



The Science Corner — Sulphuric Acid Attack on Concrete Tanks

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Introduction

Our on-site industry relies heavily on concrete for septic and pump tanks. Concrete has the benefits of strength, long service life, and cost effectiveness, but in cases where sulphur-rich water or sulphate-rich soil is present, problems arise with corrosive reaction occurring, and premature failure can be expected.

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

1. Corrosion by Sulphate-Rich Soils

Sulphate-rich soils are primarily across Western Canada, and attack the exterior of the tank. The problem is addressed by using sulphate-resistant concrete such as type-50 cement (Darby, 2004)

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 ($3\text{CaO} \cdot \text{Al}_2\text{O}_3$), calcium hydroxide ($\text{Ca}(\text{OH})_2$) and silicate hydrate ($\text{C}_3\text{S}_2\text{H}_6$)) to form two reaction products (Neuwal, 2004):

- a. **Etringite:** The formation of ettringite causes an increase in volume to the concrete matrix, leading to the physical expansion and cracking of the hardened concrete. (Neuwal, 2004)
- b. **Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$):** The formation of gypsum makes the concrete softer and can lead to failure and collapse of the concrete structure. (Neuwal, 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

Interior concrete walls are also attacked when sulphuric acid forms in the airspace above the waterline. Eastern Ontario especially has high sulphur in the source water, both as sulphate or sulphide, both of which form hydrogen sulphide in the septic tank or pump tank. The hydrogen sulphide gas comes out of solution and forms sulphuric acid in the air

space, which reacts corrosively 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 type of sulphur attack is the predominant one in septic systems.

This problem is recognized in OMAF/MOE (2003) (www.gov.on.ca/omafra/english/nm/regs/conpro/conpro04.htm) 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 in pump chamber causes the concrete to corrode and the concrete changes to soft gypsum. This type of concrete deterioration is also known as "crown rot"

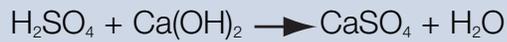
Bacterial acid corrosion is caused when anaerobic bacteria in the septic tank convert sulphate ions (SO_4^{2-}) into sulphide ions (S^{2-}), both in solution still, which in turn combines with hydrogen (H^+) to form hydrogen sulphide gas (H_2S). The H_2S gas is at first dissolved in the sewage, but then "exsolves" out into the airspace when it reaches a certain concentration. 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).

(Equation 1)



Sulphuric acid is highly reactive and reacts with calcium compounds in the concrete (e.g., $\text{Ca}(\text{OH})_2$), 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 (James, 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 roof collapse.

(Equation 2)



(Equation 3)



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).

Conclusions

Sulphur attack on concrete structures is an important issue in parts of Ontario where the water contains a high levels of sulphur. 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 which contain sulphate-rich soils. Alternatives to concrete such as polyethylene tanks that are chemically resistant to sulphur attacks can be used as well.

References

(Available on the Web or by request)