Acknowledgement

The presenter wish to thank the Waste Management Authority of Western Province of Sri Lanka for organising this workshop.

1. Colombo
2. Gampaha
3. Kalutara
4. Dambulla Ml Lavaniya
5. Negombo
6. Matara
7. Jayawardeanapura
Outline

- Urban Solid Waste and social economic development stages
- Issues in Asian cities
- Collection efficiencies
- Typical waste characteristics
- Desired material-cycle
- Options available
- A case study: Management of market waste in Jakarta
- Discussions: desired end state or objective
- Workshop: SWOT analysis

We are not alone!

- Outside local grocery store in New York city at 38th St. and 3rd Ave. This is the way it looks everyday around 9:00 pm.
  (Source: http://blogs.nyu.edu/blogs/scr243/makingmuseum/DSCN1247.JPG)
Urban solid waste

(Mendes and Imura 2004)

Issues in Asian Cities
(Mendes and Imura 2004)

<table>
<thead>
<tr>
<th>Less developed cities</th>
<th>Rapidly developing cities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td></td>
</tr>
<tr>
<td>Dhaka, Kathmandu, Karachi, Phnom Penh</td>
<td>Beijing, Shanghai, Guangzhou, Bangkok, Kuala Lumpur, Manila</td>
</tr>
<tr>
<td><strong>Trends</strong></td>
<td></td>
</tr>
<tr>
<td>Population growth</td>
<td>Population growth</td>
</tr>
<tr>
<td>Urbanization</td>
<td>Urbanization</td>
</tr>
<tr>
<td><strong>Urban characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Mix of semi-urban and urban areas</td>
<td>Rapidly urbanizing and sprawling</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td></td>
</tr>
<tr>
<td>Poverty</td>
<td>Urban growth</td>
</tr>
<tr>
<td>Financial constraints</td>
<td>Low management capacity</td>
</tr>
<tr>
<td>Poor management capacity</td>
<td></td>
</tr>
<tr>
<td><strong>GNI PPP per capita 2002</strong></td>
<td></td>
</tr>
<tr>
<td>Less than 2000</td>
<td>2000-15,000</td>
</tr>
<tr>
<td><strong>MSW generation per capita (kg/person/day)</strong></td>
<td></td>
</tr>
<tr>
<td>0.3-0.7</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td><strong>Waste characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>High bulk density</td>
<td>Evolving or changing characteristics (transition)</td>
</tr>
<tr>
<td>High organic content</td>
<td></td>
</tr>
<tr>
<td><strong>Waste management</strong></td>
<td></td>
</tr>
<tr>
<td>Priority to collection and transportation</td>
<td>Gradual improvement of final disposal</td>
</tr>
<tr>
<td><strong>MSW collection rate (%)</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;70</td>
<td>80-95</td>
</tr>
</tbody>
</table>
### Typical waste compositions

<table>
<thead>
<tr>
<th>Material</th>
<th>Less developed cities</th>
<th>Rapidly developing cities</th>
<th>Developed cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper (%)</td>
<td>3-10</td>
<td>10-25</td>
<td>20-50</td>
</tr>
<tr>
<td>Plastics (%)</td>
<td>2-8</td>
<td>8-14</td>
<td>9-22</td>
</tr>
<tr>
<td>Ash, fines, others (%)</td>
<td>2-62</td>
<td>6-18</td>
<td>3-10</td>
</tr>
<tr>
<td>Organics (%)</td>
<td>35-80(^b)</td>
<td>40-50</td>
<td>15-40</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>30-60</td>
<td>20-50</td>
<td>10-30</td>
</tr>
<tr>
<td>Bulk density or density (kg/m³)</td>
<td>300-550</td>
<td>200-350</td>
<td>150-300</td>
</tr>
</tbody>
</table>

\(^a\) Dry basis

\(^b\) The waste in Chinese cities has a low organic content due to the high ash content.

(Source: Mendes, MR and Imura, H 2004)

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### Composition of MSW

![Composition of MSW](image-url)

Source: Zurbrügg, 2002; UNEP 2001c
Composition of urban solid waste (%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Organic waste</th>
<th>Paper</th>
<th>Plastic</th>
<th>Glass</th>
<th>Metal</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>35.8</td>
<td>3.7</td>
<td>3.8</td>
<td>2.0</td>
<td>0.3</td>
<td>54.3</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>37.2</td>
<td>21.6</td>
<td>15.7</td>
<td>3.9</td>
<td>3.9</td>
<td>17.6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>70.2</td>
<td>10.9</td>
<td>8.7</td>
<td>1.7</td>
<td>1.8</td>
<td>6.2</td>
</tr>
<tr>
<td>Japan</td>
<td>17.0</td>
<td>40.0</td>
<td>20.0</td>
<td>10.0</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Laos</td>
<td>54.3</td>
<td>3.3</td>
<td>7.8</td>
<td>8.5</td>
<td>3.8</td>
<td>22.5</td>
</tr>
<tr>
<td>Malaysia</td>
<td>43.2</td>
<td>23.7</td>
<td>11.2</td>
<td>3.2</td>
<td>4.2</td>
<td>14.5</td>
</tr>
<tr>
<td>Myanmar (Burma)</td>
<td>80.0</td>
<td>4.0</td>
<td>2.0</td>
<td>0.0</td>
<td>0.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Philippines</td>
<td>41.6</td>
<td>19.5</td>
<td>13.8</td>
<td>2.5</td>
<td>4.8</td>
<td>17.9</td>
</tr>
<tr>
<td>Singapore</td>
<td>44.4</td>
<td>28.3</td>
<td>11.8</td>
<td>4.1</td>
<td>4.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>78.0</td>
<td>10.0</td>
<td>6.0</td>
<td>1.0</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>South Korea</td>
<td>31.0</td>
<td>27.0</td>
<td>6.0</td>
<td>5.0</td>
<td>7.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Thailand</td>
<td>48.6</td>
<td>14.6</td>
<td>13.9</td>
<td>5.1</td>
<td>3.6</td>
<td>14.2</td>
</tr>
</tbody>
</table>

(Source: Mendes & Imura 2004, Visvanathan & Glaue 2006)

Collection efficiencies

Source: UNEP 2003; Department of Energy (DoE) 2004; UNEP 2001a; AIT 2004; UNEP 2001b; WWF-Pakistan 2001
Desired material-cycle

(Source: Mendes and Imura 2004)

Two main approaches for waste management
(Mendes and Imura 2004)
Material recycling

Waste hierarchy

Integrated approach


Per annum, Visy Recycling collects and processes more than 900,000 tonnes of paper and cardboard, about 450,000 tonnes of glass, more than 20,000 tonnes of plastic and about 5,000 tonnes of metals in Australia.

http://www.research4development.info/caseStudies.asp?ArticleID=50162
Engineered landfill & Landfill gas (LFG)

Waste hierarchy & Integrated approach

- Waste minimization
- Reuse
- Material recycling and composting
- Energy recovery
- Incineration with or without energy recovery
- Landfill

Engineered landfill

- Engineered landfill: The Taylors Road Landfill (TRL, also known as the Lyndhurst Landfill) is located in Dandenong South, about 30 km south east of Melbourne, Victoria. It was the first fully engineered landfill in Australia!
- 1989: Company seeks permit for a sanitary facility at partially mined sand quarry at Taylors Road.
- 2009: Third monofill prescribed industrial waste (PIW) cell constructed. Community consultation begins on proposed soil processing facility.

Landfill gas recovery


Thermal treatments

Waste hierarchy

- Waste minimization
- Reuse
- Materials recycling and composting
- Energy recovery
- Incineration without energy recovery
- Landfill

Integrated approach

- Biological treatment
- Material recycling
- Collection
- Thermal treatment
- Landfill, gas use
- Mass burn
- Fuel burn


Lu Aye, 26 November 2009
Grate incinerator for domestic waste burning

Thermal treatment (mass burn)

Bolton
Location: Lancashire, UK
Operator: Greater Manchester Waste Ltd
Configuration: 1 x 10 MW
Operation: 2000
Fuel: refuse

The plant was converted from a mass-burn incinerator to a waste to energy (WTE) plant in 2000. The capacity of the plant is about 120,000 tons MSW/yr.

http://www.industcards.com/Bolton.jpg
Thermal treatment (gasification)

Gasification-Based Energy Production System Concepts

Thermal treatment (Plasma gasification)

http://www.drenergyservices.com/images/flowg_upkp.gif
Plasma gasification concern

Good for disposal of hazardous waste.

In 2004, the city of Honolulu, Hawai considered a plasma arc/torch proposal for processing municipal solid waste. The city's Department of Environmental Services evaluated the plasma process and found that using plasma arc/torch technology would significantly increase waste disposal costs without offering worthwhile environmental advantages.

http://www.honolulu.gov/refs/csd/publiccom/honnews04/plasmaarcrecommendations.htm

Thermal treatment, air gasification
(Heat application)

The downdraft gasifier designed by the National Engineering Research and Development (NERD) Centre in Sri Lanka.

Feedstock: rubber wood

Thermal treatment, air gasification
(Power application)

Control Room

Rice husk storage

Area for Gasification system

Waste water pond

Village power plant

Chatchawan Chaichana, ERDI, Chiang Mai University
Air gasifier, Da Goon Diang, Burma

Study and Demonstration of Biomass Gasification for Electricity Project, Dr. Chatchawan Chaichana, Energy Research and Development Institute, Chiang Mai University

Feed stock: Rice husk

Biological treatments

Waste hierarchy

Integrated approach
Biogasification

- Egg-shape anaerobic digesters at Woodman Point rated at 1.8 MW (right)
- A component of the biogas installation at Berrybank farm © Museum Victoria Australia 1999
Composting

A case study

Source: Lu Aye and Elita Rahmarestia Widjaya 2006
Introduction

• Interested in investigating traditional markets waste: (at that stage where ‘no treatment’, 2006)
• Highly organic compared with MSW
• More uniform waste composition
• less hazardous waste
• Institutionally, under formal management
• Would expect to have less burden in establishment of integrated waste management (IWM) if it is managed in a business scale
P. D. Pasar Jaya

• Local government company that manages traditional markets in Jakarta (151 markets)
• Wastes volume per day 1,200 m³.
• 80% (weight) are predicted to be organics (i.e. biodegradable).

Aim and Objectives

The aim is to compare options of waste management system from environmental, financial and economic aspects for traditional markets solid waste in Jakarta.

Objectives:
• To compare scenarios of waste management system from the global environmental point of view
• To estimate financial cost-benefit of each scenario
• To estimate economic cost-benefit of each scenario
Methodology

- Preliminary study: data gathering, field observations and finding related references
- Literature review of the viable technologies
- Conducting Life Cycle Assessment of possible scenarios using the computer simulation model developed
- Simple financial and economic analyses
Waste Collection

PD Pasar Jaya has a division, namely transportation, it transports wastes from 145 markets to municipality landfill, 5 markets managed individually their wastes. The waste fleet utilises 62 relatively old dump trucks

On average 120.5 trips/day
Table 1. Daily waste generation in PD Pasar Jaya 2003

<table>
<thead>
<tr>
<th>No</th>
<th>Area/Unit</th>
<th>Number of Markets within area</th>
<th>Waste Volume (m³/day)</th>
<th>Total volume</th>
<th>Putrescibles</th>
<th>Non-putrescibles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area 1 Tanah Abang</td>
<td>7</td>
<td>59.00</td>
<td>35.40</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Area 2 Senen Block III</td>
<td>12</td>
<td>78.00</td>
<td>46.80</td>
<td>31.2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Area 3 Pramuka</td>
<td>11</td>
<td>47.75</td>
<td>28.65</td>
<td>19.1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Area 4 Pal Merah</td>
<td>6</td>
<td>42.00</td>
<td>16.80</td>
<td>25.2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Area 5 Rawabadak</td>
<td>8</td>
<td>63.00</td>
<td>25.20</td>
<td>37.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Area 6 Koja</td>
<td>9</td>
<td>49.50</td>
<td>19.80</td>
<td>29.7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Area 7 Glibod</td>
<td>11</td>
<td>52.50</td>
<td>21.00</td>
<td>31.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Area 8 Cempakuning</td>
<td>8</td>
<td>36.50</td>
<td>12.30</td>
<td>24.2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Area 9 HWI</td>
<td>6</td>
<td>20.50</td>
<td>8.20</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Area 10 Jembatan Meraih</td>
<td>6</td>
<td>27.50</td>
<td>16.50</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Area 11 Tomang Barat</td>
<td>7</td>
<td>48.00</td>
<td>19.20</td>
<td>28.8</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Area 12 Cipulun</td>
<td>7</td>
<td>46.00</td>
<td>18.40</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Area 13 Mayestik</td>
<td>7</td>
<td>61.50</td>
<td>36.90</td>
<td>24.6</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Area 14 Pasar Minggu</td>
<td>6</td>
<td>49.00</td>
<td>29.40</td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Area 15 Tebet Timur</td>
<td>6</td>
<td>63.50</td>
<td>25.40</td>
<td>38.1</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Area 16 Kramat Jati</td>
<td>5</td>
<td>48.00</td>
<td>28.80</td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Area 17 Sunan Gir</td>
<td>8</td>
<td>50.50</td>
<td>20.20</td>
<td>30.3</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Area 18 Jatinegara</td>
<td>7</td>
<td>47.50</td>
<td>28.50</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Area 19 Parus Klanden</td>
<td>7</td>
<td>60.00</td>
<td>24.00</td>
<td>36.0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Area 20 Induk Kr Jati</td>
<td>1</td>
<td>250.00</td>
<td>159.00</td>
<td>91.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>145</td>
<td>145.00</td>
<td>91.45</td>
<td>53.55</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Composition of traditional market waste in Jakarta

<table>
<thead>
<tr>
<th>Component</th>
<th>% weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pasar Induk Gede Bage Badung</td>
</tr>
<tr>
<td>Putrescibles</td>
<td>86.86</td>
</tr>
<tr>
<td>Plastics</td>
<td>3.37</td>
</tr>
<tr>
<td>Paper &amp; cardboard</td>
<td>6.59</td>
</tr>
<tr>
<td>Wood</td>
<td>1.79</td>
</tr>
<tr>
<td>Glass and metal</td>
<td>1.08</td>
</tr>
<tr>
<td>Others</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Sources: (Saptari 2004; Maharani 1998; Indiany 2002; Shanti 2002)
Table 3. Estimation of the waste composition from PD Pasar Jaya

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage by weight (%)</th>
<th>Daily waste generation (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putrescibles</td>
<td>82.82</td>
<td>205 765.74</td>
</tr>
<tr>
<td>Paper and Cardboard</td>
<td>6.27</td>
<td>14 630.80</td>
</tr>
<tr>
<td>Plastics</td>
<td>5.89</td>
<td>15 574.27</td>
</tr>
<tr>
<td>Wood</td>
<td>3.40</td>
<td>8 453.33</td>
</tr>
<tr>
<td>Glass and metal</td>
<td>0.73</td>
<td>1 823.02</td>
</tr>
<tr>
<td>Others</td>
<td>0.89</td>
<td>2 204.56</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>248 451.75</td>
</tr>
</tbody>
</table>

Importance of source separation

- The strategy for establishing IWM system: Source separation (Mc Dougall et al. 2001) – for developing countries, the successful of source separation can much reduce the cost of waste handling. Treating the organic waste will significantly reduce the pollution and health problems by removing the source of leachate, combustibles gases, odours and disease carriers.
- At this moment: Lack of motivations, less campaigns & educational program (Widiastuti 2000, Yudoko 2001).
- The key strategy of IWM establishment: source separation programs should be introduced clearly in line with the next proposed wastes handling.
- The recycling by scavengers in bins collection has good contribution to recycling program.
Proposed Waste Management

As high organics fraction in nature some of the potential handling methods based on viable technologies at that moment (2005) are:

• Aerobic digestion (composting): has been practiced in Indonesia in labour intensive scales.
• Landfill for electricity generation: private sector has proposed to involve.
• Anaerobic digestion (bio gasification): not applied yet for MSW in Indonesia.

Technical review

Aerobic digestion: Windrow Composting

• Labour intensive plants: capacity 4 m³-24 m³ (Wahyono, Sahwan & Suryanto 2003).
• Centralised plant: could utilise 134 kW wheel loader (capacity 200 tonnes/day) for entire process of pilling & turning and transportation within the plant (Cointreau-Levine 1995)

Landfill for electricity generation: conventional and landfill as a bioreactor (with leachate recirculation)

Anaerobic digestion for MSW at a large capacity:

• High solid one stage digestion: Dranco, Valorga
• Low solid two stage digestion : BTA
Goal and Scope definition:
• Purpose: To compare the potential waste management systems (theoretical analysis)
• Functional unit: The management of 1 ton of traditional market waste in Jakarta
System boundaries:
• Cradle: waste in collection bins at traditional markets under PD Pasar jaya management
• Grave: when waste become inert landfill material or is converted to air and/or water emissions or any secondary saleable material
• Breadth: ‘second level’ effects such as building of capital equipment ignored. For energy factors, the pre combustions are included in the model

Waste transportation

- Bio-waste
- Putrescible, wood
- Waste treatment
- The rest
- Paper, Glass Plastic, Metal other
Waste treatment option

Aerobic digestion

- Bio waste Aerobic treatment
  - Soil amendment
  - Transported to upland for Hort. production
  - In-organic fertiliser
    - Consider limit
    - Soil amendment Application
      - 24 tons/ha. year

Waste treatment option

Anaerobic digestion

- biogas
  - Convert To electricity
  - Electricity to grid
    - In-organic fertiliser
    - Aerobic treatment

Effluent
Waste treatment option

Landfill gas (LFG) for electricity

```
LFG Capt.  
40%       
Engineered Landfill  
70%, eff 90%  
Leachate treatment  

Convert to electricity  

Electricity to grid  
```

Life cycle inventory data

Energy inventory
Diesel oil: using Indonesian diesel oil inventory data provided at Australian Data base (SIMAPRO 5.1) created by Tim Grant (RMIT centre of design)
Electricity grid: using Australian database fractioned based on fuel basis (Coal (Vic) 53%, Hydro 14%, gas cogen 29 %, gas 3.6%, oil in IC engine 0.4%)
Life cycle inventory data

Emissions from dumping (IWM 2 data base):
- emission to air: LFG emission 100% not captured
- emission to water: 1% Organic carbon emitted as COD within landfill.

Emissions from Aerobic treatment (IWM 2 data base)
Emissions from Anaerobic treatment: Emission of electricity production from biogas (SIMAPRO 5.1) and fraction of emission from aerobic treatment
Emissions from Landfill for electricity production: 60% LFG not captured but under cap, emission from electricity production from biogas and 70% leachate collected with 90% efficiency of COD and N removal

Avoided products

Electricity from existing grid (190 kWh/ton putrescibles waste treated anaerobically and 108 kWh/ton waste landfilled)

The fertiliser application for producing organic horticulture product at upland (40 km from treatment plant. Application organic fertiliser in horticulture land should not be exceed 24 tons/year.ha
**Table 4. Characterization using Eco indicator 95/Europe, version e**

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Life cycle aerobic (centralised)</th>
<th>Life cycle aerobic (lbr intensive)</th>
<th>Life cycle anaerobic</th>
<th>Life cycle landfilled energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>greenhouse</td>
<td>kg CO2</td>
<td>308</td>
<td>108</td>
<td>148</td>
<td>418</td>
</tr>
<tr>
<td>ozone layer</td>
<td>kg CFC11</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>acidification</td>
<td>kg SO2</td>
<td>-0.128</td>
<td>-0.129</td>
<td>-0.494</td>
<td>-0.304</td>
</tr>
<tr>
<td>eutrophication</td>
<td>kg PO4</td>
<td>-1.33</td>
<td>-1.32</td>
<td>-0.509</td>
<td>0.0177</td>
</tr>
<tr>
<td>heavy metals</td>
<td>kg Pb</td>
<td>-9.88E-04</td>
<td>-0.000988</td>
<td>-0.000449</td>
<td>-3.73E-05</td>
</tr>
<tr>
<td>carcinogens</td>
<td>kg BaP</td>
<td>-7.49E-09</td>
<td>-7.50E-08</td>
<td>-3.99E-06</td>
<td>-2.72E-06</td>
</tr>
<tr>
<td>winter smog</td>
<td>kg SPM</td>
<td>-0.0541</td>
<td>-0.0541</td>
<td>-0.516</td>
<td>-0.339</td>
</tr>
<tr>
<td>summer smog</td>
<td>kg C2H4</td>
<td>0.0248</td>
<td>0.0246</td>
<td>0.0368</td>
<td>0.276</td>
</tr>
<tr>
<td>pesticides</td>
<td>kg act.subst</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>energy resources</td>
<td>MJ LHV</td>
<td>-122</td>
<td>-122</td>
<td>-509</td>
<td>-315</td>
</tr>
<tr>
<td>solid waste</td>
<td>kg</td>
<td>58.9</td>
<td>58.9</td>
<td>58.9</td>
<td>240</td>
</tr>
</tbody>
</table>

**GHG Emissions**

**Greenhouse Effect (Kg CO2)**

- saving from elect prod
- methane not capt but under cap
- Biogas combst for elect.
- appic in hort land
- transport soil amend
- dumping w ood frac
- Dumping rest w aste frac
- w heel loader applic
- Aerobic digestion process
- Transport w aste
Major environmental impacts quantified

- Greenhouse gas emissions
- Acidification
- Eutrophication
- Photochemical oxidants

Sensitivity analysis

Table 5. Sensitivity analysis 10% and 30% putrescibles wastes are dumping in rest-waste

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>life cycle aerbc (cent) 10% sens</th>
<th>life cycle aerbc (cent) 30% sens</th>
<th>life cycle landfilled energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>greenhouse</td>
<td>kg CO2</td>
<td>361</td>
<td>468</td>
<td>418</td>
</tr>
<tr>
<td>ozone layer</td>
<td>kg CFC11</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>acidification</td>
<td>kg SO2</td>
<td>-0.114</td>
<td>-0.0859</td>
<td>-0.304</td>
</tr>
<tr>
<td>eutrophication</td>
<td>kg PO4</td>
<td>-1.19</td>
<td>-0.927</td>
<td>0.0177</td>
</tr>
<tr>
<td>heavy metals</td>
<td>kg Pb</td>
<td>-8.89E-04</td>
<td>-0.000691</td>
<td>-3.73E-05</td>
</tr>
<tr>
<td>carcinogens</td>
<td>kg B(a)P</td>
<td>-6.74E-08</td>
<td>-5.24E-08</td>
<td>-2.72E-06</td>
</tr>
<tr>
<td>winter smog</td>
<td>kg SPM</td>
<td>-0.0487</td>
<td>-0.0378</td>
<td>-0.339</td>
</tr>
<tr>
<td>summer smog</td>
<td>kg C2H4</td>
<td>0.0666</td>
<td>0.15</td>
<td>0.276</td>
</tr>
<tr>
<td>pesticides</td>
<td>kg act.subst</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>energy resources</td>
<td>MJ LHV</td>
<td>-110</td>
<td>-85.7</td>
<td>-315</td>
</tr>
<tr>
<td>solid waste</td>
<td>kg</td>
<td>58.9</td>
<td>58.9</td>
<td>240</td>
</tr>
</tbody>
</table>
Findings

- Options investigated
  - Composting in labour intensive local plant (CPL)
  - Composting in centralised plant (CPC)
  - Biogas production (BGP)
  - Engineered landfill for electricity generation (LFE)
- LFE has the highest environmental impacts among the options compared; LFE has significantly less impacts than open dumping
- BGP has the lowest environmental impacts except for acidification
- CPC has highest potential for success. It has the highest benefit to cost ratio and moderate environmental impacts.
- Supports from the market management and the local government would be the keys to the success.

Integrated Solid Waste Management
(Glawe et al. 2006)
References


Discussions

Short term desired objectives?
Long term desired objectives?
**SWOT analysis**

- **Strengths**: attributes of the option that are helpful to achieving the objective.
- **Weaknesses**: attributes of the option that are harmful to achieving the objective.
- **Opportunities**: external conditions that are helpful to achieving the objective.
- **Threats**: external conditions which could do damage to the objective.

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**Further information**

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The end.