Designation: D4993 – 08 (Reapproved 2014)

Standard Practice for Calculation and Adjustment of Silica (SiO_2) Scaling for Reverse Osmosis[1]

This standard is issued under the fixed designation D4993; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the calculation and adjustment of silica (SiO_2) for the concentrate stream of a reverse osmosis system. The calculations are used to determine the need for scale control in the operation and design of reverse osmosis installations. This practice is applicable for all types of reverse osmosis devices (tubular, spiral wound, and hollow fiber).

1.2 This practice is applicable to both brackish waters and seawaters.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*
D859 Test Method for Silica in Water
D1067 Test Methods for Acidity or Alkalinity of Water
D1129 Terminology Relating to Water
D1293 Test Methods for pH of Water
D3739 Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis
D4194 Test Methods for Operating Characteristics of Reverse Osmosis and Nanofiltration Devices
D6161 Terminology Used for Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis Membrane Processes

3. Terminology

3.1 *Definitions*—For definitions of terms relating to water used in this practice, refer to Terminology D1129 and D6161.

4. Summary of Practice

4.1 This practice consists of calculating the potential for scaling by SiO_2 in a reverse osmosis concentrate stream from the concentration of SiO_2 in the feed solution and the recovery of the reverse osmosis system.

4.2 This practice also presents techniques to eliminate scaling by decreasing the recovery, decreasing the SiO_2 concentration in the feedwater, adjusting the pH of the feedwater, and increasing the temperature of the feedwater.

5. Significance and Use

5.1 In the design and operation of reverse osmosis installations, it is important to predict the SiO_2 scaling properties of the concentrate stream. Because of the increase in the concentration of SiO_2 and the change in pH, the scaling property of the concentrate stream will be quite different from that of the feed solution. This practice permits the calculation of the scaling potential for the concentrate stream from the feedwater analysis and the reverse osmosis operating parameters.

5.2 Scaling by SiO_2 will adversely affect the reverse osmosis performance. This practice gives various procedures for the prevention of scaling.

5.3 The presence of certain metals, for example, Al^{+3}, may significantly alter the solubility of SiO_2 via formation of insoluble metal silicates. This practice does not address this phenomena.

6. Procedure

6.1 Determine the concentration of SiO_2 in the feed stream in accordance with Test Method D859.

6.2 Measure the temperature of the feed solution.

6.3 Measure the pH of the feed solution using Test Methods D1293.

NOTE 1—If acid is used for control of $CaCO_3$ scale, measure the pH after acid addition.

6.4 Determine the total alkalinity of the feed solution using Test Methods D1067 and express as $CaCO_3$.

NOTE 2—If acid is used for control of calcium carbonate ($CaCO_3$) scale, determine the total alkalinity after acid addition.

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[1] This practice is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.08 on Membranes and Ion Exchange Materials.

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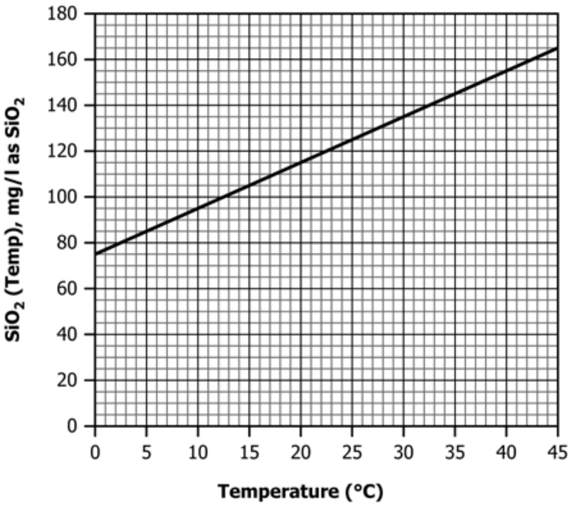

FIG. 1 Solubility of SiO_2 Versus Temperature

7. Calculation

7.1 Calculate the SiO_2 concentration in the concentrate stream from the SiO_2 concentration in the feed solution, the recovery of the reverse osmosis system, and the SiO_2 passage as follows:

$$SiO_{2c} = SiO_{2f} \times \frac{1 - Y(SP_{SiO2})}{1 - Y}$$

where:

SiO_{2c} = silica concentration in concentrate as SiO_2, mg/L,
SiO_{2f} = silica concentration in feed as SiO_2, mg/L,
Y = recovery of the reverse osmosis system, expressed as a decimal, and
SP_{SiO2} = silica passage, expressed as a decimal.

NOTE 3—SP_{SiO2} can be obtained from the supplier of the reverse osmosis system.

7.2 Calculate the pH of the concentrate stream from the pH of the feed stream using the procedure given in Practice D3739.

NOTE 4—For seawater systems, the calculated pH of the concentrate stream can be 0.1 to 0.2 higher than measured pH values if the feed pH is above 7.0. In these cases, empirical correlations between the feed pH and the concentrate pH as a function of conversion can be used to more accurately calculate the concentrate pH. Check with the supplier of the reverse osmosis device to determine if empirical correlations should be used.

7.3 From Fig. 1, obtain the solubility of SiO_2 as a function of temperature ($SiO_{2temp.}$).

NOTE 5—Temperature of the concentrate is assumed equal to temperature of feed solution. If the temperature of the water is known to vary, use the minimum temperature for the calculations.

7.4 From Fig. 2,[2] obtain the pH correction factor for the concentrate pH calculated in 7.2.

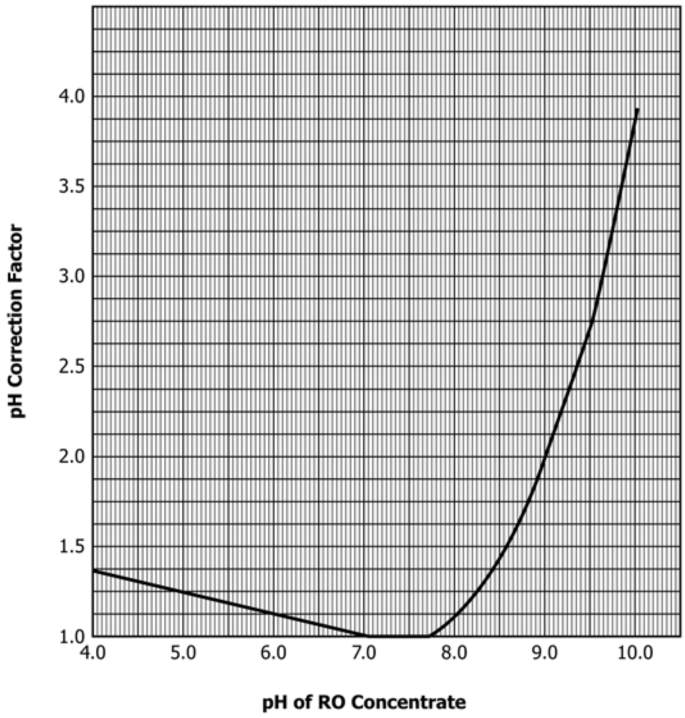

FIG. 2 SiO_2 pH Correction Factor

7.5 Calculate the solubility of SiO_2 corrected for pH ($SiO_{2corr.}$) by multiplying the solubility of SiO_2 obtained in 7.3 by the pH correction factor obtained in 7.4.

7.6 Compare the silica concentration in the concentrate (SiO_{2c}) obtained in 7.1 with the silica solubility ($SiO_{2corr.}$) obtained in 7.5. If SiO_{2c} is greater than $SiO_{2corr.}$, silica scaling will occur and adjustment is required.

NOTE 6—Some suppliers may use a safety factor. Check with the supplier of the reverse osmosis device to determine if some fraction of the $SiO_{2corr.}$, for example, 0.9 $SiO_{2corr.}$, should be used to compare with SiO_{2c}.

8. Adjustments for Scale Control

8.1 If SiO_{2c} is less than $SiO_{2corr.}$ or the recommended fraction of $SiO_{2corr.}$, a higher recovery can be used with respect to scaling by silica. Reiteration of the calculations at higher recovery can be used to determine the maximum conversion with respect to scaling by silica.

8.2 If SiO_{2c} is greater than $SiO_{2corr.}$ or the recommended fraction of $SiO_{2corr.}$, a lower recovery must be used to prevent scaling. Reiteration of the calculations can be used to determine the allowable recovery with respect to scaling by silica.

8.3 If the maximum allowable recovery is lower than desired, lime plus soda ash softening employing either magnesium oxide or sodium aluminate can be used in the pretreatment system to decrease the SiO_2 concentration in the feed stream and thus permit higher conversion with respect to scaling by silica. It is important that the softening process be performed properly in order to prevent formation of insoluble metal silicates in the reverse osmosis system.

8.4 Since the solubility of silica increases below a pH of about 7.0 and above a pH of about 7.8, pH adjustment with

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[2] Alexander, G. B., Hester, W. M., and Iler, R. K., "The Solubility of Amorphous Silica in Water," *Journal of Physical Chemistry*, Vol 58, 1954, p. 453.

either acid or base can permit a higher recovery with respect to silica scaling. However, the reverse osmosis membrane must be able to operate at the adjusted pH and for the high pH, $CaCO_3$ scaling must be prevented. Check with supplier of reverse osmosis device for permitted operating pH range.

8.5 The maximum allowable recovery with respect to silica scaling can be increased significantly by increasing the water temperature using a heat exchanger. However, the reverse osmosis membrane must be able to operate in the adjusted temperature range. Check with supplier of reverse osmosis device for permitted operating temperature range.

9. Reverse Osmosis in Operation

9.1 Once a reverse osmosis system is operating, the scaling potential of SiO_2 can be directly calculated from the analyses of the concentrate stream and compared with the projected scaling potential calculated above.

10. Use of Computers for the Determination of Scaling Potential

10.1 The preceding calculations are adaptable to simple computer analysis.

11. Keywords

11.1 fouling; reverse osmosis; scaling; silica; solubility

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