Using Sonication for In-Well Softening of Semivolatile Compounds

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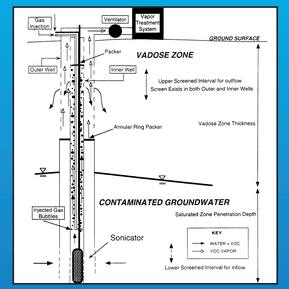
Technology Description

- Sound transmitted through liquid as wave of alternating positive- and negative-pressure cavitation cycles.



In-well sonication of halogenated organic contaminants in groundwater. Process uses
- *in-well sonication*
- *in-well vapor stripping*
- *in-situ biodegradation*

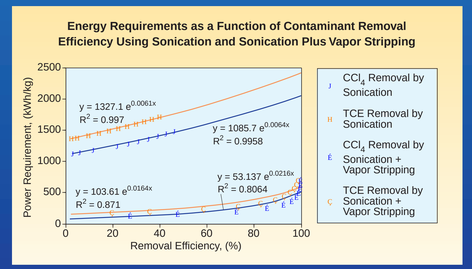
- Compression (positive pressure) cycles push molecules together while expansion (negative pressure) cycles pull molecules apart.
- Acoustic cavitation affects chemical reactions.
- During expansion cycle, also called rarefaction, separated molecules form tiny microbubbles.
- The microbubbles grow to a critical size and implode, releasing a large amount of energy.
- Pressures from 500 to 1,000 atmospheres and temperatures around 5,000°K have been observed in the implosions.
- The collapsing bubble interface results in hydroxyl and hydrogen radicals. These radicals destroy chlorinated organic compounds very effectively.

Preliminary Operating Requirements

Calculation of electrical energy required per unit mass removed (kWh/kg):

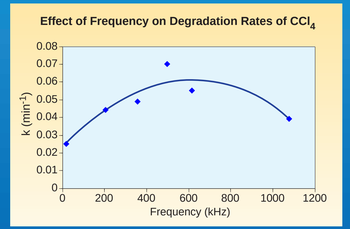
$$\frac{\text{Electrical Energy}}{\text{Mass}} = \frac{P \times t \times 10^6}{V \times 60 \times (C_i - C_f)}$$

Sonication power capacity = 600 W
Power intensity = 35.8 W/cm^2 (~17%)
P = 600 x 0.17 = 102 W (0.102 kW)
t = Treatment time, (min)
V = Total volume of solution, (L) = 0.5 L
C_i = Initial contaminant concentration = 50 mg/L
C_f = Final contaminant concentration = (mg/L)

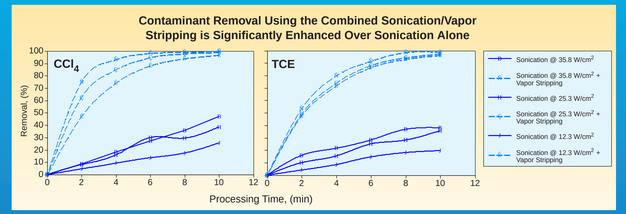


Summary and Conclusions

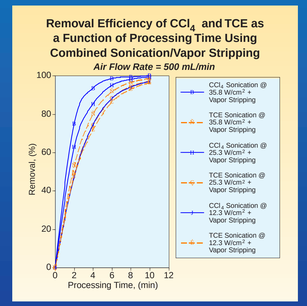
- Sonication and vapor stripping effective at removing VOCs such as CCl_4 and TCE from groundwater.
- Vapor stripping at 500 mL/min removes CCl_4 and TCE more efficiently than sonication.
- The higher the power intensity, the greater the removal of CCl_4 and TCE and the higher the resulting first order rate constant.
- The optimum sonication frequency is around 500 kHz.

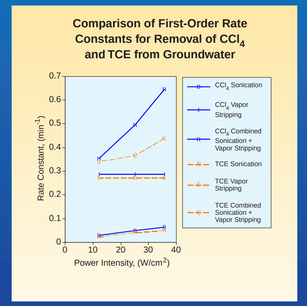


- Greater than 90% removal of CCl_4 and 80% removal of TCE can be achieved within 4 minutes processing time.



- The power intensity dependency is observed in the sonication and the sonication plus vapor stripping systems.
- Operating costs for the combined sonication/ vapor stripping system are lower than for the cost of sonication alone.
- Combining sonication with vapor stripping enhances removal of CCl_4 and TCE as compared to removal by either system alone and results in higher first-order rate constants.





Contaminants Being Studied

- Carbon tetrachloride (CCl_4)
- Trichloroethylene (TCE)
- 1,1,2,2-Tetrachloroethylene (PCE)
- 1,1,1-Trichloroethane (TCA)
- Ethylenedibromide (EDB)

Benefits

- Remediation performed *in-situ*
- Complementary treatment systems can drastically reduce or remove semivolatile organic compounds (SVOCs) or volatile organic compounds (VOCs) from solution
- Can convert hard-to-degrade organics into more volatile organic compounds
- Eliminates handling or disposal of water
- Improved efficiency shortens site remediation time and reduces costs

Future Efforts

- Perform continuous flow experiments on combined sonication/vapor-stripping system.
- Continue identification of breakdown/partial degradation products and mass balance closure.
- Determine corrosion/scaling potential of process in "real world" (e.g., hard water, competing ions, etc.) environments.
- Continue modeling zone of influence, treatment zone, and time requirements in subsurface (Stanford University).
- Perform large-scale pilot demonstration of combined in-well sonication/in-well vapor stripping/in-situ biodegradation (treatment in a large "sandbox").
- Perform systems/economics analysis.
- Identify potential commercialization partners.

Acknowledgment

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