Appendix 4. Laboratory Comparison between StablCal and Polymer Turbidity Standards using pink clay at the Kansas Water Science Center Laboratory, Lawrence, Kansas

Comparison Description

Station name: Kansas Water Science Center Laboratory, Lawrence, Kansas.

Equipment: A Yellow Springs Instrument (YSI) EXO water-quality monitor equipped with two YSI EXO turbidity sensors calibrated using two different standards were deployed in a laboratory turbidity testing apparatus for comparison between the two standards. (See “Performance Evaluation Tests,” “Laboratory Tests,” p. 7 of main report, for a full description of laboratory methods.) The Hach model 2100AN laboratory turbidimeter with a flow-through cell was used as a reference to measure the turbidity in the apparatus bucket every 15 minutes before adding more sediment. No datum corrections were applied to either dataset.

Testing material and water: Pink clay and deionized water

Calibration standard used: One sensor was calibrated with Hach StablCal turbidity standard and one sensor was calibrated with YSI polymer standard.

Laboratory comparison date: March 21, 2017.

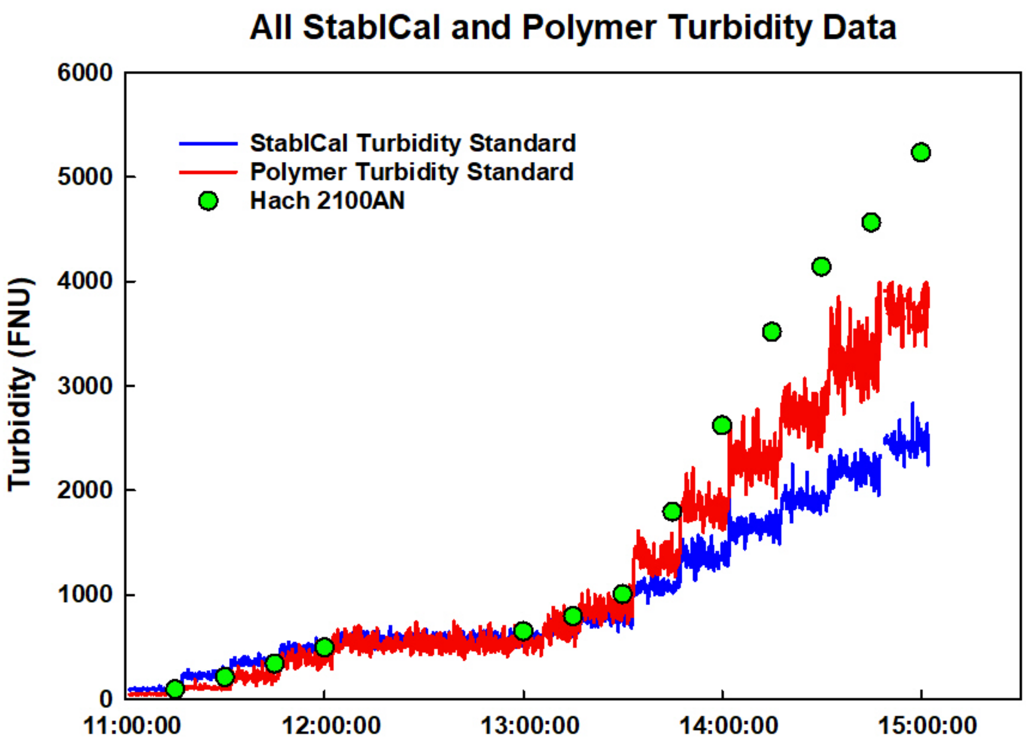
Datasets

All data were collected using U.S. Geological Survey [USGS] protocols (U.S. Geological Survey, variously dated) and are published in King (2021). Data were edited to remove periods where material was added to the testing apparatus, leaving the steady-state data for analysis.

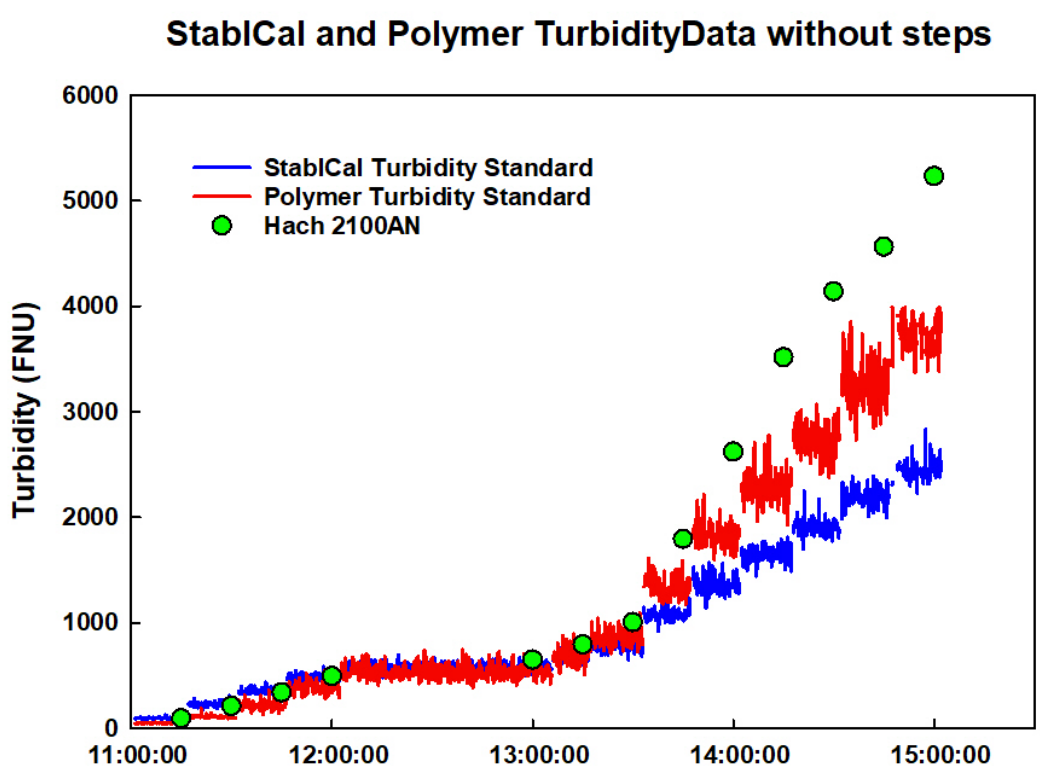
Polymer Standard Identification

	124 FNU Lot Number	1,010 FNU Lot Number
Polymer #1	17A693064	17B793997

Time Series



All StablCal and Polymer Turbidity Data
StablCal Turbidity Standard
Polymer Turbidity Standard
Hach 2100AN
Turbidity (FNU)
6000
5000
4000
3000
2000
1000
0
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00



StablCal and Polymer TurbidityData without steps
StablCal Turbidity Standard
Polymer Turbidity Standard
Hach 2100AN
Turbidity (FNU)
6000
5000
4000
3000
2000
1000
0
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00

Statistical Analyses – StablCal and Polymer Data

Slope comparison

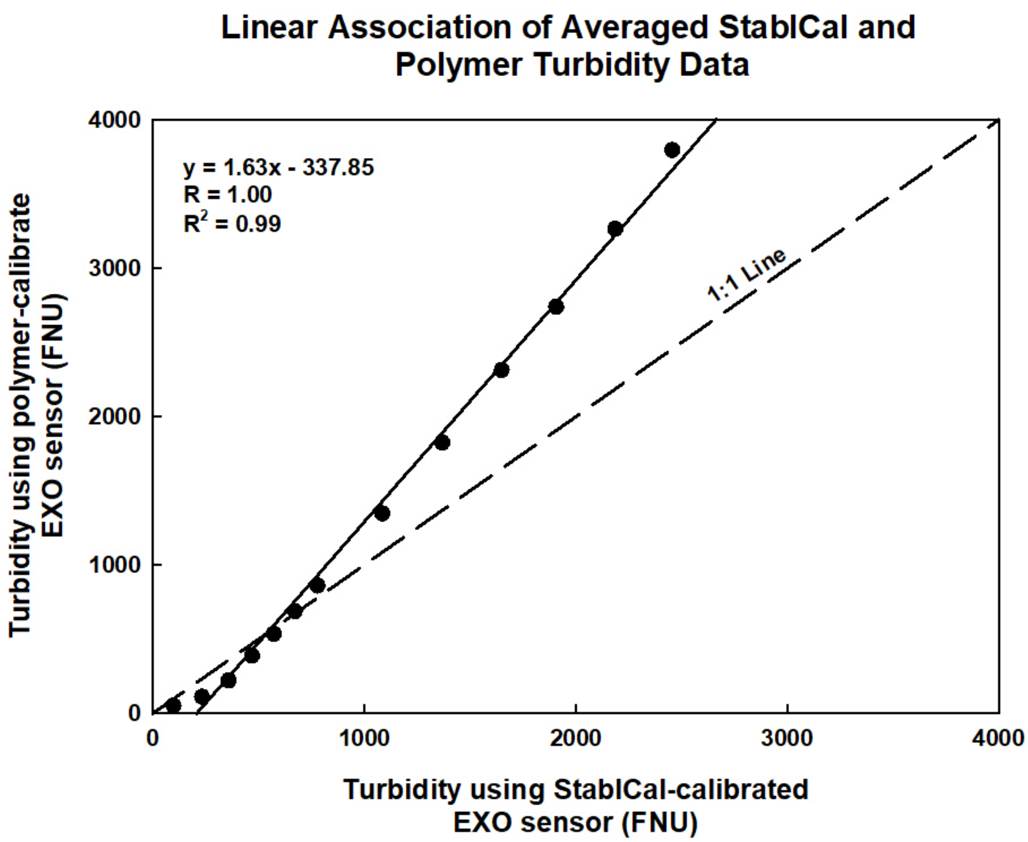
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using two different calibration standards at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 21, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

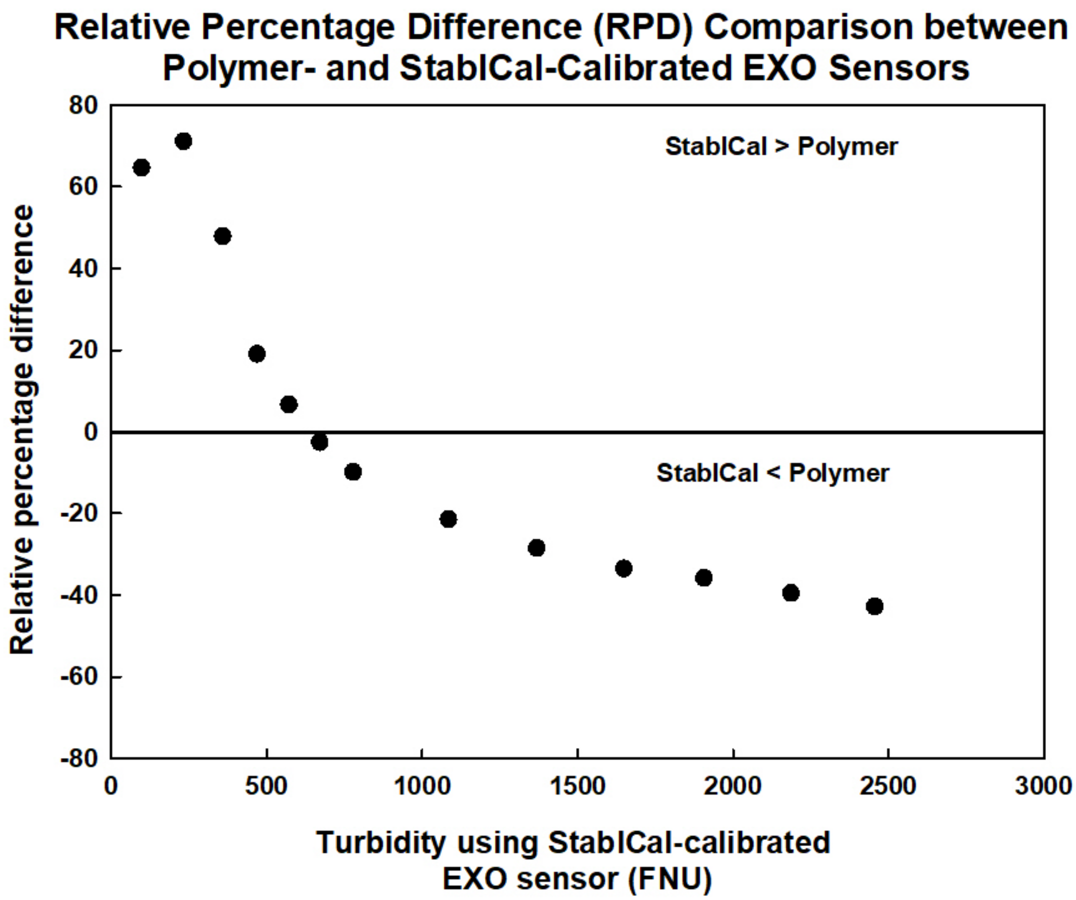
$$y = 1.63x - 337.85$$

where

y = turbidity measured with polymer-calibrated EXO sensor (FNU)

x = turbidity measured with StablCal-calibrated EXO sensor (FNU).





Wilcoxon Signed-Rank Test for StablCal and Polymer data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed ($P < 0.050$)

Group	**N**	**Missing**	**Median**	**25%**	**75%**
StablCal	13	0	777.841	413.608	1777.828
Polymer	13	0	858.462	303.730	2526.198

W= 45.000 T+ = 68.000 T-= -23.000
Z-Statistic (based on positive ranks) = 1.572
P(est.)= 0.124 P(exact)= 0.127

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.127).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  StablCal and Polymer
V = 68, p-value = 0.1272
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -32.02524 645.66852
sample estimates:
(pseudo)median
      291.4963
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 3 to 71 percent (median: 34 percent; mean: 33 percent). The data did not pass the Shapiro-Wilk test for normality ($P<0.05$); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the StablCal- and polymer-calibrated EXO sensors was not statistically significant ($P>0.05$).

Statistical Analyses - StablCal and Hach 2100AN Data

Slope comparison

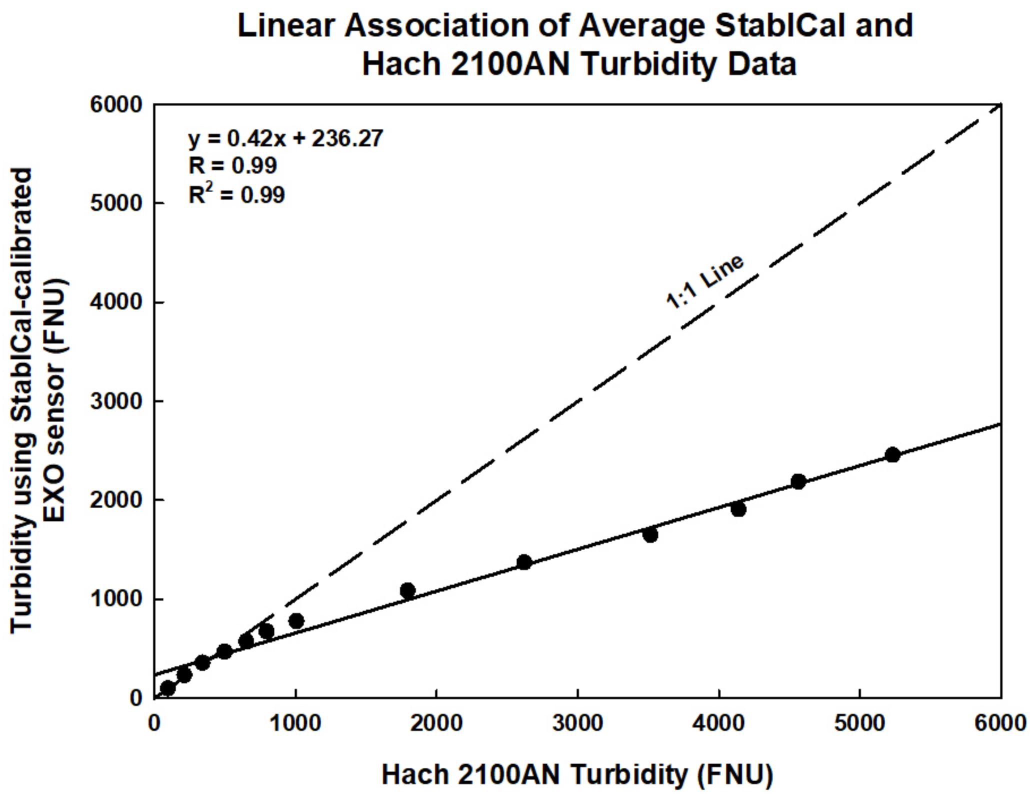
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using StablCal turbidity standard and compared to turbidity measured with a Hach 2100AN laboratory turbidimeter at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 21, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

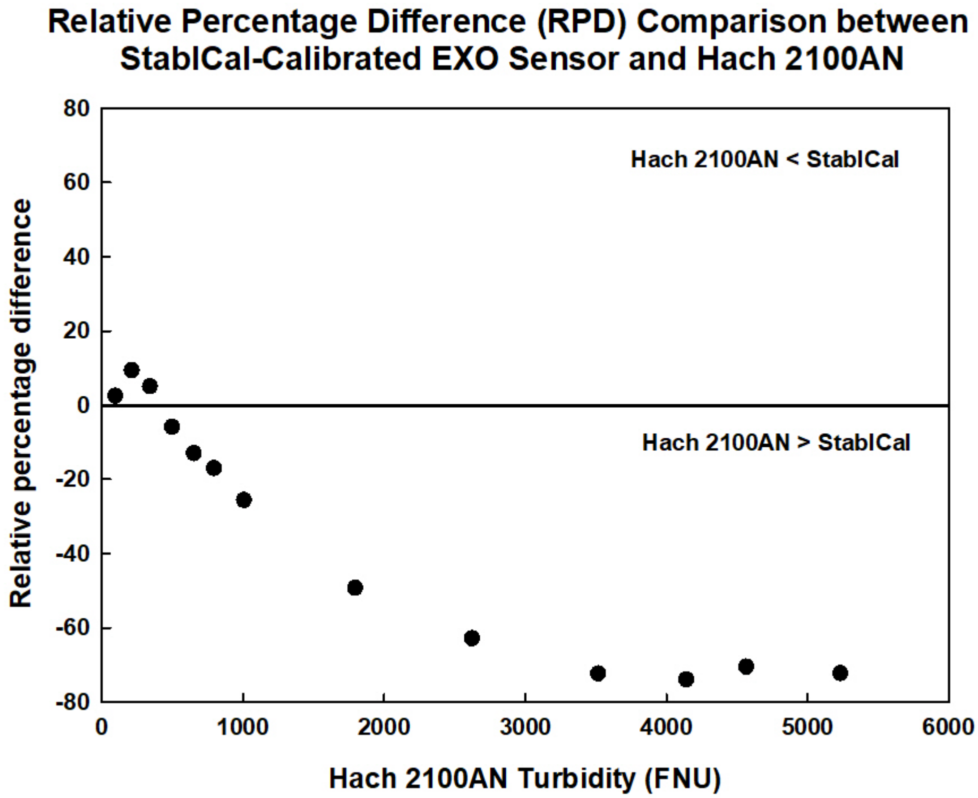
$$y = 0.42x + 236.27$$

where

y = turbidity measured with StablCal-calibrated EXO sensor (FNU)

x = turbidity measured with Hach 2100AN turbidimeter (FNU).


Linear Association of Average StablCal and
Hach 2100AN Turbidity Data
y = 0.42x + 236.27
R = 0.99
R2 = 0.99
1:1 Line
Turbidity using StablCal-calibrated
EXO sensor (FNU)
Hach 2100AN Turbidity (FNU)
0
1000
2000
3000
4000
5000
6000



Wilcoxon Signed-Rank Test for StablCal and Hach 2100AN

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed ($P < 0.050$)

Group	N	Missing	Median	25%	75%
Hach 2100AN	13	0	1006.000	418.750	3829.000
StablCal	13	0	777.841	413.608	1777.828

W= -79.000 T+ = 6.000 T-= -85.000
Z-Statistic (based on positive ranks) = -2.760
P(est.)= 0.006 P(exact)= 0.003

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference ($P = 0.003$).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  Hach 2100AN and StablCal
V = 85, p-value = 0.003418
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
   76.23686 1471.67559
sample estimates:
(pseudo)median
      932.7438
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.99). Relative percentage difference ranged from 3 to 74 percent (median: 26 percent; mean: 37 percent). The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the StablCal-calibrated EXO sensor and Hach 2100AN turbidimeter was statistically significant (P<0.05).

Statistical Analyses - Polymer and Hach 2100AN Data

Slope comparison

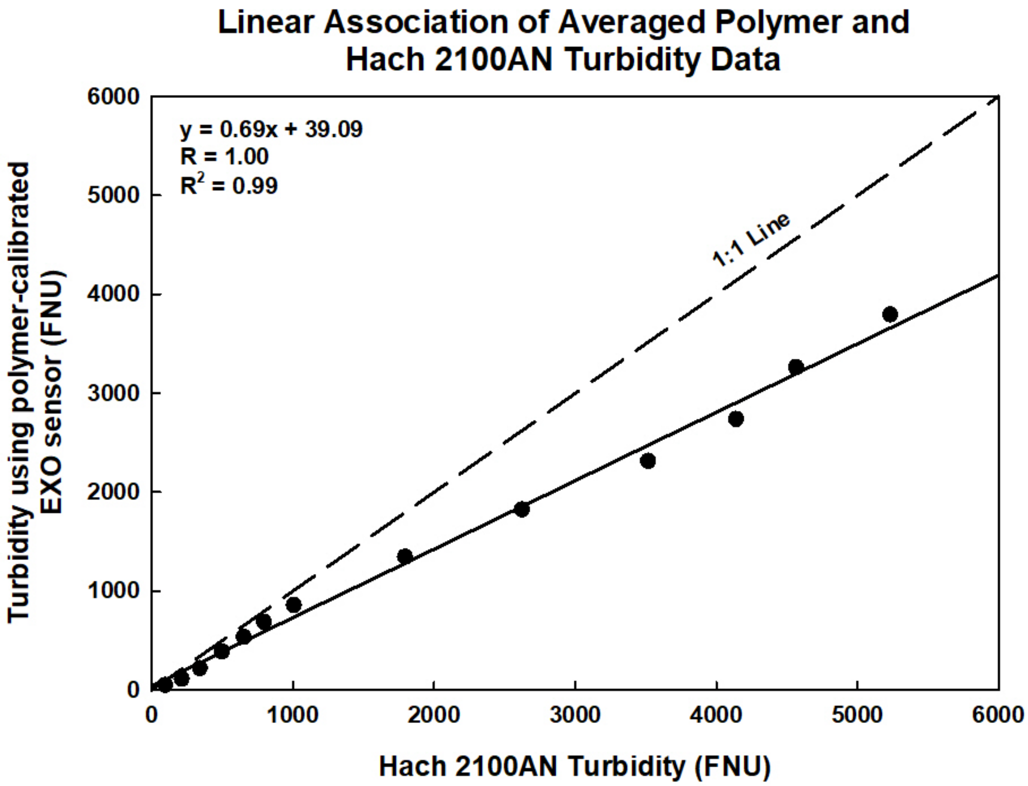
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor was calibrated using polymer turbidity standard and a Hach 2100AN laboratory turbidimeter at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 21, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

$$y = 0.69x + 39.09$$

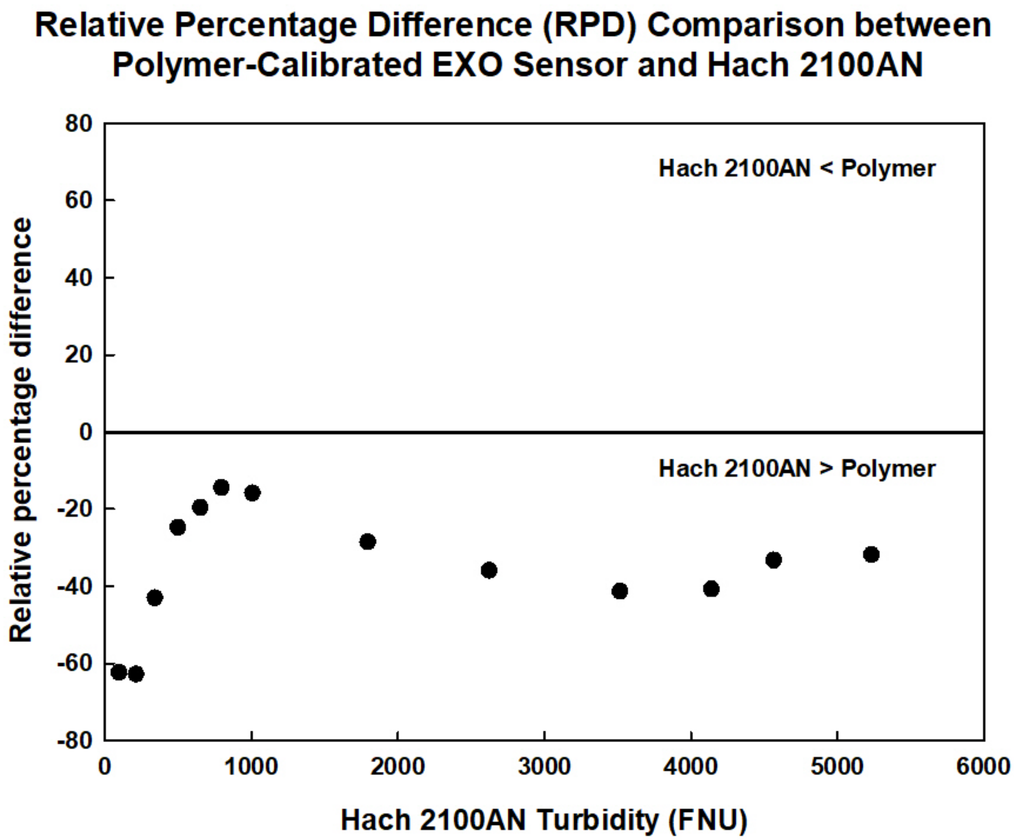
where

y = turbidity measured with polymer-calibrated EXO sensor (FNU)

x = turbidity measured with Hach 2100AN turbidimeter (FNU).



Linear Association of Averaged Polymer and
Hach 2100AN Turbidity Data
y = 0.69x + 39.09
R = 1.00
R2 = 0.99
1:1 Line
Turbidity using polymer-calibrated EXO sensor (FNU)
Hach 2100AN Turbidity (FNU)
0
1000
2000
3000
4000
5000
6000



Wilcoxon Signed-Rank Test for Polymer and Hach 2100AN

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed ($P < 0.050$)

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Hach 2100AN	13	0	1006.000	418.750	3829.000
Polymer	13	0	858.462	303.730	2526.198

W= -91.000 T+ = 0.000 T-= -91.000
Z-Statistic (based on positive ranks) = -3.180
P(est.)= 0.002 P(exact)= <0.001

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  Hach 2100AN and Polymer
V = 91, p-value = 0.0002441
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 113.7880 825.6718
sample estimates:
(pseudo)median
       652.257
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 14 to 63 percent (median: 33 percent; mean: 35 percent). The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-tank test was performed. The difference between median values for the polymer-calibrated EXO sensor and Hach 2100AN turbidimeter was statistically significant (P<0.05).

Selected References

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v. 74, no. 368, p. 829–836.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources—Hydrologic analysis and interpretation: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 522 p. [Also available at https://doi.org/10.3133/twri04A3.]

King, L.R., 2021, Laboratory and field data for selected turbidity standard and sensor comparisons, October 2014 to September 2017: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9EVSDHH.

U.S. Geological Survey, variously dated, The national field manual for the collection of water-quality data: U.S. Geological Survey Techniques and Methods, book 9, chaps A1–A10. [Also available at https://water.usgs.gov/owq/FieldManual/.]