# Potential for Biogas Recovery from Anaerobic Ponds in New Zealand

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# Outline

- Ponds in NZ
- Anaerobic pond designs
- Biogas potential from wastewaters
- Economic issues
- NIWA FRST funded research

# Ponds in New Zealand

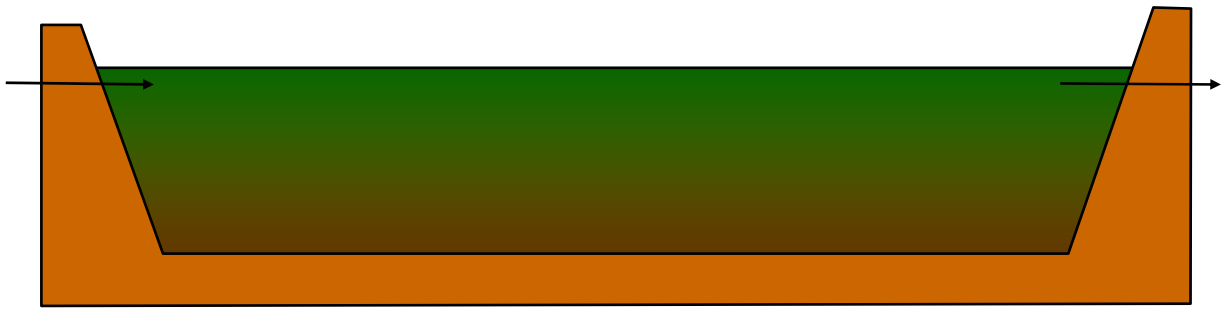
- Domestic sewage ponds (~200)
  - Facultative + Maturation
  - Anaerobic (~3?)
- Agricultural / Industrial ponds
  - Dairy farm (~1000)
    - Anaerobic + Facultative
  - Dairy factory (e.g.Tirau)
  - Piggery
  - Meat processing
  - Pulp and paper mill

# Domestic Sewage Ponds

- MWD, 1974 Design
  - Facultative

Aerobic surface

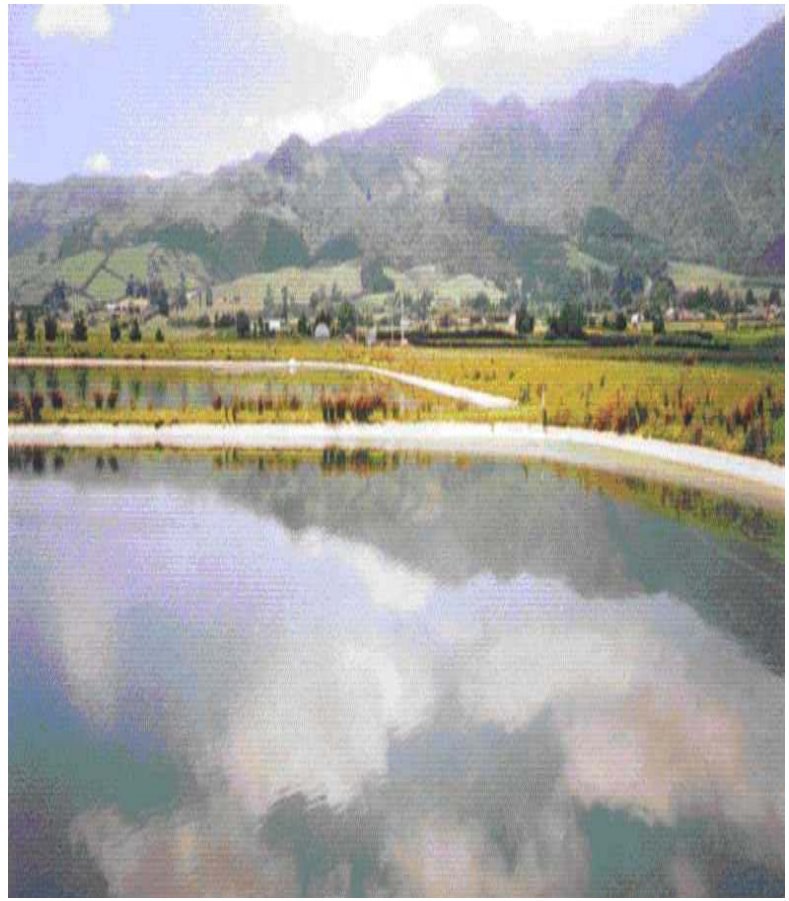
Anaerobic bottom



  - Areal $BOD_5$ loading:
    - 84 kg $ha^{-1}$ $d^{-1}$
  - 1.0 – 1.5 m deep
  - Wind mixed

# Domestic Sewage Ponds

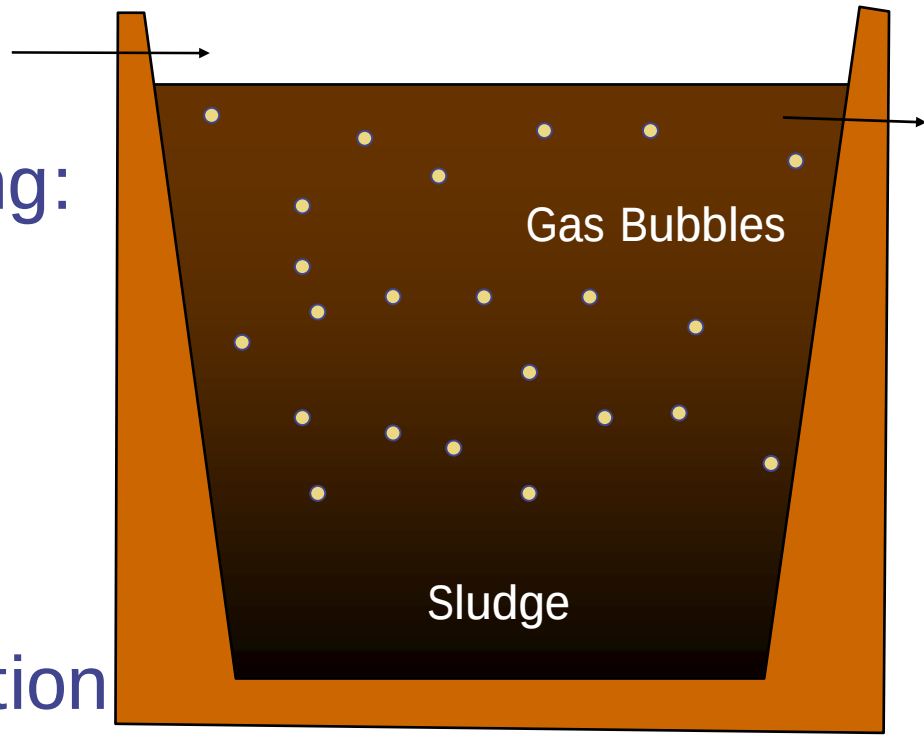
- Performance
  - Efficient BOD removal
  - Some anaerobic digestion
  - Incomplete digestion
  - Sludge accumulation
  - Methane emissions?



# Dairy Farm Anaerobic Ponds

- DEC, 1996 design
  - Volumetric $BOD_5$ loading:
  - 0.020-0.028 kg $m^{-3}$ $d^{-1}$

    Southland - Northland
  - 4-5 m deep
  - Solids sedimentation
  - Partial anaerobic digestion
  - Sludge removal 3-5 years



# Dairy Farm Anaerobic Ponds

- Performance
  - Efficient TSS/BOD removal
  - Low loading
  - Methane emissions?

# Pond-based Anaerobic Digestion

- AD not optimised in conventional NZ ponds
- Some GHG emissions – How much?
- How can ponds be improved to:
  - Convert more biomass to biogas
  - Economically collect biogas
    - For use as energy source
    - To reduce GHG emissions
    - Reduce cover area
  - Reduce sludge accumulation
    - Sludge removal interval

# Anaerobic Pond Design

- Domestic Sewage
  - NZ?
  - Typical design
  - High Rate Anaerobic Ponds
- Agricultural Waste
  - US design

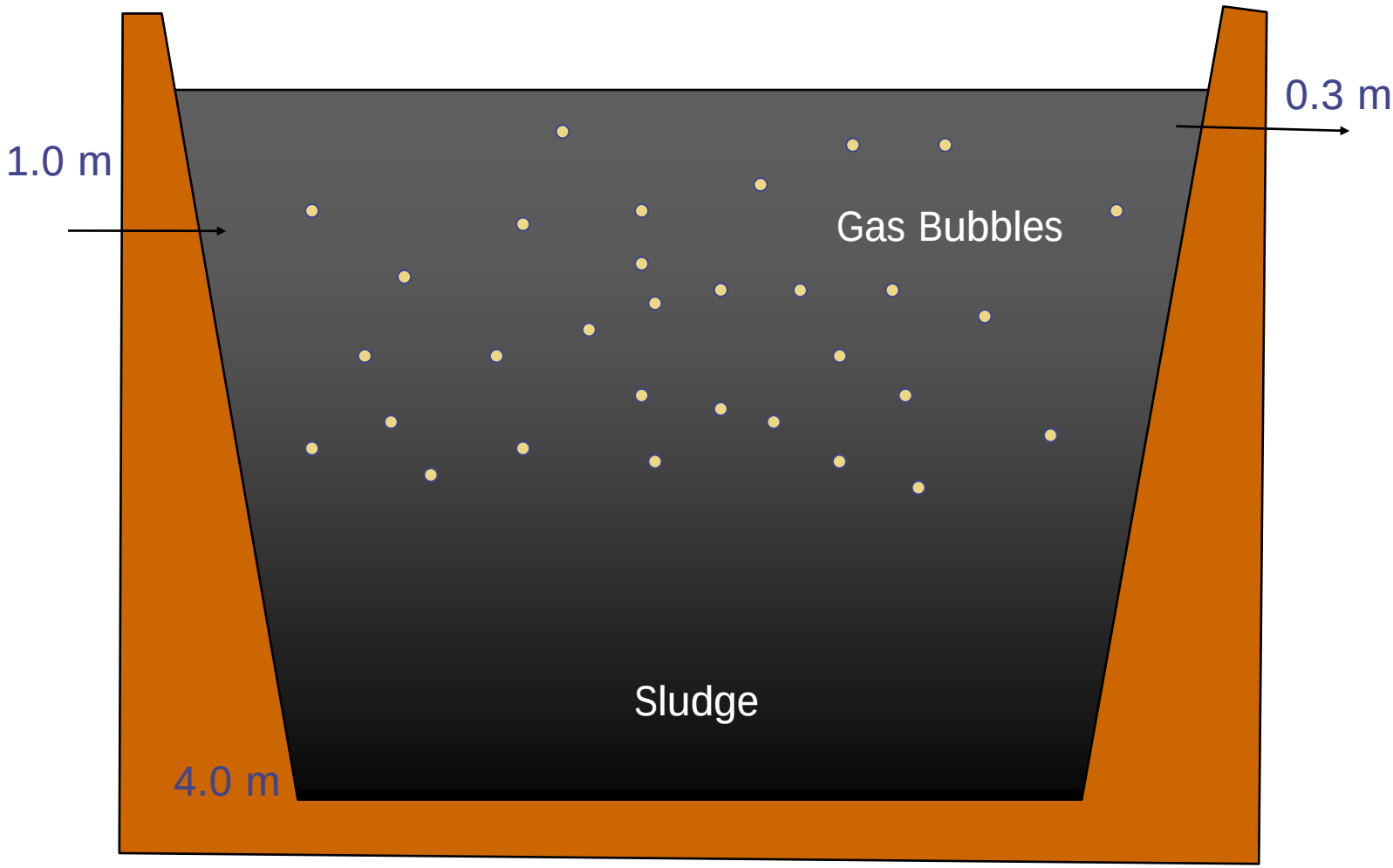
# Domestic Sewage Anaerobic Ponds

(e.g. Mara, 2004)

| | |
|---|---|
| Wastewater solids (%): | < 1 |
| Volumetric $BOD_5$ loading ($kg/m^3/d$): | 0.1 - 0.4 |
| Temperature dependent (min mean monthly air temp $^oC$) | <10 - >35 |
| Depth (m): | 2 - 5 |
| Hydraulic retention time (d): | 1 - 5 |
| $BOD_5$ removal (%): | 45 - 80 |
| Sludge removal interval (y): | 1 - 3 |

# Domestic Sewage Anaerobic Ponds

(e.g. Mara, 2004)



# High Rate Anaerobic Ponds

- Mimic conditions within UASB digester
- Influent dispersed near pond bottom
- Effluent from near surface
- Wastewater passes through sludge blanket
- Designs vary with:
  - Volumetric loading
  - Pond dimensions
  - Sludge removal interval

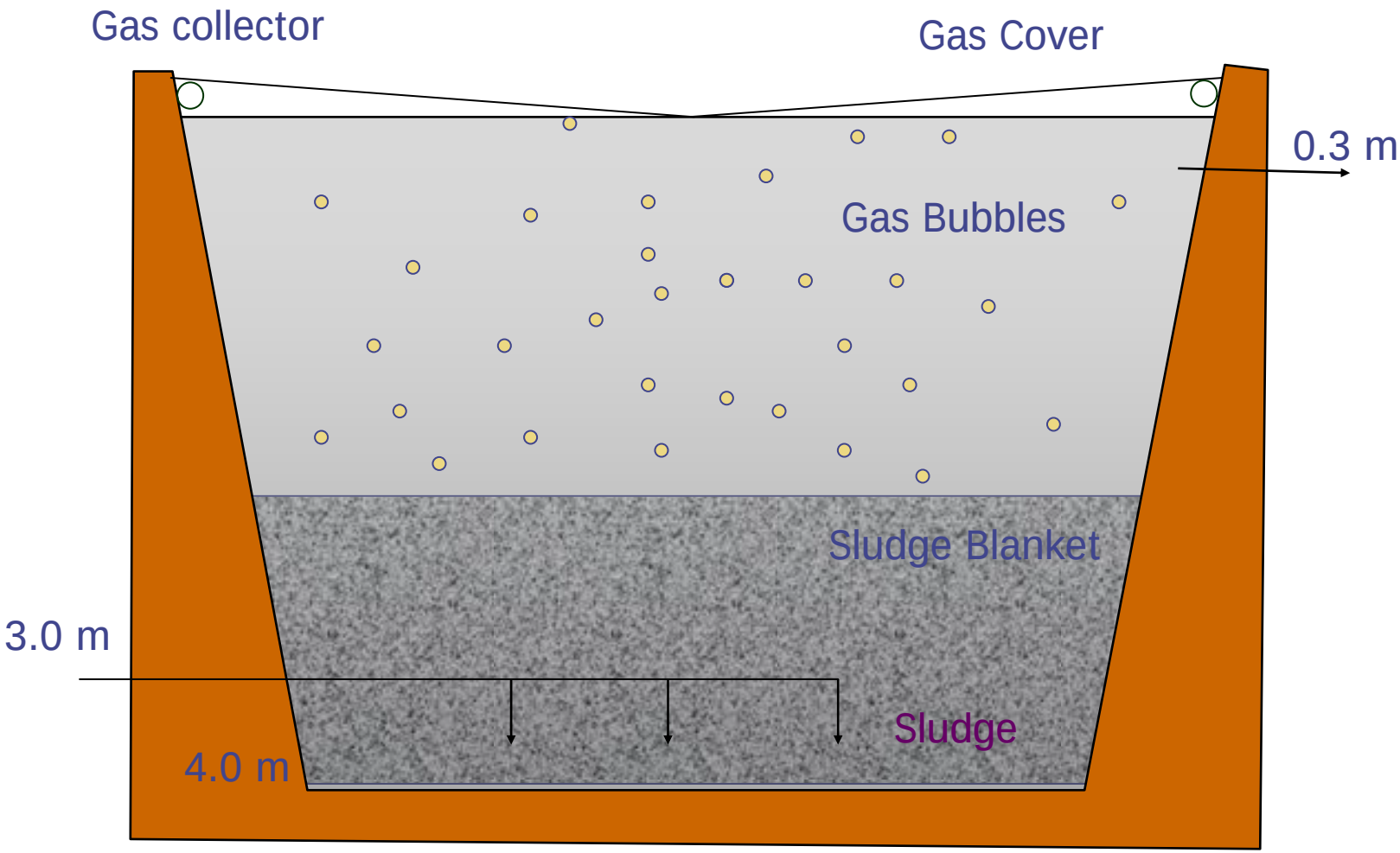
# Fermentation Pit

(Oswald, 1991)

| | |
|---|---|
| Wastewater Solids (%): | <3.0 |
| Volumetric $BOD_5$ loading ($kg/m^3/d$)<br>%Solids and temperature dependent | 0.06 - 1.0<br><1%, <4.5°C - 3%, >27°C |
| Depth (m): | 4.0m |
| Hydraulic Retention Time (d): | 1 - 3 |
| $BOD_5$ Removal (%): | >60% |
| Sludge Removal Interval (y) | (20% volume)<br>>20 |

# Fermentation Pit

(Oswald, 1991)



# High Rate Anaerobic Lagoon

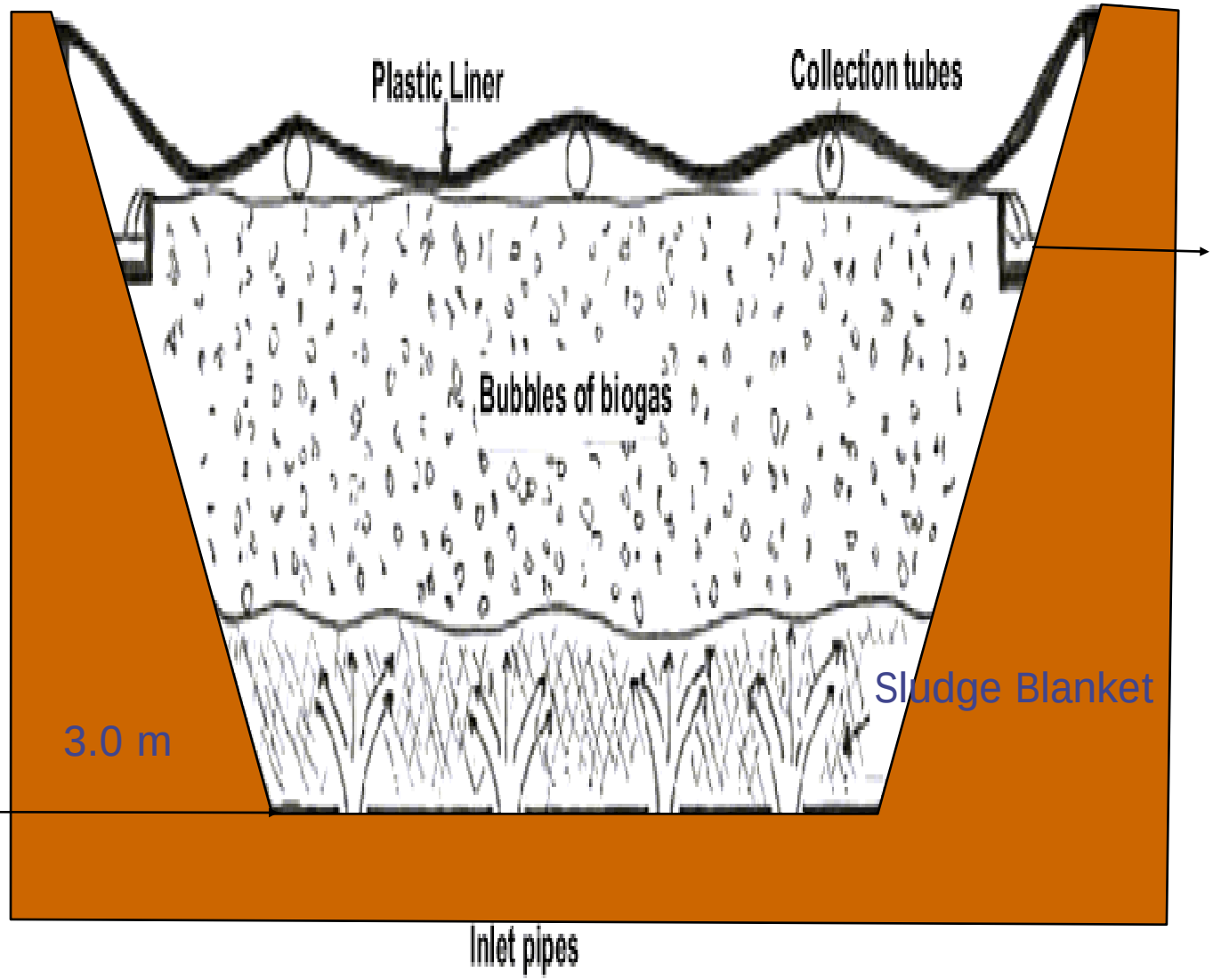
(Messenger, 1994)

| | |
|---|---|
| Wastewater solids (%): | < 1 |
| Volumetric $BOD_5$ loading ($kg/m^3/d$): | 0.1 - 0.4 |
| Depth (m): | 3 |

- Influent to pond bottom
- Effluent recirculation (1:1)
  - Assist mixing
  - pH buffering
- Alkalinity dosing
  - pH buffering

# High Rate Anaerobic Lagoon

(Messenger, 1994)



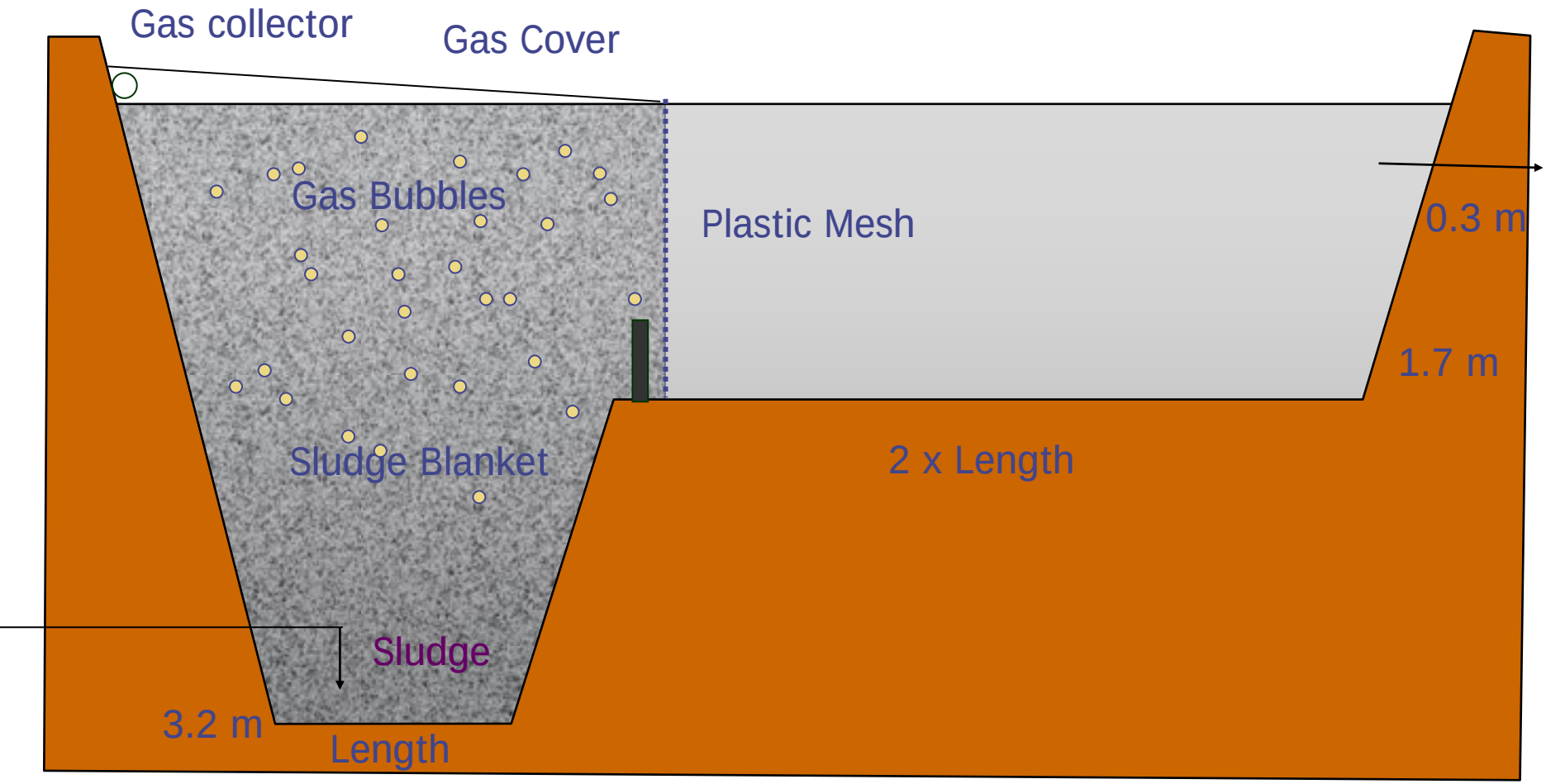
# High Rate Anaerobic Pond

(Pena Varon, 2004)

| | |
|---|---|
| Wastewater solids (%): | < 1 |
| Volumetric $BOD_5$ loading ($kg/m^3/d$): | 0.45 |
| Hydraulic retention time (d): | 0.65 |
| $BOD_5$ removal (%): | <70 |
| Sludge removal interval (y): | 1 - 3 |

# High Rate Anaerobic Pond

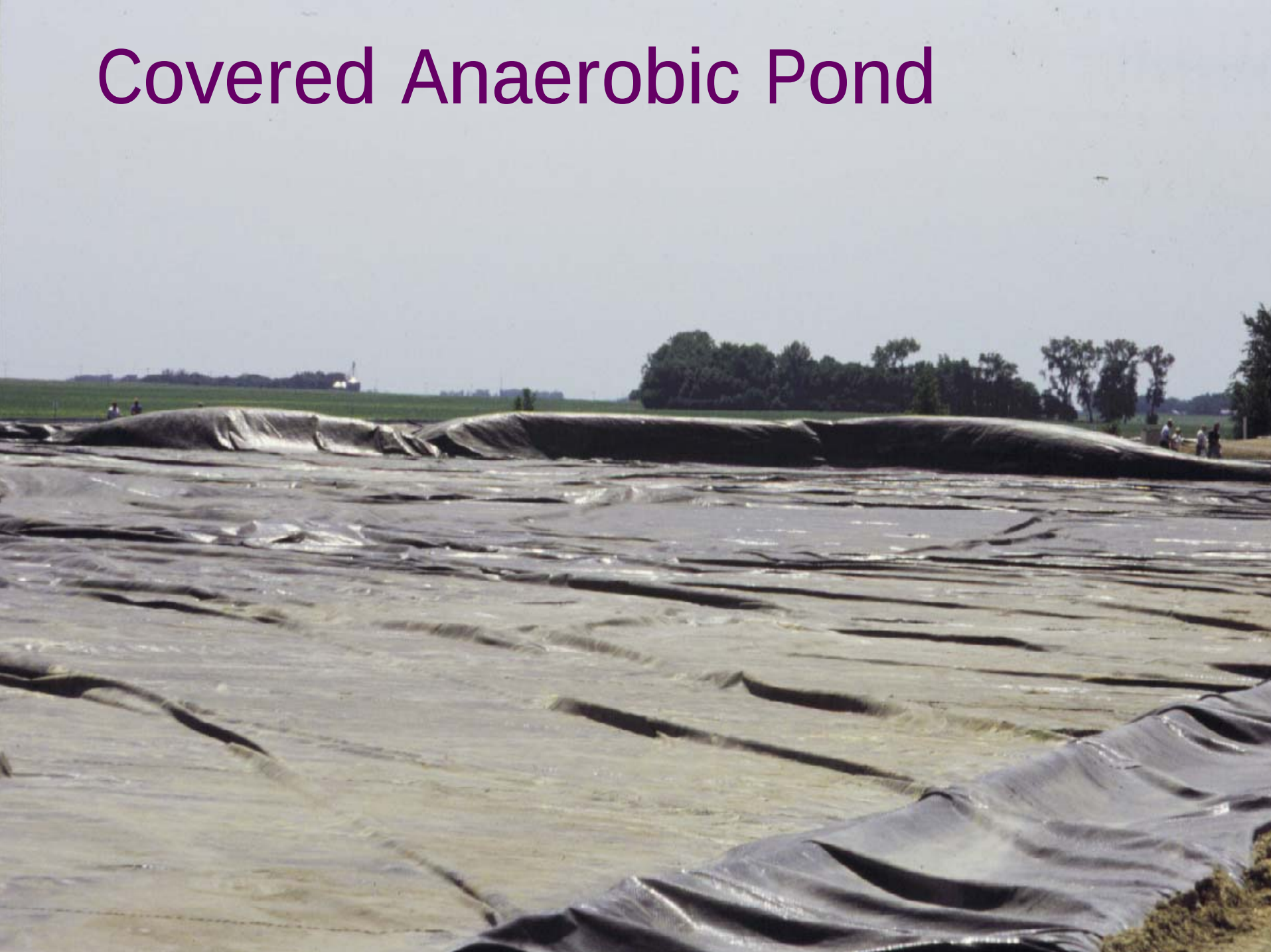
(Pena Varon, 2002)



# Agricultural Anaerobic Ponds (USA)

| | |
|---|---|
| Wastewater Solids (%): | < 3 |
| Depth (m): | 3 - 9 |
| Hydraulic Retention Time (d): | 30 - 90 |
| $BOD_5$ Removal (%): | 60 - 80 |
| Sludge Removal Interval (y) | 1 - 5 |

# Covered Anaerobic Pond

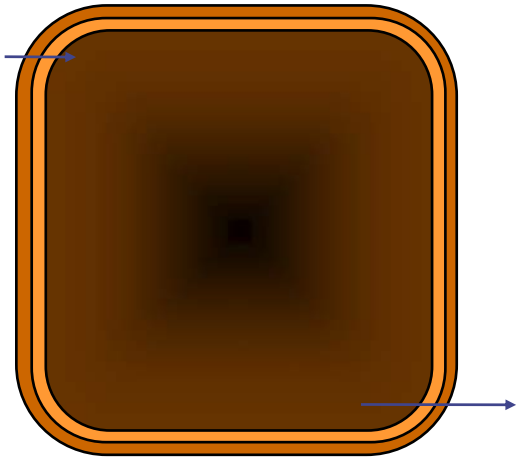


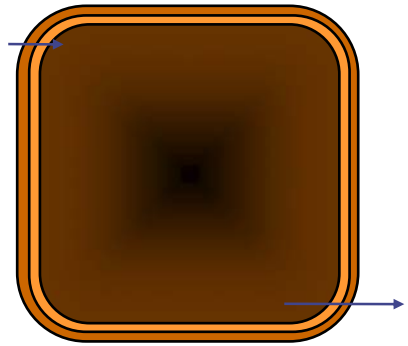
# Agricultural Anaerobic Ponds

| | Volumetric VS loading ($kg/m^3/d$) |
|---|---|
| Cattle (dairy) | 0.08 - 0.19<br>NZ Ponds 0.06 – 0.09 |
| Pigs | 0.06 - 0.12 |
| Chicken | 0.007 - 0.135 |

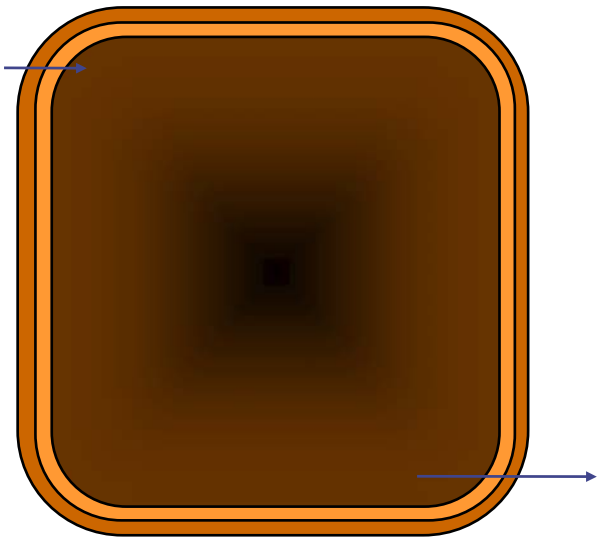
- NZ Dairy shed anaerobic pond volumes could be lower

# Dairy Farm Anaerobic Ponds

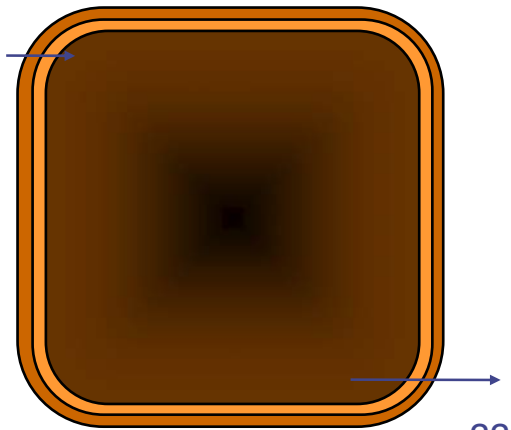




New Zealand Design



US Design



# Improving AP efficiency

- Higher BOD/VS loading rate
- Lower HRT
- UASB conditions – reactor design, inflow / outflow
- Lower sludge accumulation

- Waste solids content / water use
- Insulation/heating
- Mixing

- Two stage ponds

- Problems – crusting?

# Earthen Plug Flow Digester

| | |
|---|---|
| Wastewater solids (%): | > 9 |
| Volumetric VS loading ($kg/m^3/d$): | 1 - 3 |
| Depth (m): | 2 - 5 |
| Hydraulic retention time (d): | 20 - 40 |

- Long troughs with surface cover
- Waste pushed from one end to other
- Un-mixed but heated (mesophilic)
- Waste is scraped, not flushed
- Premixing to ensure consistency

# Plug Flow Digester

# Wastewater Biogas Potential

| Waste Type | Waste Production (kg VS /d) | Biogas Production (65% $CH_4$) ($m^3$/kg VS) | Energy Value (6.3kWh/$m^3$) (kWh/d) | Per 1000 individuals Electrical Energy (25% efficiency) (kWh/d) | Saving ($0.11 / kWh) ($/y) |
|---|---|---|---|---|---|
| Sewage | 0.11 | 0.4 | 285 | 71 | $2,858 |
| NZ Dairy | 0.40 | 0.34 | 857 | 214 | $8,600 |
| Dairy | 4.0 | 0.34 | 8570 | 2140 | $86,000 |
| Piggery | 0.29 | 0.67 | 1224 | 306 | $12,200 |
| Chicken | 0.01 | 0.60 | 53 | 13 | $500 |

# Biogas Uses

- Heating
- Cooling
- Electricity generation

- Thermal use
  - Lower capital  and O/M costs
  - Modify natural gas equipment

# Economic Issues

- Anaerobic pond size – construction costs
- Gas cover design - cost
- Insulation / Heating / Mixing – capital, O&M
- Gas scrubbing - capital, O&M
- Engine / Generator - capital, O&M
- Value of electricity, heat

# Covered Anaerobic Pond

# Conclusions

- Anaerobic Ponds can improve treatment and recover biogas
  - Need to demonstrate/develop improved designs
- Biogas recovery installation costs still high
  - Need to reduce costs
    - Cover – reduce area – loading rate / % solids – water use
    - O&M – desludging – digestion efficiency
    - Engine generator – low cost retrofit?

# FRST Funded Research

- Pond Based Anaerobic Digestion
  - Biogas production from NZ APs
  - Improve Anaerobic Pond performance
    - Reduce sludge accumulation
    - Increase biogas production
    - Design and performance models
  - Laboratory, pilot and full-scale
  - Domestic sewage, Dairy farm waste, other?

# FRST Funded Research

- Scrubbing of biogas in High Rate Algal Ponds (Aerobic, $CO_2$ deficient )
  - Pond-based scrubbing
    - Affect on treatment performance (+ve / -ve)
    - Affect on algal production
    - Design and performance models
  - Laboratory, pilot and full-scale

# FRST Funded Research

- Anaerobic Digestion of Algal biomass
  - Pond-based digestion
    - Affect on treatment performance (+ve / -ve)
  - Pre treatment
  - Potential biogas production
  - Laboratory, pilot and full-scale