WRF 4973 Fact Sheet: ID 1560

Strategy: Instrumentation and Controls

Sensors and Instrumentation

UV Analyzer (multiple-wavelength UV absorbance detection system).
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Multiparameter Probe.
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This fact sheet acts as an extension of Fact Sheet 1501 (Instrumentation and Controls) and it is a companion to Fact Sheet 1510 (Improve Control, Stability, and Efficiency). While Fact Sheet 1501 introduces the use of advanced instrumentation and controls (I&C) schemes for nutrient optimization at water resource recovery facilities (WRRFs), this fact sheet focuses on sensors and/or instrumentation.

This fact sheet presents the use of sensors to support nutrient optimization as part of an overall I&C solution (refer to Fact Sheet 1510 for control strategies). Different types of sensors, the use of sensors, and operation and maintenance (O&M) of sensors are discussed in this fact sheet. Key sensors discussed include ion-selective electrodes (ISEs), gas-sensing electrodes (GSEs), optical sensors, and wet analyzers.

Fact Sheet Application Checklist

R = fact sheet relevant to item
PR = fact sheet is potentially relevant to item depending on application, existing conditions, etc.

Category		
Category	PR	Intensification
	PR	Chemical addition
	PR	Carbon management
	R	I&C strategies
	PR	Sidestream mgmt.
	PR	Energy savings
	PR	Chemical savings
	PR	Operational savings
		By other means
Nutrient	R	Ammonia
	R	NOx
	PR	TN
	R	Ortho-P
	R	TP
Scale (design flow)	R	Small (<1 mgd)
	R	Medium (1–10 mgd)
	R	Large (>10 mgd)

Goal	R	Improve reliability
	R	Reduce nutrient
	R	Reduce O&M cost
Group	R	Optimize existing CNR
	R	Optimize existing TNR
	PR	NutRem in secondary plant
Process		Small
		Pond
		Fixed film (secondary)
		Conventional act. sludge (CAS)
	R	Nitrifying act. sludge (NAS)
	R	Conventional NutRem (CNR)
	R	Tertiary NutRem (TNR)
		Other

CAS = conventional activated sludge (BOD only)
NAS = nitrifying activated sludge (without denitrification)
CNR = conventional nutrient removal no chemical/no filter, etc.
TNR = tertiary nutrient removal with chemical, filter, etc.

Technology Summary Evaluation

Footprint	1	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	4–5	Technology ranking based (LIFT) see below*
Energy efficiency	2	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M impact	2	Scale 1–5: 1 = cost much less; 3 = cost similar to conventional; 5 = cost much more
Material/consumables	2	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	1	Scale 1–3: minimal/none = 1; some = 2; significant = 3 (e.g., chemical process)

* Technology ranking based on Leaders Innovation Forum for Technology (LIFT) Water Research Foundation (WRF) Technology Development Level (TDL) definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional

Descriptions/Evaluation

Strategy	Instrumentation and controls: sensors and instrumentation
Description	As introduced in Fact Sheet 1501, I&C is a key part of nutrient removal process control. This fact sheet discusses sensors and instrumentation used to facilitate advanced control strategies.
Application	Sensors used for measuring dissolved oxygen (DO), ammonia, nitrate, nitrite, phosphate, and total suspended solids (TSS) concentrations are presented in this fact sheet. Measurement of oxidation-reduction potential (ORP) as well as a number of supplemental sensors are also discussed. Online measurements may be conducted with ISEs, GSEs, optical probes, and wet-chemistry analyzer systems. Suppliers of online measurement sensors include Hach, YSI/WTW, Endress+Hauser, ABB, and S::CAN. See Table 1 below for sensors/instrumentation options.
Constituents removed	Ammonia, oxidized nitrogen (nitrate + nitrite) (NO_x), total nitrogen (TN), Ortho-P, total phosphorus (TP)
Development status*	LIFT TDLs 4–5. Most strategies are well developed. New approaches and probes continue to emerge.
O&M considerations	Probes should be calibrated and validated to maintain accurate readings Probes require cleaning periodically Online wet chemistry uses sampling and typically requires a filtration unit Chemical reagents required for online sensors using wet chemistry
Benefits	Provide accurate and continuous monitoring of process streams to verify performance and maintain stable operation Allow for fine tuning and early warning of process performance Optimize chemical and energy use Reduce operator effort (offset by increased maintenance)
Limitations	Instrument and probe maintenance (offset by decreased operator time)
Design considerations	Probe locations must be carefully evaluated to collect representative samples.
Potential fatal flaws	I&C cannot overcome equipment limitations—for example, blower control may be limited by equipment capacity (high end) and ability to turn down to low demands (low end).
Footprint requirements	Small
Residuals	None
Cost considerations	Depends on probe type and function. Determine specific cost based on life-cycle analysis (LCA) and include both capital and O&M cost.
Past experience	Raleigh, North Carolina; San Antonio Water System (SAWS); Lincoln, Nebraska; Denver, Colorado, Metro Wastewater Reclamation District (MWRD) Robert Hite Facility; Grand Rapids, Michigan
Publications	Miller, M.; P. Regmi, J. Jimenez. 2019. Sensors Versus Analyzers: The Case for Ammonia-based Aeration Control. Proceedings of the 92nd Water Environment Federation's Technical Exhibition Conference (WEFTEC), Chicago, Illinois. Regmi, P., B. Holgate, D. Fredericks, M.W. Miller, B. Wett, S. Murthy, C.B. Bott. 2015. Optimization of a mainstream nitritation-denitritation process and anammox polishing. Water Science Technology. 72(4), 632–642. Rieger, L., R.M. Jones, P.L. Dold, and C.B. Bott. 2012. "Myths about Ammonia Feedforward Aeration Control." Proceedings of the 85th Water Environment Federation's Technical Exhibition and Conference, New Orleans, Louisiana.

	Schraa, O., L. Rieger, J. Alex, I. Miletic. 2019. Ammonia-based aeration control with optimal SRT control: improved performance and lower energy consumption. Wat. Sci. Tech. 79(1), 63–72.
Related fact sheets	1501: Instrumentation and Controls Overview 1510: Improve Control, Stability, and Efficiency 1150: Use of Chemicals to Improve Nutrient Removal 1401: Process Options to Optimize Carbon Usage 1410: Fermentation—Basics 1450: DO Control to Increase Denitrification 1701: Reduce Energy Use—Overview Energy 1740: Operational Changes to Save Energy 1820: Chemical Testing and Selection 1910: Operational Adjustments to Reduce Energy 1920: Operational Adjustments to Reduce Chemical
Date updated	9/10/2022
Contributors	Leiv Rieger, Eric Evans, Erika Bailey, JB Neethling, Anand Patel

Note

* Technology ranking based on LIFT WRF TDL definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional (https://www.waterrf.org/sites/default/files/file/2019-07/LIFT%20Scan%20Application-LIFT%20Link%2BHub_0.pdf : accessed September 2020)

Additional Information

Sensor and Analyzer Options

This section discusses four main sensor and analyzer types: ISEs, GSEs, optical probes, and wet-chemistry analyzers. All of these sensor types are field-installed to support the I&C strategies laid out in the fact sheets. Table 1 provides a summary of sensors, target nutrients, and a brief description. The sensors in Table 1 fit into one of the categories below.

Ion-Sensing Electrode

ISEs measure dissolved ions based on electrical potential based on principles following the Nernst Equation. The electrode measures potentiometric differences depending on the concentration of the target ion in solution. As a result, ISE-type sensors are used to measure ion species in solution such as nitrate and ammonium.

Gas-Sensing Electrode

GSEs measure dissolved gases in solution with the use of a gas-permeable membrane that allows the target dissolved gas to cross the membrane into an intermediate solution. Once the dissolved gas passes into the intermediate solution, the activity in the intermediate solution is impacted. The activity is measured by an ISE calibrated to the concentration of the dissolved gas. DO sensors are a common type of GSE. GSE-type sensors are less commonly implemented in favor of optical probes and ISEs.

Optical Probes

Optical probes are used to measure analytes such as DO, nitrate, and nitrite. Optical sensors function by emitting light onto a coated surface. The light emitted is reflected off the surface and onto a photo diode that measures the intensity of the light. When higher concentrations of the analyte are present, the intensity of the light reflects changes.

Wet-Chemistry Analyzer

Wet chemistry systems consist of a cabinet mounted in the field supplied with reagents for analytical testing. Wet chemistry analyzers are used for measuring ammonia and phosphate. These systems use different approaches to measuring analytes including GSEs and colorimetry.

Table 1. Sensor/Instrumentation Options.

Sensor	Nutrient	Sensor Description
DO probe (optical)	Dissolved Oxygen Nitrate Nitrite	Light-emitting diode (LED)-based optical probe for measuring DO in bulk solution
Ammonia probe Ammonia analyzer (wet chemistry)	Ammonium TN	Ammonium and nitrate ISE and ammonia wet chemistry cabinet based on colorimetry
ORP probe	Multiple	ORP: older approach to evaluate environment—aerobic, anoxic, anaerobic.
Total solids (TS) optical probe	Multiple	TS measurement often used to gauge mixed liquor suspended solids (MLSS) and return activated sludge (RAS)/waste activated sludge (WAS) concentrations

Sensor	Nutrient	Sensor Description
Radar (level, blanket level)	Multiple	Radar signal can be "tuned" to measure liquid, foam, and sludge blanket levels
Flow meter	Multiple	Ultrasonic sensors (used with flumes and weirs) and magmeters used to measure flow
Phosphate analyzer (wet chemistry)	Phosphorus (phosphate)	Phosphate wet chemistry cabinet based on colorimetry
Airflow meter	Multiple	Multiple types: thermal mass meter, vane flow sensor
Pressure sensor	Multiple	Transduce measures water column pressure to monitor depth

Abbreviations

BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
DO	Dissolved oxygen
GSE	Gas-sensing electrode (sensor)
I&C	Instrumentation and controls
ISE	Ion-selective electrode
LCA	Life-cycle analysis
LED	Light-emitting diode
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
mgd	Million gallons per day
MLSS	Mixed liquor suspended solids
MWRD	Metro Wastewater Reclamation District
NAS	Nitrifying activated sludge
NO_x	Oxidized nitrogen (nitrate + nitrite)
NutRem	Nutrient removal
O&M	Operations and maintenance
ORP	Oxidation-reduction potential
RAS	Return activated sludge
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
SAWS	San Antonio Water System
TDL	Technology Development Level
TN	Total nitrogen

TNR	Tertiary nutrient removal
TP	Total phosphorus
TS	Total solids
TSS	Total suspended solids
UV	Ultraviolet
WAS	Waste activated sludge
WRF	The Water Research Foundation
WRRF	Water resource recovery facility