



FILMTEC Membranes

Water Chemistry and Pretreatment: Silica Scale Prevention

Silica Scale Prevention

Dissolved silica (SiO_2) is naturally present in most feed waters in the range of 1–100 mg/L. The prevailing forms of silica are meta silicic acids as $(\text{H}_2\text{SiO}_3)_n$ with low n numbers. Since silicic acid is a weak acid, it is mostly in the undissociated form at or below a neutral pH. Supersaturated silicic acid can further polymerize to form insoluble colloidal silica or silica gel, which can cause membrane scaling. The maximum allowable SiO_2 concentration in the concentrate stream is based on the solubility of SiO_2 .

The scaling potential for the concentrate stream will be quite different from that of the feed solution because of the increase in the concentration of SiO_2 and the change in pH. It can be calculated from the feed water analysis and the RO operating parameters.

As the pH exceeds neutral, silicic acid dissociates into the silicate anion $(\text{SiO}_3^{2-})_n$. This can react with calcium, magnesium, iron, manganese or aluminum to form insoluble silicates.

It was indicated that aluminum is the most powerful precipitant of silicic acid [/12](#), and the occurrence of silica scaling is mostly correlated with the occurrence of aluminum or iron [/13](#). It has been reported that, when Al^{3+} and Fe^{3+} coexist in the pretreated feed water, silica is precipitated even below its saturation [/14, 15](#). Both Al^{3+} and Fe^{3+} , therefore, must be less than 0.05 mg/L in the feed water, even if the silica level is below saturation. Since Al^{3+} and Fe^{3+} salts are used for coagulation in municipal and other industrial water processing, frequent and accurate measurements of these ions are needed even though the feed water itself does not contain high levels of aluminum and iron ions. Fouling with metal silicates may occur from a chemical reaction and precipitation process (scaling), and also from colloidal fouling with submicron particles entering the membrane system. Feed water acidification and preventive acid cleanings are possible measures in cases of a metal silica scaling potential. If colloidal silica and silicates are present in the feed water, a flocculation/filtration process and/or a fine grade prefilter (1 μm or less) should be chosen.

The scaling potential of soluble silica (silicic acid) in the absence of trivalent metal cations can be calculated as follows. The calculation requires the following data for the feed solution (after acid addition, if acid is used for control of calcium carbonate):

- SiO_2 concentration
- Temperature
- pH
- Total alkalinity

Calculation [/16](#)

1. The SiO_2 concentration in the concentrate stream is calculated from the SiO_2 concentration in the feed solution and the recovery of the reverse osmosis system:

$$\text{SiO}_{2c} = \text{SiO}_{2f} \left(\frac{1}{1 - Y} \right)$$

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

2. Calculate the pH of the concentrate stream from the pH of the feed stream using the procedure given in [Calcium Carbonate Scale Prevention \(Section 2.4.2\)](#).

3. From Figure 2.10, obtain the solubility of SiO_2 as a function of temperature (SiO_2 temperature). The temperature of the concentrate is assumed equal to the temperature of feed solution. If the temperature of the water is known to vary, use the minimum temperature for calculations.
4. From Figure 2.11, obtain the pH correction factor for the concentrate pH calculated in Step 2.
5. Calculate the solubility of SiO_2 corrected for pH ($\text{SiO}_{2\text{corr}}$) by multiplying the solubility of SiO_2 obtained in Step 3 by the pH correction factor obtained in Step 4.
6. Compare the silica concentration in the concentrate (SiO_{2c}) obtained in Step 1 with the silica solubility ($\text{SiO}_{2\text{corr}}$) obtained in Step 5. Once a reverse osmosis system is operating, the scaling potential of SiO_2 can be directly calculated from the analysis of the concentrate stream and compared with the projected scaling potential calculated above. If SiO_{2c} is greater than $\text{SiO}_{2\text{corr}}$, silica scaling can occur and adjustment is required.

Adjustments for Scale Control

- If SiO_{2c} is less than $\text{SiO}_{2\text{corr}}$, 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.
- If SiO_{2c} is greater than $\text{SiO}_{2\text{corr}}$, 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.
- 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 (see [Liming Softening, Section 2.3.6](#)) 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.
- Since the solubility of silica increases below a pH of about 7.0 and above a pH of about 7.8, pH adjustment with either acid or base can permit a higher recovery with respect to silica scaling. For the high pH, however, CaCO_3 scaling must be prevented.
- The maximum allowable recovery with respect to silica scaling can be increased significantly by increasing the water temperature using a heat exchanger. The maximum temperature permitted for continuous use is 45°C .
- Scale inhibitors such as high molecular weight polyacrylates can also be used to increase the solubility of silica.

Table 2.10 Solubility of SiO₂ versus temperature / 16

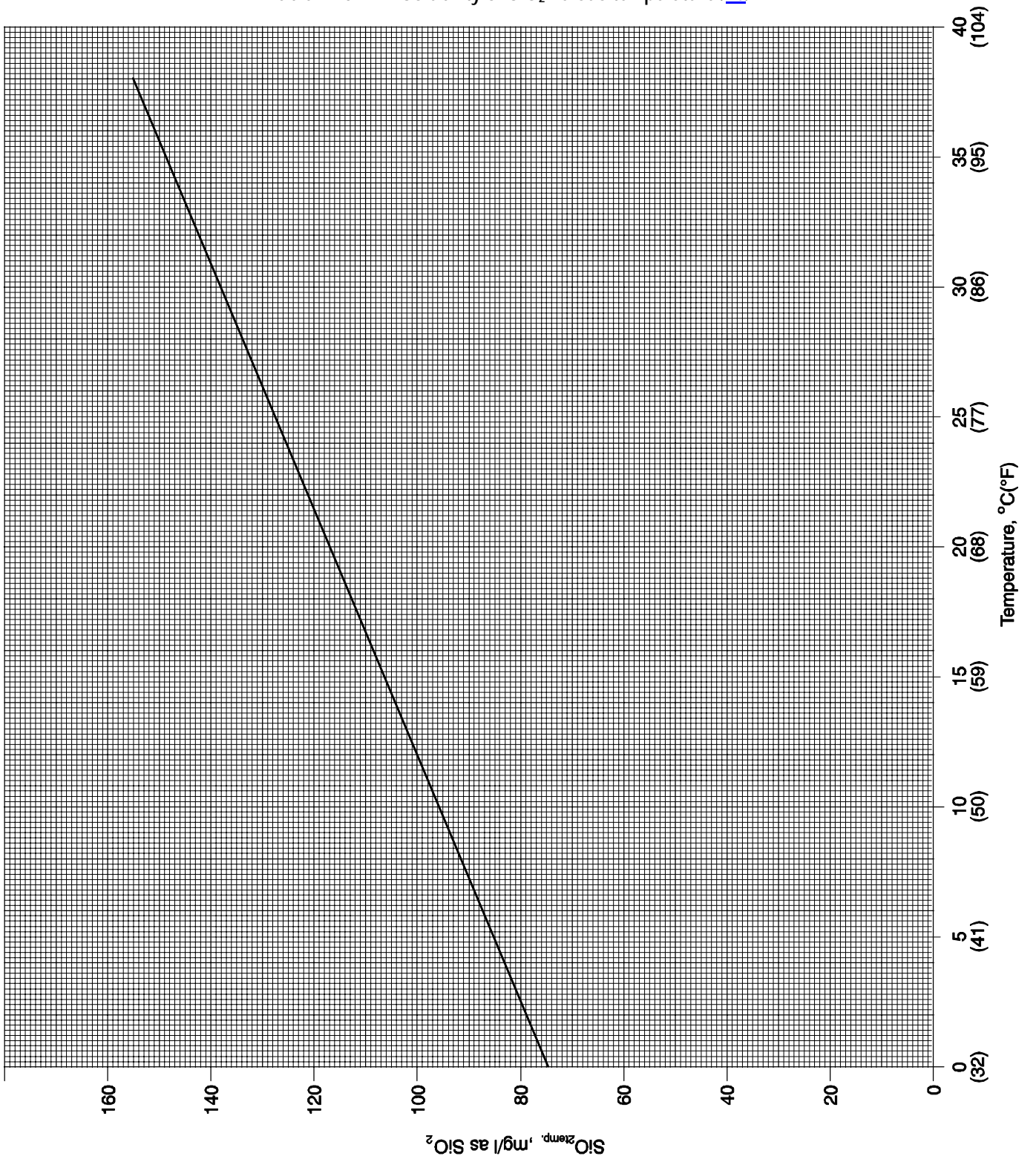
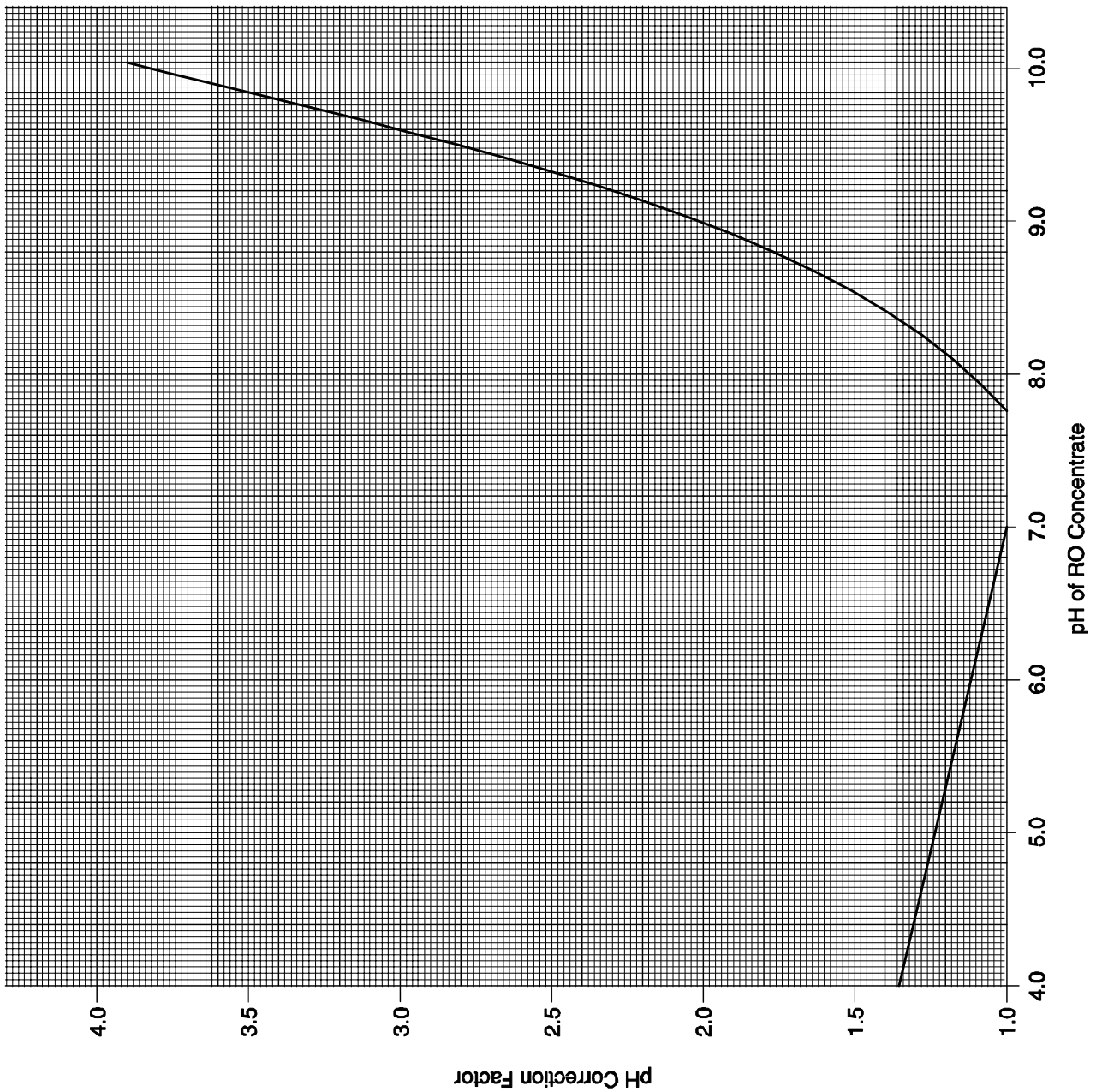


Figure 2.11 SiO₂ pH correction factor /16, 17/



FILMTEC™ Membranes
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