Sulphur Attack on Concrete Tanks – A problem in the on-site wastewater industry that needs to be addressed

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Introduction

The on-site wastewater industry relies heavily on the usage of concrete tanks. The use of concrete has many benefits such as strength, long service life and cost effectiveness. However, in cases where the location contains sulphur-rich waters and/or sulphate-rich soil, extreme care and precaution must be exercised before using concrete tanks. If such caution is not taken, septic systems in these areas can lead to premature failure.

Sulphate-rich soil attacks concrete in contact with the soil, and is important mainly in Western Canada and certain parts of Ontario. This attacks the concrete structure from the outside and can be addressed by use of sulphate resistant concrete such as type-50 cement (Darby, 2004)

Concrete can also be attacked from the inside through sulphuric acid formation on the walls of the tank. Parts of Ontario (especially Eastern Ontario) have high sulphur in the source water, either as sulphate or sulphide, which forms hydrogen sulphide in the septic tank/ pump tank. The hydrogen sulphide in turn forms sulphuric acid in the air space in septic tanks and pump tanks. The sulphuric acid reacts with the concrete, decreasing the structural strength and durability, and increasing the permeability. This causes concrete tanks to corrode and crack, also known as "crown rot" (Crites and Tchobanoglous, 1998), which ultimately causes them to collapse and fail.

This problem is recognized in OMAF/MOE (2003) for animal wastes, but not yet in CSA B66 for human wastes. The damaging effects of sulphur on concrete are illustrated in Figure 1.

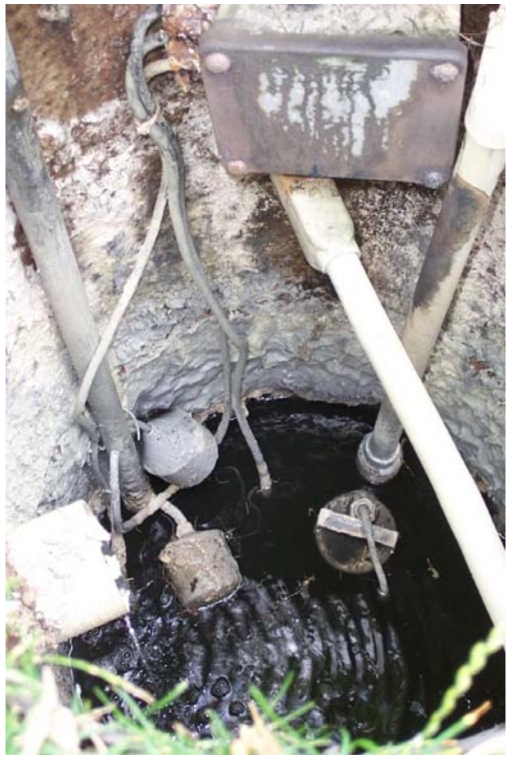

Figure 1
Sulphur attack on pump chamber causes the concrete to corrode. This type of concrete deterioration is also known as "crown rot"

The two most common methods in which concrete septic tanks can be attacked include:

1. *Corrosion by Sulphate-Rich Soils*

Through a series of chemical reactions, sulphate ions (SO_4^{2-}) in the soil react can react with hydration products present in hardened cement {such as tricalcium aluminate ($3CaO \bullet Al_2O_3$), calcium hydroxide ($Ca(OH_2)$) and silicate hydrate ($C_3S_2H_8$)} to form two reaction products (Neuwald, 2004):

a. **Ettringite:** The formation of ettringite causes an increase in volume to the concrete matrix, leading to the physical expansion and cracking of the hardened concrete. (Neuwald, 2004)

b. **Gypsum ($CaSO_4 \bullet 2 H_2O$):** The formation of gypsum makes the concrete softer and can lead to failure and collapse of the concrete structure. (Neuwald, 2004)

Depending on the amount of sulphur in contact with the concrete, it may be necessary to protect the concrete with a plastic liner, sulphate resistant concrete mix, or a protective adhesive coating. Sulphate-resistant concrete tanks are dealt with in CSA B66, but it is the responsibility of the local regulatory authority to determine where soils require the use of sulphate-resistant concrete.

2. *'Bacterial Acid' Corrosion*

Bacterial acid corrosion is caused when anaerobic bacteria in the septic tank convert sulphate (SO_4^{2-}) into sulphide (S^{2-}), which in turn combines with hydrogen (H^+) to form hydrogen sulphide gas (H_2S). In the presence of oxygen from incoming water or from the air space in the septic tank or pump tank, exsolved hydrogen sulphide gas is converted to sulphuric acid (H_2SO_4) as shown in **Equation 1** (Metcalf and Eddy, 2003).

$$\text{Organic matter} + SO_4^{2-} \rightarrow \mathbf{S^{2-}} + H_2O + CO_2$$

$$\mathbf{S^{2-}} + 2H^+ \rightarrow \mathbf{H_2S} \qquad \textbf{(Equation 1)}$$

$$\mathbf{H_2S} + 2\,O_2 \rightarrow H_2SO_4$$

Sulphuric acid is highly reactive and reacts with calcium compounds in the concrete (eg. $Ca(OH)_2$), ultimately to produce calcium sulphate ($CaSO_4$) and water (H_2O) as shown in **Equation 2** (Thomson, 2000**).** Typically calcium sulphate and water are in equilibrium with gypsum as shown in **Equation 3** (Drever, 1988). Similar to the corrosion by sulphate-rich soils, the formation of gypsum in the concrete through the 'Bacterial Acid' pathway causes the concrete to soften, ultimately leading to the tank to collapse.

$$\mathbf{H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O} \qquad \textbf{(Equation 2)}$$

$$\mathbf{CaSO_4 + H_2O \leftrightarrow CaSO_4 \bullet 2\,H_2O} \qquad \textbf{(Equation 3)}$$

This type of sulphur attack is the predominant one in septic systems. The septic tank is a biochemical reactor, where anaerobic (without oxygen) reactions occur to break down solids into gaseous compounds, which are primarily CO_2 (carbon dioxide) and CH_4 (methane). In wastewaters high in sulphate or sulphide, anaerobic bacteria produce hydrogen sulfide (H_2S) gas, which rises into the open air space of the septic tank and pump tank (Thomson, 2000). Moisture on the sidewalls of the concrete tank allows aerobic or facultative bacteria to thrive and convert hydrogen sulphide into sulphuric acid, which corrodes the concrete.

This kind of attack can be protected by concrete liners and coatings as well, but it is important to remember that the areas that are most susceptible are the concrete walls at the waterline and in the air space of the septic tank and pump tank. To be more cost effective, the liner or coating can be applied above the waterline, which includes any concrete risers and manholes located in the air space.

Another option is to improve the overall quality of concrete tanks by increasing strength and durability of the concrete (decrease water-to-cement ratio). For farm agriculture storage, they require a minimum 28-day compressive strength of 40 mPa and a water-to-cement ratio when reinforced concrete is exposed to severe manure gases (OMAF, 2004). However, these specifications will not prevent concrete corrosion, but will delay it. Adding supplementary cementing materials such as slag fly ash can improve resistance to chemical attack (Bickley, 2001).

Conclusion

Sulphur attacks are a major issue in parts of Ontario which contain a high content of sulphur in water. To prevent premature failure of concrete structures in septic systems, it is important for regulators and concrete tank manufacturers to take responsibility and be aware of locations with sulphur-rich waters or contain sulfate-rich soils. Alternatives to concrete can be used as well, such as polyethylene tanks that are chemically resistant to sulphur attacks.

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