DUPONT

Tech Manual Excerpt

Water Chemistry and Pretreatment

Calcium Phosphate Scale Prevention

Calcium Phosphate Scale Prevention

Calcium phosphate fouling was not common until reverse osmosis technology was widely applied to municipal wastewater. Due to water shortages, municipal wastewater recycle or reuse has become one a major application area of reverse osmosis. Along with this new application, preventive actions for calcium phosphate scaling are needed.

Phosphorus is a common element in nature and is widely distributed in many minerals. In natural water and wastewater streams, phosphorus compounds exist in the following forms: /*18*/

- Particulate phosphate
- Orthophosphate (PO_4^{3-}): Orthophosphates may be present as H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-} depending on pH. $H_2PO_4^-$ and HPO_4^{2-} are the prevailing species in neutral wastewater.
- Polyphosphates: Important components in textile washing powders and other detergents. Depending on the product, they may contain 2 – 7 P atoms.
- Organic phosphorus: Phosphorus is an essential element for living organisms.
- The most common mineral form of phosphorus is apatite, which is a calcium phosphate with variable amounts of OH^-, Cl^-, and F^- (hydroxy-, chloro-, or fluoroapatite). Some other phosphate minerals contain aluminum and/or iron. Because of their low solubility, the following phosphate compounds can be considered as causes of phosphate scaling in an RO/NF operation (see Table 1).

Table 1: Low solubility phosphate compounds

Compound	Formula	pK_{sp}
Brushite	$CaHPO_4 \cdot 2H_2O$	6.68
Calcium phosphate	$Ca_3(PO_4)_2$	28.9
Octacalcium phosphate	$Ca_4H(PO_4)_3 \cdot 3H_2O$	46.9
Hydroxyapatite	$Ca_5(PO_4)_3OH$	57.74
Fluoroapatite	$Ca_5(PO_4)_3F$	60
Magnesium ammonium phosphate	$MgNH_4PO_4$	12.6
Aluminum phosphate	$AlPO_4$	20
Iron phosphate	$FePO_4$	15

Form No. 45-D01558-en, Rev. 4
April 2020

Calcium Phosphate Scale Prevention (Cont.)

Calcium phosphate and apatites are less soluble in neutral and alkaline conditions and dissolve in acid /18/. Aluminum and iron phosphates, however, are less soluble at moderately acidic conditions. Thus it is important to remove aluminum and iron in a pretreatment step as well. Because of the complexity of phosphate chemistry, it is not easy to predict a threshold level of phosphate scaling. The calcium phosphate stability index (SI), however, was proposed by Kubo et al /19/. The calcium phosphate stability index is determined by the levels of calcium and phosphate present, pH, and temperature. A negative SI signifies a low potential for calcium phosphate scaling; a positive value indicates the potential for calcium phosphate scaling. SI is determined by the following equation:

$$SI = pH_a - pH_c \qquad \text{Eq. 1}$$

where:

pH_a = actual pH of a feedwater

pH_c = critical pH calculated by the following experimental equation:

$$pH_c = \frac{11.755 - \log(CaH) - \log(PO_4) - 2\log t}{0.65} \qquad \text{Eq. 2}$$

where :

CaH = Calcium hardness as ppm $CaCO_3$

PO_4 = Phosphate concentration as ppm PO_4

t = Temperature as °C

Calcium Phosphate Scale Prevention (Cont.)

Figure 1 shows the effect of critical phosphate concentrations of $Ca_3(PO_4)_2$ scaling on feed calcium hardness and pH based on the equation.

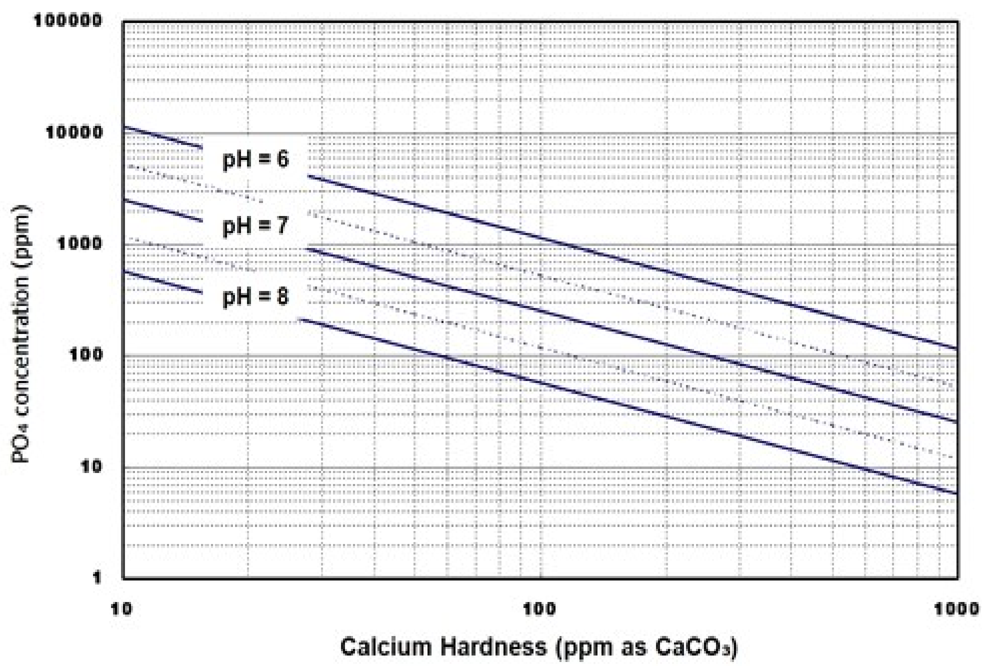

Figure 1: Critical phosphate concentration under various pH at 25°C

Note: When feedwater contains high levels of fluoride, ammonia and aluminum, critical phosphate concentration might be lowered due to formation of fluorapatite, aluminum phosphate, etc.

To minimize the risk of phosphate scaling, it is important to reduce not only orthophosphate, but also calcium, fluoride, and aluminum concentration. A low feed pH helps to control phosphate scaling. Appropriate commercial antiscalants good for phosphate scaling are also available.

Phosphate scaled membranes are best cleaned at low pH (see Chapter 6 of the FilmTec™ Reverse Osmosis Membranes Technical Manual (Form No. 45-D01504-en)).

Excerpt from FilmTec™ Reverse Osmosis Membranes Technical Manual (Form No. 45-D01504-en), Chapter 2, "Water Chemistry and Pretreatment."

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