Appendix 3. Laboratory Comparison between StablCal and Polymer Turbidity Standards using white 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 with different turbidity standards was 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: White 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 24, 2017.

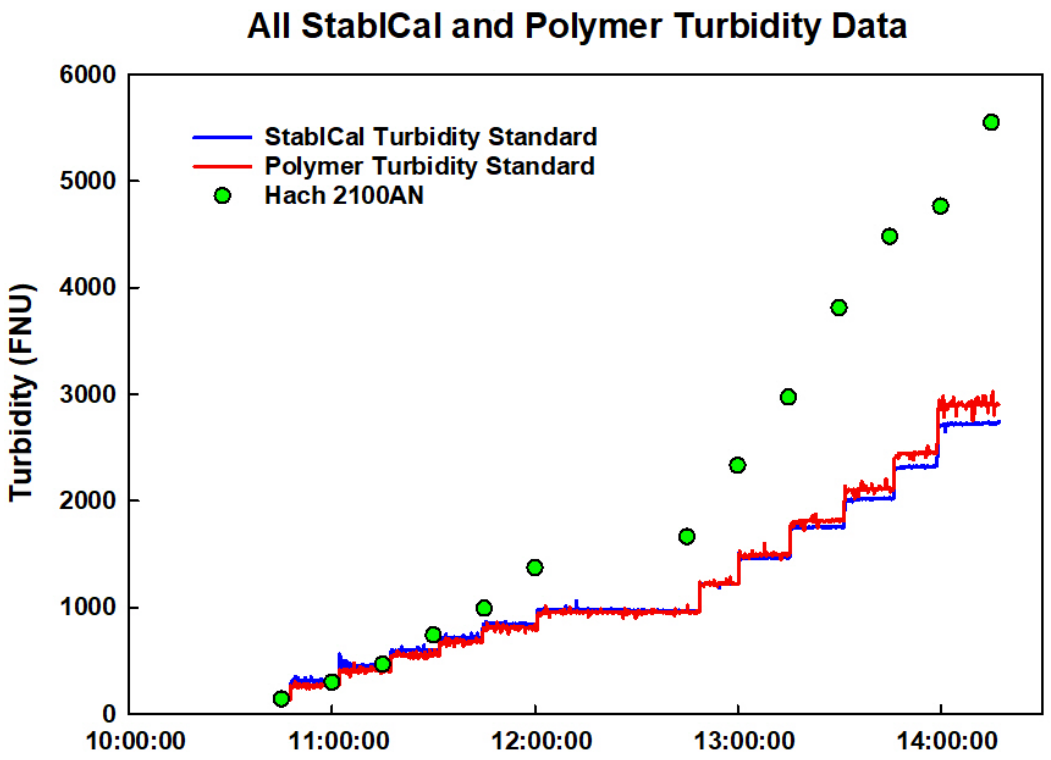
Datasets

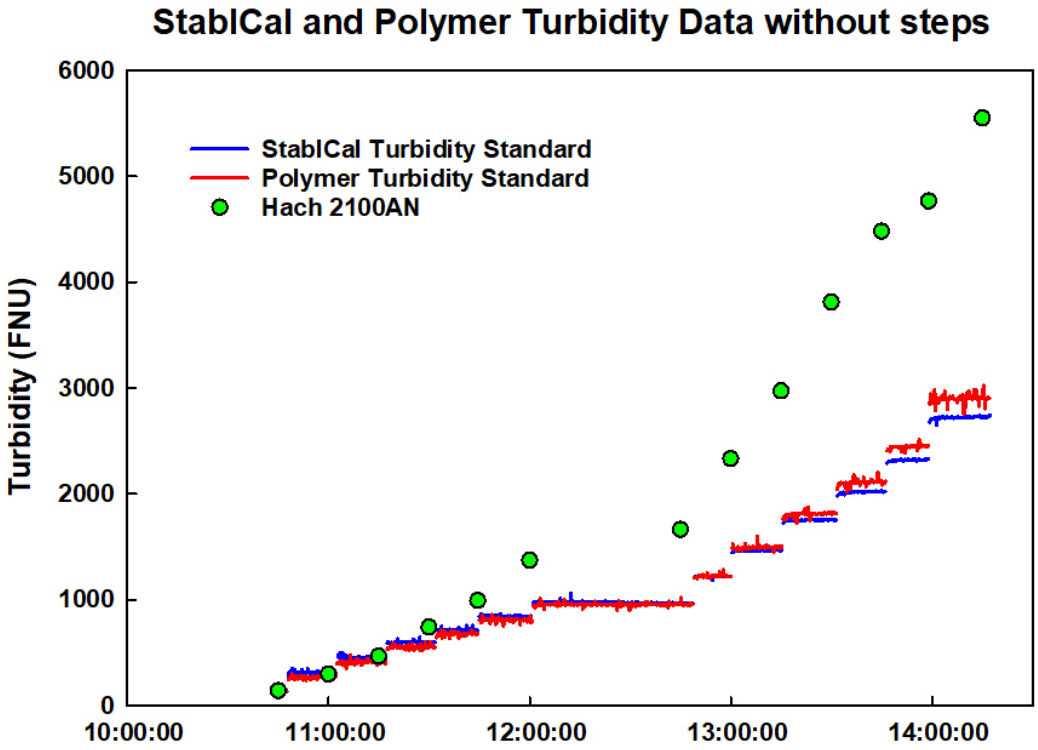
All data were collected using U.S. Geological Survey [USGS] protocols (U.S. Geological Survey, variously dated) and are published in King (2021). Data were edited to remove time periods where material was added to the testing apparatus, leaving the steady-state data for analysis.

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)
0
1000
2000
3000
4000
5000
6000
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00


StablCal and Polymer Turbidity Data without steps
StablCal Turbidity Standard
Polymer Turbidity Standard
Hach 2100AN
Turbidity (FNU)
0
1000
2000
3000
4000
5000
6000
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00

Statistical Analyses - Stablcal and Polymer Data

Slope Comparison

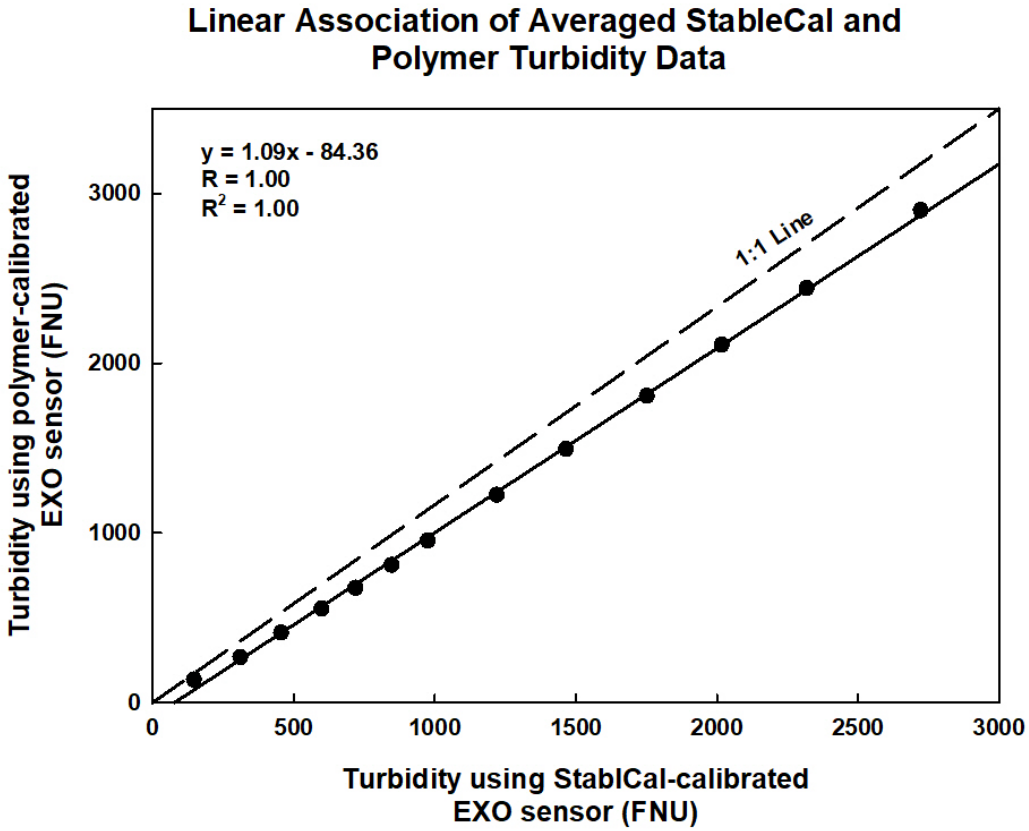
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using two different calibration standards at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 24, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

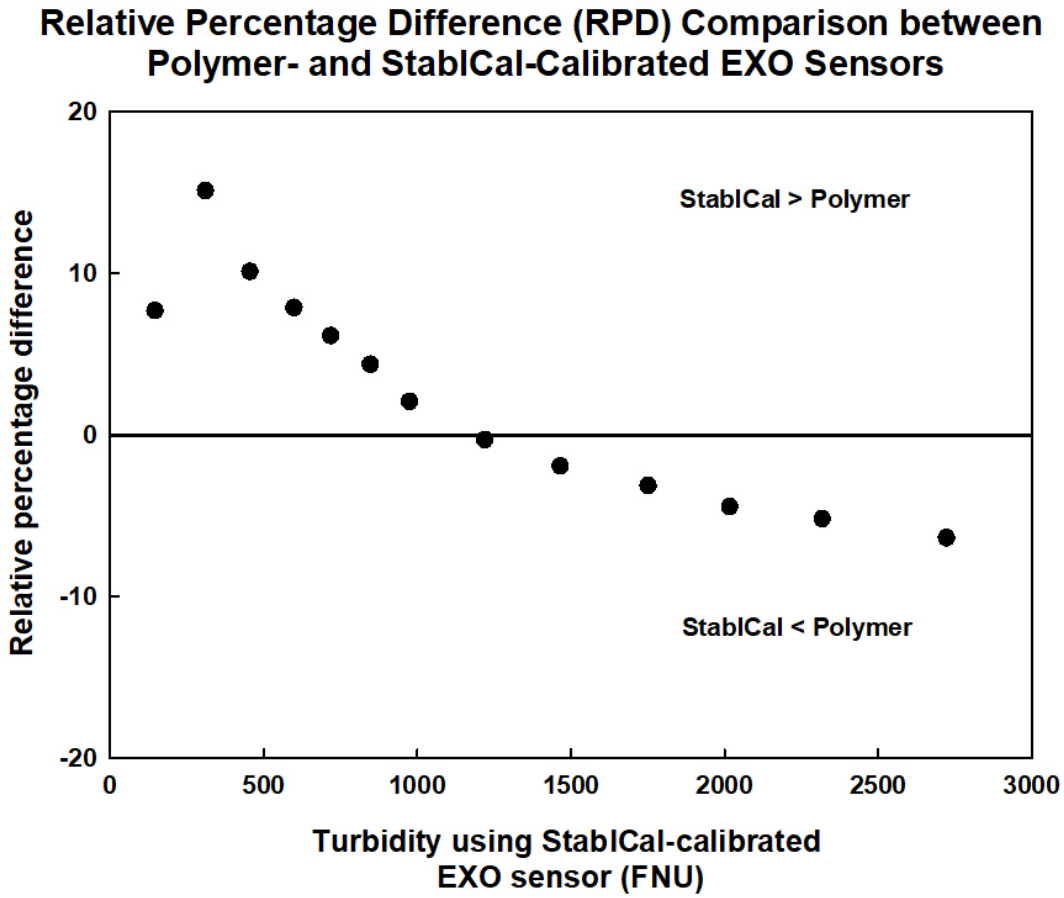
$$y = 1.09x - 84.36$$

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	974.650	526.846	1884.181
Polymer	13	0	954.719	482.322	1958.044

W= 11.000 T+ = 51.000 T-= -40.000
Z-Statistic (based on positive ranks) = 0.384
P(est.)= 0.727 P(exact)= 0.735

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.735).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction
```

```
data:  StablCal and Polymer
V = 51, p-value = 0.7267
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -32.00000  68.49998
sample estimates:
(pseudo)median
      6.500051
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 0 to 15 percent (median: 5 percent; mean: 6 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

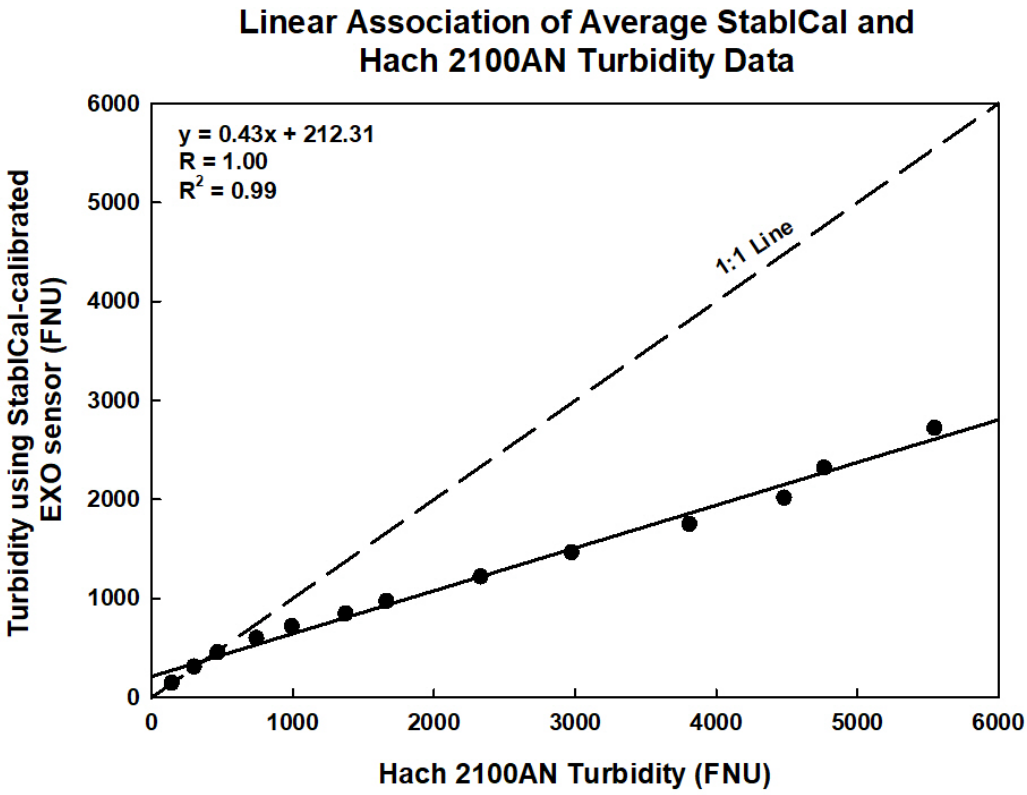
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using StablCal turbidity standard and compared to turbidity measured with a Hach 2100AN laboratory turbidimeter at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 24, 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:

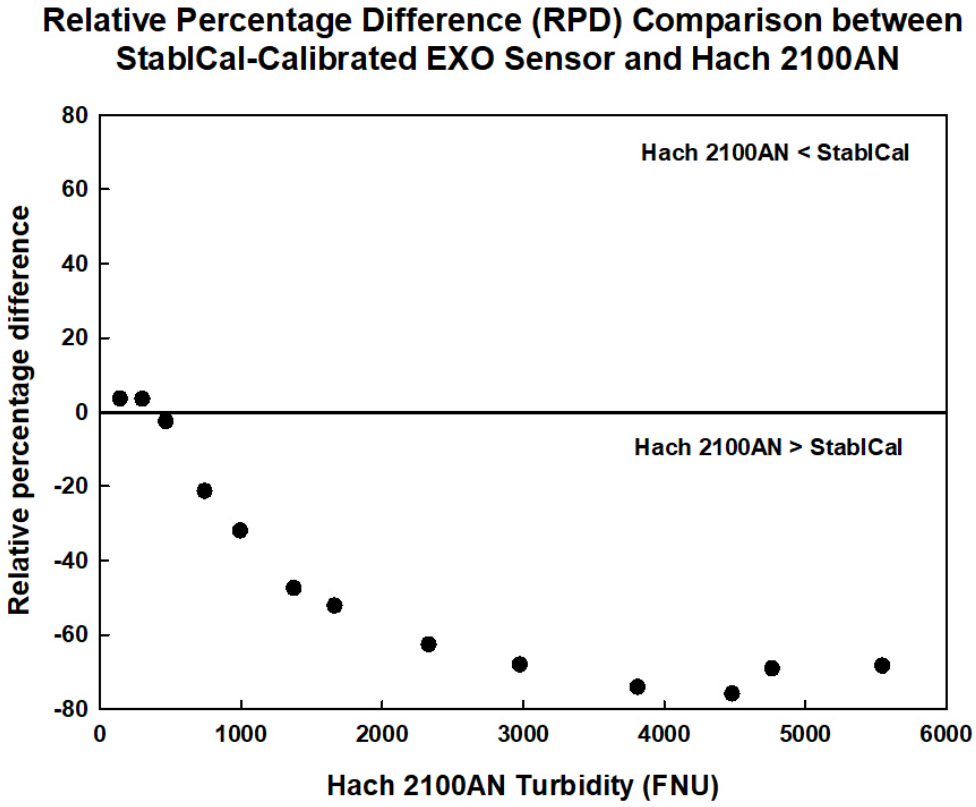
$$y = 0.43x + 212.31$$

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 = 0.43x + 212.31
R = 1.00
R2 = 0.99
1:1 Line
Turbidity using StablCal-calibrated EXO sensor (FNU)
Hach 2100AN Turbidity (FNU)
0
1000
2000
3000
4000
5000
6000


Relative Percentage Difference (RPD) Comparison between StablCal-Calibrated EXO Sensor and Hach 2100AN
Hach 2100AN < StablCal
Hach 2100AN > StablCal
Relative percentage difference
Hach 2100AN Turbidity (FNU)
80
60
40
20
0
-20
-40
-60
-80
0
1000
2000
3000
4000
5000
6000

Paired t-test for StablCal and Hach 2100AN Data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Passed (P = 0.052)

Paired t-test:

Treatment Name	N	Missing	Mean	Std Dev	SEM
Hach 2100AN	13	0	2275.654	1860.437	515.992
StablCal	13	0	1195.721	808.005	224.100
Difference	13	0	1079.933	1059.521	293.858

t = 3.675 with 12 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: 439.671 to 1720.195

Two-tailed P-value = 0.00318

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

One-tailed P-value = 0.00159

The sample mean of treatment Hach 2100AN exceeds the sample mean of treatment Formazin by an amount that is greater than would be expected by chance, rejecting the hypothesis that the population mean of treatment Formazin is greater than or equal to the population mean of treatment Hach 2100AN. (P = 0.003)

Power of performed two-tailed test with alpha = 0.050: 0.920

Power of performed one-tailed test with alpha = 0.050: 0.965

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 2 to 76 percent (median: 52 percent; mean: 45 percent). The data passed the Shapiro-Wilk test for normality (P=0.052); therefore, a paired t-test was performed. The difference between mean values for the StablCal-calibrated EXO sensor and the Hach 2100AN turbidimeter was statistically significant (P<0.05).

Statistical Analyses – Polymer and Hach 2100AN Data

Slope Comparison

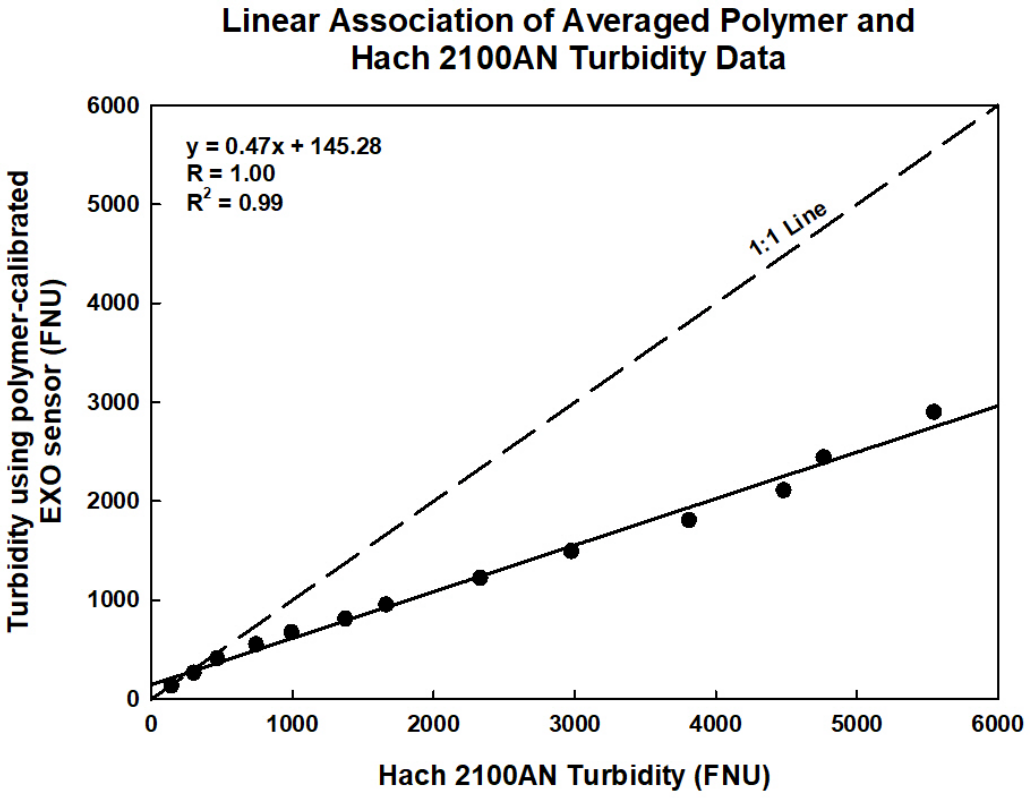
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor was calibrated by using polymer turbidity standard and compared to turbidity measured with a Hach 2100AN laboratory turbidimeter at Kansas Water Science Center laboratory, Lawrence, Kansas, on March 24, 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:

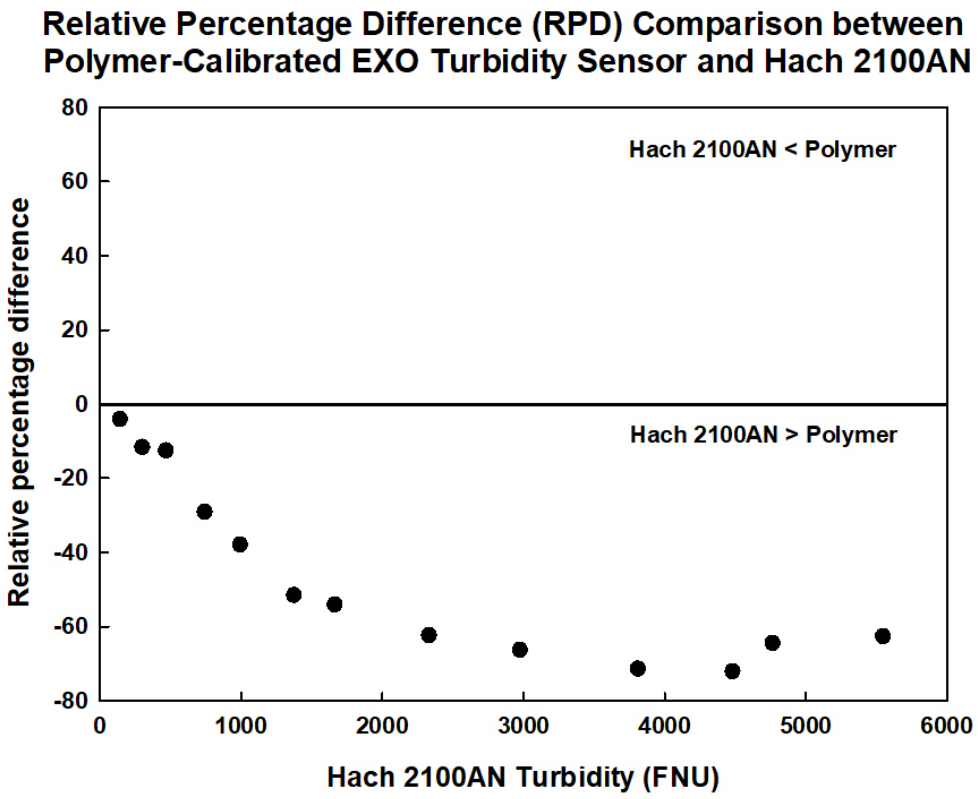
y = 0.47x + 145.28

where

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

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





Wilcoxon Signed-Rank Test for Polymer and Hach 2100AN

Sigma Plot Statistical Output:

Normality Test (Shapiro-Wilk): Passed (P = 0.060)

Paired t-test:

Data source: Data 4 in White Clay_1 Lot Number Comparison.JNB

Treatment Name	N	Missing	Mean	Std Dev	SEM
Hach 2100AN	13	0	2275.654	1860.437	515.992
Polymer	13	0	1214.270	877.875	243.479
Difference	13	0	1061.384	989.978	274.570

t = 3.866 with 12 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: 463.146 to 1659.621

Two-tailed P-value = 0.00225

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P = 0.002)

One-tailed P-value = 0.00112

The sample mean of treatment Hach 2100AN exceeds the sample mean of treatment Polymer by an amount that is greater than would be expected by chance, rejecting the hypothesis that the population mean of treatment Polymer is greater than or equal to the population mean of treatment Hach 2100AN. (P = 0.002)

Power of performed two-tailed test with alpha = 0.050: 0.943

Power of performed one-tailed test with alpha = 0.050: 0.977

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 4 to 72 percent (median: 54 percent; mean: 46 percent). The data passed the Shapiro-Wilk test for normality (P=0.060); therefore, a paired t-test was performed. The difference between mean values for the polymer-calibrated EXO sensor and the 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/.]