Basic Nitrification Facts

Nitrification is the biological removal (oxidation) of ammonia (NH_4^+) by certain bacteria in the presence of oxygen. This special group of bacteria is called “nitrifiers” or “nitrifying bacteria”, or “nitrification bacteria”.

Classical Equation For The Nitrification Process

NH_4^+ + O_2 + ***Nitrosomonas sp.*** → NO_2^- + O_2 + ***Nitrobacter sp.*** → NO_3^-
(ammonium ion) (nitrite) (nitrate)

Nitrification is an aerobic process, with the actual process equations:
$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$ + energy
$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$ + energy
$NH_4^+ + 2.0\ O_2 \rightarrow NO_3^- + 2\ H^+ + H_2O$ + energy (Overall net reaction)

Nitrification can be seen from these equations as an oxygen-requiring and pH/alkalinity reducing process through the generation of H ions (acid).

Sources of Ammonia

1. Urea, a simple organic nitrogen compound in urine breaks down to CO_2 and NH_4^+ in the presence of heterotrophic bacteria and water (H_2O).
2. Proteins containing $–NH_2$ (amine) groups breakdown to form ammonia through a process called deamination.
3. Other organic nitrogen compounds such as amines and quaternary ammonium compounds (disinfectants, cleaners, etc.)
4. Other inorganic compounds such as fertilizers.

Forms of Ammonia – pH Dependent

1. Ammonium ion (NH_4^+) is predominant form at pH’s < 9.0. It is the least toxic form and is water-soluble. It is the form that living organisms respond to and can utilize within certain limits.
2. Ammonia gas (NH_3) is predominant at pH’s above 9.0. It is the most toxic form of ammonia to animals and aquatic life.

Process Requirements

1. 4.6 mg/l or ppm O_2 needed for every ppm NH_4^+ oxidized or removed. Another way of looking at this is 4.6 lbs. of oxygen is needed to remove 1 lb. of ammonia.
2. 7.2 mg/l of alkalinity is needed to remove 1 mg/l NH_4^+ above a baseline of 50 mg/l total (M) alkalinity. For example, to remove 10 mg/l NH_4^+, 122 mg/l of alkalinity (7.2 X 10 + 50) is required as a minimum.
3. Alkalinity boosters used can be soda ash ($NaCO_3$), sodium bicarbonate or baking soda, ($NaHCO_3$). Others used with less frequency would be caustic (NaOH) and lime ($Ca(OH)_2$).
4. Low cBOD, preferably < 200 mg/l. However, nitrification can proceed at higher cBOD levels depending on toxicity and/or bacterial population numbers.
5. pH maintenance between 7.6 and 8.2 is usually ideal, but not totally necessary. Nitrification can still proceed at slightly higher or lower pH's.

Inhibition of the Nitrification Process

1. Toxicity in form of toxic chemicals and heavy metals (0.25 mg/l or higher).
2. Septicity and associated sulfides (H_2S, etc.) and organic acids.
3. Excessive ammonia (ammonia toxicity) 400-500 mg/l+.
4. Low Temperatures – Nitrification ceases at <5 ˚C, with optimal conditions ranges of 28-32 ˚C. Nitrification proceeds at roughly 50% at 16 ˚C and 20% at 10 ˚C.
5. Low rainfall/little soil run-off as nitrifiers live in the top 2 inches of topsoil.
6. Low Dissolved Oxygen < 0.5 mg/l, with 2-3 mg/l being ideal for efficient ammonia removal.
7. Low pH/alkalinity, with nitrification ceasing at a pH of < 5.0.

Miscellaneous Facts

1. Nitrifying bacteria are generally known as autotrophs or autotrophic bacteria. They utilize inorganic carbons such as CO_2, carbonates (CO_3^{-2}), and bicarbonates (HCO_3^-).
2. They are different from heterotrophs or heterotrophic bacteria that use organic carbon compounds to grow and gain energy. Heterotrophs are the predominant form in wastewater plants and some can generate or double every 20-30 minutes under ideal growth conditions.
3. Nitrifiers are slow-growing organisms with *Nitrosomonas* doubling every 8 hours and *Nitrobacter* every 12 hours under ideal laboratory conditions. Typical plant conditions may extend to 24 or more hours the doubling rate.