Viscous Heating Effect on Deactivation of Helminth Eggs in VIP Sludge

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Introduction:

- Viscous heating by extrusion of faecal material alone can deactivate Soil Transmitted Helminth (STH) eggs present in sludge.

- Baseline parameters for deactivation:
  1. Minimum temperature required for deactivation
  2. Local maximum temperatures
  3. Thermal efficiency

- Laboratory-scale units built and tested with results presented here.
Background:

Soil Transmitted Helminthes (STH)

• parasites transmitted via eggs or larvae which are deposited in soil through indiscriminate defecation.

• Methods to “interrupt the vicious cycle of disease transmission” are desired.

• Destroying eggs at the point of deposition has the potential to reduce infection rates.
Background:

Viscous Heating

- Can be used to increase the temperature of faecal sludge uniformly.
- Fiction among the molecules generate heat when in a high shear field.
- Amount of heat generated is a function of: (1) Fluid Viscosity, (2) System Pressure, and (3) Shear Rate
- Effluent temperatures can range from pasteurization to greater than the boiling point of water.
Methods and Materials:

Sludge Source Acquisition and Processing

• Obtained from VIP latrines in the eThekwini Municipality (Durban) South Africa.

• Screened down to 1.2 mm prior to use.

• Two samples:
  A. 25 L VIP Sludge with 0 STH/10 g sludge
  B. 1.5 L VIP Sludge with ≈ 10,000 STH / 10 g sludge

• Dehydrated potatoes were added to increase viscosity.
Methods and Materials:

Equipment Operation

- Deactivation evaluated at 3.5 degree intervals from 50-85°C
  - RPM Tested: 1100, 1300, 1400
  - Flow Rate Tested: 1, 2, 4 g/s

- 20 g samples set aside for STH analysis.

- Samples sealed and placed in 13 °C water bath.

- 1 Liter sample set aside for rheology analysis
Methods and Materials:
Sample Analysis

*Ascaris lumbricoides* (or suum) → Fertilized, Undeveloped egg

- Infertile egg → Non-viable eggs
  - Dead egg
- Viable or potentially viable eggs → 2-cell, 4-cell, 8-cell, etc., developing egg
  - Egg containing an immotile larva which looks healthy
  - Egg containing a motile larva

Egg containing a necrotic (dead) larva
Methods and Materials:

Data Analysis

Deactivation regressed in JMP Statistical software and Excel.

\[
\frac{C(T)}{C_0} = \exp\left( t \ast -A_{app} \exp\left( \frac{E_{app}}{RT} \right) \right)
\]

Where:

C: Concentration (eggs/10g)

C_0: Initial Concentration (eggs/10g)

t: time (s)

A_{app}: Apparent Arrhenius Constant (s^{-1})

E_{app}: Apparent Activation Energy (J/mol)

R: Gas Constant (8.314 J/molK)

T: Temperature (K)
Methods and Materials:

Data Analysis

Efficiency calculated from operating parameters and sludge properties.

\[ \eta = \frac{Q_{sludge}}{Q_{in}} = \frac{(T_{out} - T_{in})Cm}{Q_{in}} \]

Where:

\( \eta \): Efficiency
\( T_{out} \): Temperature of effluent (C)
\( T_{in} \): Temperature at inlet (C)
\( C \): Specific Heat (Approximated at water)
\( m \): mass flow rate (g/s)
Results:
Pre Incubation Deactivation

![Graph showing changes in C/C0 with effluent temperature at different flow rates.](image)

- 1 g/s
- 2 g/s
- 4 g/s

R2 = 0.8607
Results:
Post Incubation Deactivation

Effluent Temperature (°C)

C/Co

1 g/s
2 g/s
4 g/s

R² = 0.922485
**Results:**

Max Steady State and Min Required Temperature as a Function of Mass Flow Rate

![Graph showing the relationship between mass flow rate and temperature for different moisture contents.](attachment:image.png)

- **Min. Temp. Reqd. For 99.9% Deactivation**
- **Max. S.S. Temp. At Max Power Input**

Legend:
- MC = 77%
- MC = 65%
- MC = 60%
Results:
Pre Incubation Deactivation

\[ \eta = 18.8 + 20.4 \ln(m') \]

Adjusted \( R^2 = 0.9792 \)
Conclusions:

- Viscous heating by extrusion of faecal material alone can deactivate Soil Transmitted Helminth (STH) eggs present in sludge.

- Temperatures above 70°C showed greater than 90% deactivation.

- Operating near a temperature of 85°C showed 100% deactivation.

- High Moisture content is undesirable.
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