditional methods for determination of the LOD of a linear curve fit fail with non-linear curves. However, we can obtain an accurate LOD as well as calculate uncertainty for any point on the curve out to 3 standard deviations.

Serial dilution with DI water was performed to ensure each target analyte was within the range of the test kit. The details of this process are given in the Water Lens instruction card.

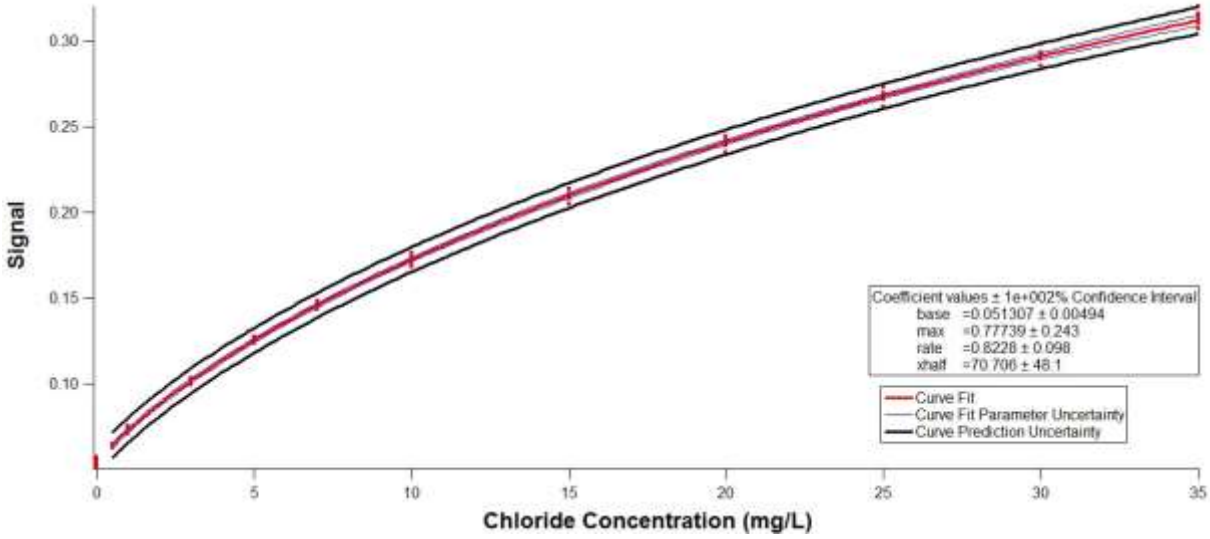

Figure 1: *Calibration curve for Chloride assay*. The replicates of each point on the curve are represented by red dots. The curve fit which relates the absorbance signal to the concentration is shown as the bold red line. The uncertainty in the variables of the equation to 3 standard deviations are shown as thin blue lines above and below the curve fit. This uncertainty combined with the 3rd standard deviation of the points in the fit is shown as the bold black lines above and below the fit.

3. Common Concerns

Interferences affect every analytical method, from an ICP-MS down to a strip of pH paper. Our system is no exception. To account for the effects of interferences, two things must be known: how the interference affects the result, and how much of the interference is present. This is a significant problem with running legacy field kits one parameter at a time. For example, the legacy field sulfate assay has a negative interference from chloride. Chloride is also very common in water samples, so the sulfate assay alone frequently yields results much lower than reality, due to this interference not being accounted for. Without measuring for interferences at the same time, the true concentrations of many parameters will be uncertain.

One of the strengths of the Water Lens test kit is that so many different parameters are measured at the same time. In doing this, we measure the most common interferences for each of our assays at the same time. We have done extensive research in our lab to determine the way that each interference affects each of our assays. We can then use our field measurements to quantify each of the interferences. Using this data, our software corrects each of our measurements for interferences automatically before showing any result.

Interferences are also addressed by chemical formulation. Interferences can only be corrected for if the assay remains functional in their presence. Assays in the Water Lens field kit are specifically formulated to tolerate as high of a concentration of common interferences as possible while permitting the operation of correction algorithms. Many different formulations of each assay are tested during product development to optimize accuracy, tolerance of interferences, and user friendliness.

In addition to our QA/QC process for our assays, we maintain the calibration of our instruments. If a plate reader loses its calibration, we replace the reader with a freshly calibrated unit as soon as possible. We will also swap readers out with freshly calibrated ones at regular intervals to preempt any possible shift. We have similar protocols for maintaining the calibration of our pipettes.

Dilutions are a critical component of running the Water Lens kit. We have developed a serial dilution kit that is fast, accurate, and easy to perform. Using our kit, a user can go from a raw sample to a filtered, 10x, 100x, 1,000x, and 10,000x dilution in about 90 seconds. This is accomplished using a fixed volume pipette for sample transfer and a bottle top DI water dispenser unit. We have done extensive testing on these units. The error in their dispensing volumes has been determined to be negligible.

Most of our assays are run as 8 replicates of the same test. If any one of the wells is an outlier, our software is equipped with a two-pass outlier detecting algorithm to remove it so it is not used to calculate the final value. This system is designed such that if too many outliers are present, no result is calculated and the user is informed that the test should be rerun. While it is possible for user error to yield an incorrect result, many of the most common places for a mistake to be made can be detected by the software. If any data in the final report is not self-consistent, the software notifies the user that an error was encountered rather than give an incorrect result.

4. Accuracy

Environmental labs in the United States are held to strict accuracy standards set by the EPA. These standards are enforced and certified by the National Environmental Laboratory Accreditation Program (NELAP). Environmental laboratories in the United States are sent proficiency standards by labs that partner with NELAP to test their accuracy. In order to continue their operations, environmental labs must meet the EPA accuracy standards on 80% of all of their results. The EPA sets the accuracy standards independently for each analyte, but as of December of 2016 the accuracy standard for inorganic cations and anions is generally +/- 15%. In other words, in order for labs to be certified (and maintain that certification), their results need to be within 15% of the correct answer 80% of the time.

Although Water Lens does not operate as an environmental laboratory (and therefore does not intend to seek NELAP accreditation), we hold ourselves accountable to these same standards. In addition to adhering to these standards, we at Water Lens chose to verify our kit's accuracy against actual produced water samples, rather than lab-made standards. We believe that our accuracy should reflect what our users will experience in the field; not just under ideal lab conditions. This approach was chosen to add another layer of confidence in our accuracy when analyzing oilfield water samples. By adhering to these standards, we provide our clients with the confidence that the Water Lens system will consistently provide accurate data, whether in the field or in the laboratory.

The following information confirms that when testing produced oilfield water samples, Water Lens either meets or exceeds the proficiency testing standards established by the NELAP institute. Water Lens analyzed a total of twenty-one samples, which were acquired from the field or submitted from customers and other interested parties. All samples were analyzed for cations and anions using the Water Lens field kit. The results were then compared with data gathered using Water Lens internal laboratory equipment (Method ASTM D6919 for cations and EPA 300.0 for anions). A graphical interpretation of these results compared with the EPA standards is shown

in **Figure 2**. These results show that the Water Lens test kit exceeds the standard set by the EPA on fully equipped environmental labs on real world samples, rather than synthetics.

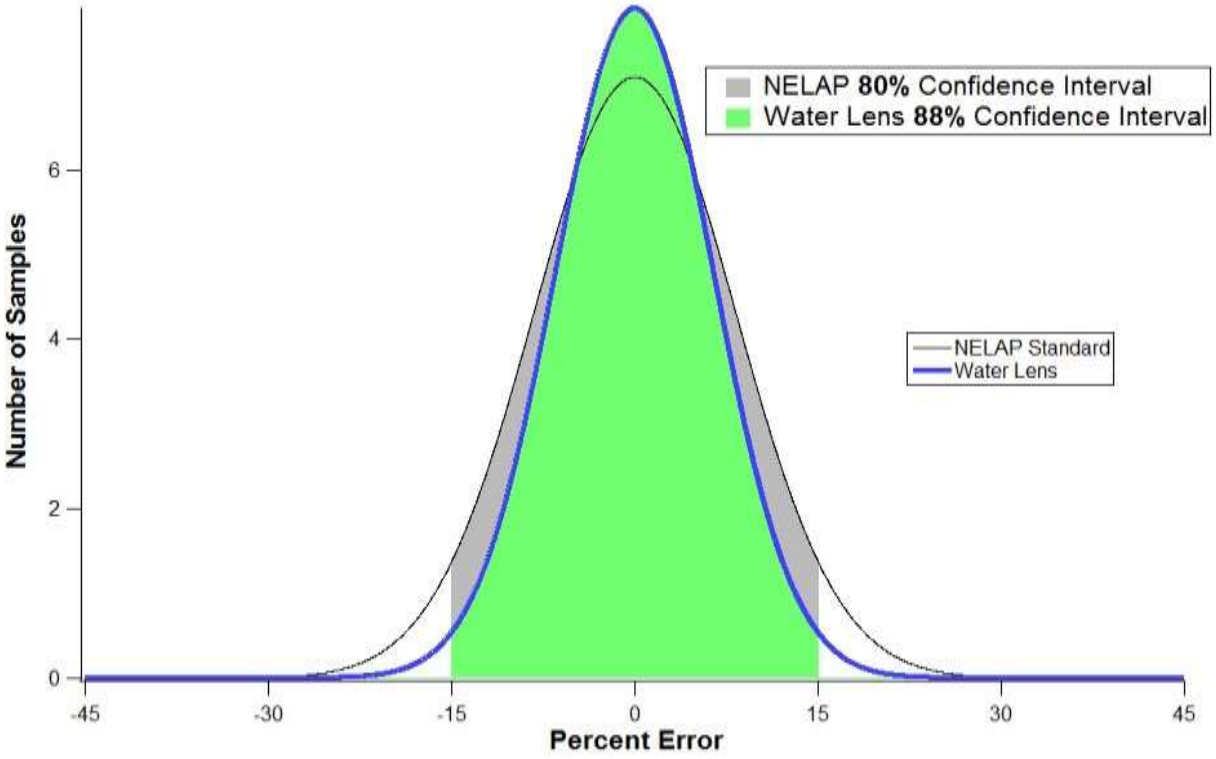

Figure 2. *Average of Water Lens test kit results compared with EPA standard. The dark blue Gaussian distribution represents Water Lens' confidence interval of 88% compared with the standard 80%.*