Sewage Sludge –
*Inevitable production of a renewable resource*

Dr Bill Barber

23 February 2012 Geelong
Stricter wastewater standards – Secondary Treatment

Nutrient removal – Chemical Dosing
World-wide Sludge Production

![World Sludge Production Diagram](image)

### World Sludge Production

![Swimming Pool Image](image)
Increasing sludge production in Europe mainly due to stricter environmental standards.
**Sludge Processing**

- Wastewater treatment
- Sludge Type
- Thickening
- Mechanical
- Biological
- Chemical
- Thermal
- Other
- Anaerobic Digestion
- Composting
- Liming
- Lime + Supp Heat
- Dewatering
- Transport
- Drying
- Gasification
- Oil from Sludge
- (Super Critical)
- Wet Air Oxidation
- Outlets

**What can you do with it?**

- Environmental Drivers
- Wastewater Treatment
- Biosolids Production
- Reduction of pathogens, organics, metals, etc.
- Land Application
- Combustion
  - Wet
  - SC(WAO)
  - Dry
  - Mono-incineration
  - Co-firing
- Other
  - Wet Air Oxidation
  - Stockpiling
  - Building aggregates
  - Resource recovery
  - Protein extraction
- Landfill
- Forestry
- Recycling
- Food crops
- Non-food crops
- Energy crops
- Power stations
- Factories
- Land Reclamation
- Recycling
- Food crops
- Non-food crops
- Energy crops
What else can you do with it?

POOP BURGER: Japanese Researcher Creates Artificial Meat From Human Feces

Story by Jeff Hughes

Japan scientist synthesizes meat from human feces

It’s being called the "poop burger". Japanese scientists have found a way to use human feces.

Somehow this feels like a Vonnegut plotline: population boom equals food waste matter. Absurd yes, but Japanese scientists have actually discovered a way to use human feces.

Mitsuyuki Ikeda, a researcher from the Okayama Laboratory, has developed a way to explore the possible uses of the sewage and Ikeda found that the mud could be turned into meat.

Would you eat a turd burger?

- **YES WITH A SIDE OF FRIES PLEASE!**
  - 9,777 votes
- **NO WAY THE DONKEY'S Slobber Enough!**
  - 3,158 votes
- **NOT SURE, I'D HAVE TO SEE IT UP CLOSE FIRST.**
  - 4,113 votes

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European Sludge Outlets

![Graph showing European sludge outlets from 2001 to 2007.](image-url)
Energy Recovery

Energy – Price

Oil Price [$US/barrel]

Dec 81  Jun 83  Dec 84  Jun 86  Dec 87  Jun 89  Dec 89  Jun 91  Dec 91  Jun 93  Dec 93  Jun 95  Dec 95  Jun 97  Dec 97  Jun 99  Dec 01  Jun 03  Dec 05  Jun 07  Dec 08  Jun 10  Dec 11
Energy – Security

Natural Gas [Trillion cubic metres]

- Global Gas demand
- OECD Countries
- Non-OECD Countries
- European Union (ex FSU)
- Former Soviet Union

Proved World Reserve

Former Soviet Union Reserve

at end 1990

at end 2000

at end 2009
Russia has stopped all gas supplies to Ukraine after the collapse of talks to send a row over unpaid bills and prices.

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The EU urged Russia and Ukraine to resume negotiations and not to let the dispute disrupt supplies to Europe.

A similar row between Gazprom and Ukraine at the beginning of 2006 led to gas shortages in several EU countries.

Pipes across Ukraine carry about a fifth of the EU’s gas needs.

The new holders of the EU presidency, the Czech Republic, urged the parties to “rapidly reach a successful outcome” to their dispute.

“All existing commitments to supply and transit must be honred,” it added.

Both Russia and Ukraine insist that gas supplies transported via Ukraine to the European Union will continue as usual.

Russia turns off the taps again: Moscow slashes gas supplies to Belarus amid claims of £130m in unpaid bills

Last updated at 10:20 PM on 21st June 2010

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Energy recovery from sludge – MAD with CHP

- Energy in pure biomass: 6480 kWhr
- In dry solids: 4860 kWhr
- In biogas: 3159 kWhr
- After fugitive gas losses: 1935 kWhr
- After heat losses: 1529 kWhr
- After efficiency losses: 658 kWhr

Export as Renewable Power: 658 kWhr

Things which influence gas production:
- Wastewater Treatment
- Maintenance
- Equipment Selection

[Bar chart showing generation with categories: AI SAS, AI 30C, CHP availability 80%, Baseline, AI 6% DG, Clean digesters, AI 8% VS, CHP availability 90%, AI advanced MAD, Electrical conversion 41%, AI primary]
Water Industry
Advanced Anaerobic Digestion

Ultrasonics  Chemical Lysis  Thermal Hydrolysis
High Pressure Shear  Medium Pressure Maceration  Acid Phase
Electric Pulse  Rapid Decompression  Biological Hydrolysis

Benefits of Advanced Digestion

Greater Stability  Higher biogas production  Smaller Digestion Plants
Better dewatering  Reduced secondary emissions  Advanced treated
## Performance

<table>
<thead>
<tr>
<th></th>
<th>Biological</th>
<th>Thermal</th>
<th>Acoustic</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Organics</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Standard</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Advanced</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Sterilisation (ABP)</td>
<td>×</td>
<td>✓</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>High DS (OLR)</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>VS destruction</td>
<td>58%</td>
<td>62%</td>
<td>62%</td>
<td>70%</td>
</tr>
<tr>
<td>Complexity</td>
<td>×</td>
<td>✓</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>Energy Demand</td>
<td>✓</td>
<td>×</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Dewaterability</td>
<td>×</td>
<td>✓</td>
<td>(NH₃)</td>
<td>(NH₃)</td>
</tr>
</tbody>
</table>

### Energy recovery from sludge - Advanced MAD with new CHP

- In pure biomass: 6480 kWhr
- In dry solids: 4860 kWhr
- In biogas: 3159 kWhr
- After fugitive gas losses: 3023 kWhr
- After heat losses: 2426 kWhr
- After efficiency losses: 1213 kWhr

Energy in Renewable Power: 1213 kWhr
Alternative Biogas Uses

Biogas

\[ \text{CH}_4 \ 65\% \]
\[ \text{CO}_2 \ 35\% \]

Co-generation

Further Processing

Clean-Up

Compression

Anaerobic Digestion Facility

Heat

Biomethane

\[ \text{CH}_4 \ 96\% \]
\[ \text{CO}_2 \ 4\% \]
Alternative uses for Biogas

Davyhulme

- Biogas to Grid
  - 4000 – 7000 m³ biogas/hr
  - Pressure Swing Adsorption preferred technology to produce 96% CH₄ biomethane
  - 230 m³/hr biogas cleaned
  - Injection to grid
  - Compression and vehicle use
Energy Recovery
Thermal

Calorific Value of Substances

- Methane
- LPG
- Diesel
- Petrol
- Shredded tyres
- Coal (black)
- Sludge Digestate
- Sludge
- Jaffa Cake
- Coal (brown)
- Wood
- Jam Doughnut
- Digestate
- Garlic Bread
- NSW Red wine
- Guinness
### Thermal sewage sludge treatments

#### Benefits

<table>
<thead>
<tr>
<th>Incineration</th>
<th>Drying</th>
<th>Co-combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total destruction</td>
<td>Proven at full-scale</td>
<td>Fraction of the costs and plant of incineration</td>
</tr>
<tr>
<td>Energy recovery</td>
<td>High volume reduction</td>
<td>Commercially proven at full scale with both sludge and numerous refuse derived fuels (such as chicken litter)</td>
</tr>
<tr>
<td>Fly ash may be recycled</td>
<td>Partial pasteurisation</td>
<td>Can take dewatered or dry cake</td>
</tr>
<tr>
<td>Proven at full-scale</td>
<td>Storage and handling of product may be easier than sludge cake (especially if pelletised)</td>
<td>Reduces fossil fuel requirements</td>
</tr>
<tr>
<td>Reduces reliance on landfill</td>
<td>Longer storage times possible</td>
<td>Sludge burnt by company who have expertise in burning materials</td>
</tr>
<tr>
<td></td>
<td>Larger range of disposal options than sludge cake</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increases calorific value of sludge prior to thermal destruction</td>
<td></td>
</tr>
</tbody>
</table>

#### Disadvantages

<table>
<thead>
<tr>
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<th>Drying</th>
<th>Co-combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>High capital and operating costs</td>
<td>Critically dependent on third parties</td>
</tr>
<tr>
<td>Public Perception</td>
<td>Needs auxiliary fuel such as natural (or biogas)</td>
<td>May result in tightening regulations at power station</td>
</tr>
<tr>
<td>Very low on waste hierarchy</td>
<td>Potentially complex operation</td>
<td>Public perception</td>
</tr>
<tr>
<td>Requires complex gas cleaning</td>
<td>Potential handling problems</td>
<td>Limited to power stations with advanced flue gas treatment facilities</td>
</tr>
<tr>
<td>Removes phosphorous from ecosystem</td>
<td>Very sensitive to fluctuations in load (especially dry solids)</td>
<td>Methane build-up problems</td>
</tr>
<tr>
<td>Produces a number of hazardous wastes</td>
<td>Issue with fibres and other materials</td>
<td>May be forced to dry cake</td>
</tr>
<tr>
<td>High capital cost</td>
<td>With direct dryers, production of gas which may require further treatment.</td>
<td>Competition from other refuse derived fuels</td>
</tr>
<tr>
<td>High operating cost</td>
<td>Critically reliant on gas prices</td>
<td>Numerous take-overs of power station companies may disrupt long term contracts</td>
</tr>
<tr>
<td></td>
<td>Rewetting of raw dried sludge has resulted in pathogen regrowth</td>
<td>Fluctuations in sludge quality may discourage power plant owners from accepting sludge</td>
</tr>
</tbody>
</table>

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*Note: The table above summarizes the benefits and disadvantages of thermal sewage sludge treatments using incineration, drying, and co-combustion methods.*
Drying Theory
- Two falling rate curves
- 1 MW/t we (0.72 MW for water evaporation)
- 50 kWe/t we
- Pelletiser
- Operational breakdown
  - Energy 55%
  - Staff 30%
  - Maintenance 10%
  - Other 5%

Drying Technology

- Conductive:
  - Belt
  - Drum
  - Thin Film
  - Solar
- Convective:
  - Paddle
  - Tray
- Hybrid:
  - Fluidised bed
Direct Dryers: Rotary Drum Dryer

- Andritz, Siemens, Baker-Rullman
- Medium to Large
- High operating temperature, Complex
- Multipass Design
- High Pellet Quality

In-Direct Dryers - Paddle Dryer

- Komline Sanderson, Fenton, Therma-Flite
- Small to Medium
- 180 – 230 °C
- Can use waste heat
- Single Pass Design
- No need for biosolids recycle
Fluidized Bed Dryer, Hybrid

- Andritz, Schwing
- Medium to Large
- Can use waste heat
- Low operating temp (85 °C)

Solar Drying

- Veolia, Wendewolf, Parkson, Huber
- Large footprint, low energy
- 850 kg/m²/yr in Europe
- 0.5 – 0.6 m²/t we/yr
  - 1 – 3.5 kg we/m²/d
- Thickness 100 > 350mm
- Largest plant 150 MLD
Economic and carbon analysis (long transport distance)

Cost

Carbon Footprint

Economic and carbon analysis (short transport distance)

Cost

Carbon Footprint
Impact of transport on processing costs

Impact of transport on carbon footprint
1. Sludge cake enters system and is screened (400 mm) mesh. Silo holds 70 m³.
2. Material is pumped (45 m³/hr) to storage silo which holds 240 m³.
3. Sludge is pumped (<30 m³/hr at 80 bar) distance of 150 m to storage hoppers.
4. Controlled amounts of dewatered cake (0.5 – 4%) are fed into 4 boilers, each of which have 4 t/hr spare water evaporation capacity.
5. Methane and air are extracted from all areas containing sludge to prevent build-up of hazardous gases.
Sludge cake pump

Nutrient recovery
Phosphorous

- World population increasing
  - Becoming urbanized
  - Changing food habits
  - Global demand increased 4.7 million tones in 3 years (equivalent to USA consumption)
    - 0.6 – 1.6 kg P/person.year

- Peak P predicted at 2035?
  - 50 – 100 years of easily mined P remain
  - >60% of all reserves in Morocco
  - China imposed P export tax (+110%)

Adapted from Cordell et al., 2009. The story of phosphorus: Global food security and food for thought
Phosphorus

- 90% of phosphorus consumed by humans is wasted
- If recovered, this phosphorus could meet 20% of current global demand
- Over half of this phosphorus is in sludge
  - Generally this is a nuisance at a sewage works
- This is lost during thermal processing
  - Incineration

Struvite

\[ \text{Mg}^{2+} + \text{NH}_4^+ \text{PO}_4^{3-} + 6 \text{H}_2\text{O} \rightarrow \text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O} \]
Phosphorus

PEARL®
- Removes phosphorus and ammonia loads
- Prevents sludge scale formation
- Recovers nutrient value
- Promotes environmental sustainability
- Provides attractive whole-life financial value

Biosolids as a resource

1 tonne sewage sludge

<table>
<thead>
<tr>
<th>0.42 tonne oil equivalent</th>
<th>0.08 kW electricity</th>
<th>200 m³ biomethane</th>
<th>50 kg N</th>
<th>25 kg P</th>
<th>15.3 oz troy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$305</td>
<td>$70</td>
<td>$25</td>
<td>$40</td>
<td>$26,000</td>
<td></td>
</tr>
</tbody>
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Summary

- Sludge production is increasing globally
  - Stricter legislation; Population increase; Greater urbanization
- It is also becoming increasingly difficult to treat

- Many ways which energy can be recovered from sludge
  - Anaerobic digestion; biogas upgrading; thermal recovery
    (mono- and co-firing as cake or dried material)

- Nutrient recovery becoming more important to address
  phosphorous requirements and to assist with carbon
  reduction

Thank you

bill.barber@aecom.com
Case-study

Energy Recovery using *Super Critical Wet Air Oxidation (SCWAO)*
*Alternative to Incineration*

Super Critical Wet Air Oxidation (SCWAO)

- **Solid**
- **Liquid**
- **Gas**

221 bar

374°C
SCWAO

Bruxelles Nord – Thermal Hydrolysis with WAO

- 18000 TDSA
  - Operational 2006/7
- Mixed primary and secondary sludge
- Sub-critical oxidation
  - 50 bars
  - 250°C
  - Uses catalyst
- Less than 5% organics in solid residue
- Effluent contains 25% COD load