Removal of norovirus from water by coagulation, flocculation and sedimentation processes

AN EXAMPLE CALCULATION: pH CHANGE OF WATER AFTER ADDITION OF ALUM STOCK SOLUTIONS

1. The initial alkalinity of raw water = (22 mg/L as CaCO₃) / [(50,000 mg as CaCO₃)/(equivalent/L)] = 4.4 × 10⁻⁴ equivalent/L

2. 30 mg/L as Alum (Al₂(SO₄)₄·18H₂O) = 0.45 × 10⁻⁴ moles/L as Alum = 1.8 × 10⁻⁴ equivalent/L
   40 mg/L as Alum (Al₂(SO₄)₄·18H₂O) = 0.60 × 10⁻⁴ moles/L as Alum = 2.4 × 10⁻⁴ equivalent/L
   50 mg/L as Alum (Al₂(SO₄)₄·18H₂O) = 0.75 × 10⁻⁴ moles/L as Alum = 3.0 × 10⁻⁴ equivalent/L

3. New alkalinity after adding an Alum stock solution:
   30 mg/L Alum: initial alkalinity (4.4 × 10⁻⁴ equivalent/L) – 30 mg/L as Alum (1.8 × 10⁻⁴ equivalent/L) = 2.6 × 10⁻⁴ equivalent/L
   40 mg/L Alum: initial alkalinity (4.4 × 10⁻⁴ equivalent/L) – 40 mg/L as Alum (2.4 × 10⁻⁴ equivalent/L) = 2.0 × 10⁻⁴ equivalent/L
   50 mg/L Alum: initial alkalinity (4.4 × 10⁻⁴ equivalent/L) – 50 mg/L as Alum (3.0 × 10⁻⁴ equivalent/L) = 1.4 × 10⁻⁴ equivalent/L

4. Meanwhile, Alkalinity = [HCO₃⁻] + 2[CO₃²⁻] + [OH⁻] = [H⁺] = (α₁ + 2α₂) C_T + [OH⁻] – [H⁺]
   (i) where α₁ = distribution coefficient for [HCO₃⁻]
   (ii) α₂ = distribution coefficient for [CO₃²⁻]
   (iii) α₁ and α₂ are pH dependent
   (iv) C_T = total concentration of carbonate

   Therefore, 4.4 × 10⁻⁴ equivalent/L = [(α₁ at pH 6.8 = 7.596 × 10⁻¹) + 2(α₂ at pH 6.8 = 2.204 × 10⁻⁴)]
   C_T + 10⁻⁷.2 – 10⁻⁶.8. (The initial pH of the water was 6.8.)

   Therefore, C_T = 5.79 × 10⁻⁴

5. If we assume [OH⁻] and [H⁺] is negligible (near neutral pH), then
   Alkalinity = (α₁ + 2α₂) C_T
   For 30 mg/L Alum: 2.6 × 10⁻⁴ equivalent/L = (α₁ + 2α₂) (5.79 × 10⁻⁴). Therefore, (α₁ + 2α₂) = 0.449 → pH 6.2
   For 40 mg/L Alum: 2.0 × 10⁻⁴ equivalent/L = (α₁ + 2α₂) (5.79 × 10⁻⁴). Therefore, (α₁ + 2α₂) = 0.339 → pH 6.0
   For 50 mg/L Alum: 1.4 × 10⁻⁴ equivalent/L = (α₁ + 2α₂) (5.79 × 10⁻⁴). Therefore, (α₁ + 2α₂) = 0.242 → pH 5.8

6. With the information above and the data on turbidity removal in actual jar tests, an alum dose of 40 mg/L (which gave the maximum reduction of turbidity and an optimum pH between 5–6.5) was selected as the optimum Alum concentration.