The Opportunities and Challenges of Waste-Recycling for Semiconductor Plants

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Overview of Industrial Waste Management in Science Parks
Waste Management Flow and Treatment Overview

- Waste Prevention and Minimization
- Waste Collection
- Waste Diversion through Recycle and Reuse
- Composting of Waste Fractions
- Sanitary Landfilling
- Incineration and Other Thermal Processes
- Anaerobic Digestion of Waste Fractions
- Residual Landfill
Domestic Waste Overview of Taiwan

- In 2014, domestic waste was 26,250 kiloton in Taiwan, in which municipal waste was 28% and enterprise waste was 72%.

- The waste-recycling rate of municipal waste was 56%, enterprise waste was 81%, therefore the final disposed wastes are both around 3,000 kiloton.

Industrial Waste Overview of Taiwan

- According to the EPA, total enterprise waste weighed 18,880 kilotons in 2014, in which 88% was industrial waste.

- The highest industrial waste was slag from steel industry (28%), and the waste from electronics was 670 kilotons (3.5%).

Electronic Waste Overview of Science Parks

- In 2014, Science Parks generated 630 kilotons of industrial waste, which was 3.3% of total enterprise waste. Obviously 88% of them was originated from semiconductor and optoelectronics manufacturing.

- The waste-recycling rate of optoelectronics was about 80%, and semiconductor manufacturing was about 92% in recent years.
Typical Wastes from a Semiconductor Plant

• In Taiwan, semiconductor manufacturing generated **310 kilotons** wastes in 2014.

• The major wastes coming from semiconductor manufacturing are acid (43%), solvent (25%) and sludge (18%).

Data source: EPA, Industrial Waste Report and Management System
# Typical Waste from a Semiconductor Plant

<table>
<thead>
<tr>
<th>Category</th>
<th>Volume</th>
<th>Recycled Products</th>
<th>Sell/Pay Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄, H₃PO₄, HF</td>
<td>51%</td>
<td>Industrial H₂SO₄</td>
<td>6% Sell 94% Pay</td>
</tr>
<tr>
<td>Thinner, IPA, NMP</td>
<td>14%</td>
<td>Industrial Solvent</td>
<td>100% Sell</td>
</tr>
<tr>
<td>(NH₄)₂SO₄, TMAH</td>
<td>12%</td>
<td>(NH₄)₂SO₄, NH₄OH, /TMAH</td>
<td>21% Sell 79% Pay</td>
</tr>
<tr>
<td>CaF₂ Sludge</td>
<td>8%</td>
<td>Cement</td>
<td>Pay</td>
</tr>
<tr>
<td>SiO₂ Sludge</td>
<td>5%</td>
<td>Cement</td>
<td>Pay</td>
</tr>
<tr>
<td>CuSO₄</td>
<td>4%</td>
<td>Cu/CuSO₄</td>
<td>Sell/Pay</td>
</tr>
<tr>
<td>Waste Plastic Mixtures</td>
<td>2%</td>
<td>Plastic Barrel</td>
<td>Sell</td>
</tr>
<tr>
<td>Active Carbon, Non-Toxic Waste Chemical, Waste Wiper…etc.</td>
<td>4%</td>
<td>Incineration or Landfill</td>
<td>Pay</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
<td><strong>Recycling Rate</strong></td>
<td><strong>~20% Sell</strong> 95% <strong>Pay</strong></td>
</tr>
</tbody>
</table>
Waste Treatment Industry of Taiwan

**Strength**
- Supported by governmental policy with complete and compulsory regulations.
- Government monitor treatment facility and loading ratio, therefore, to prevent insufficient treatment capacity.
- Wastes sources are stable and sufficient.

**Weakness**
- It is difficult to trace the reuse status for recycled products.
- The authorities are dispersed in 10 different administrations such as MOEA and so on.
- The penalty of Waste Clearance Regulation is relatively loose than other environmental regulations.

**Opportunities**
- Due to the raise of environmental awareness in Taiwan. The enterprises are more willing to invest and develop technologies for waste treatment and recycling.
- To improve waste value through a refined classification and pretreatment at the sources.
- To improve industry’s premium and credibility of environmental protection.

**Threats**
- Society distrust waste-treatment industry. The recycled products has not yet been accepted by consumers, the market is still restricted.
- The waste treatment process involves several companies in loop and increases possibility of abuses.
- It is difficult to build a new treatment plant. Once the plants are full loaded, wastes can no longer be treated.
Status of the Polluted Sites under EPA’s Observation

- According to the EPA, there **19 illegal dumping sites** are polluted and controlled for recovery. The major illegal wastes include sludge, slags and **waste liquid**.

- Based on pollution area, **76%** of the affected area is polluted by **heavy metal** (mercury, nickel, cadmium, chromium, copper, zinc, lead) and the other **24%** is **organic solvent** (benzene, phenol).

Data source: EPA, Environment Resource Database
Establish Waste-Recycling Value Chain in Semiconductor Plants
Waste Management Hierarchy

Waste Economics

- Recycling is processing **used materials** into **new, useful products**. This is done to reduce the consumption of raw materials that would have been used.

- Recycling also uses **less energy** and great method of **controlling air, water and soil pollution**.

**Buy Recycled**
Waste Management Process

• Start from... identifying and quantifying your waste. Organize a waste management team to drive things forward.

• Generate an waste reducing action plan. Get commitment from senior management for the action plan.

• Identify the possible disposal options if the waste is unrecyclable. Select your waste carriers carefully and make sure that your Duty of Care responsibilities are met.

• Monitor and review your achievements. Communicate your success to interested stakeholders outside your organization.
Recycling – Transform the Value of Waste from Negative to Positive

• After a proper converting process, to raise the quality and price value of recycled waste and to compete with new product.

• In Taiwan, Nearly 60% of industries depend on recycling industry to provide partial raw materials to balance cost with imported materials. The annual production of recycling industry is growing doubly in the last decade and reached NT$ 67.8 billion in 2015.

• The steel slags, furnace dust, solvent and metal contribute the most to the production amount.

Data source: IDB, Industrial Waste Clearance, Treatment and Recycling information net
Innovation on Waste Recovery

• Since the waste generated by each company is unique, therefore it is necessary to have professional teams for recycling. Brainstorm to generate ideas and creative methods of waste recovering. Only a long-term commitment can increase profits through reducing waste.

• Generally speaking, the first priority of waste-recycling tasks is to analyze the ingredients of the wastes, to investigate a proper classification method for simplifying the complexity of the waste and to manage the waste according to the recycling structure.

• One of the best strategies is to treat the waste with waste, to transform it into a useful or valuable material.
Waste Sulfuric Acid Recycling – Electronic Grade

Information source: AUECC (a Linde/LienHua Company)
Waste Sulfuric Acid and Ammonia Nitrogen Recycling – Industrial Grade

Information source: TSMC
On-Site Chemical Recycling Facility – TMAH

Information source: TSMC
On-Site Electroplating Facility – Copper Sulfate

Information source: TSMC
Artificial Fluorite Sintering Facility – Calcium Fluoride

Information source: CHC Resources (a China Steel Company)
## Sustainable Waste-Recycling Index – Sales Rate

<table>
<thead>
<tr>
<th>Category</th>
<th>Volume</th>
<th>Recycled Product (Present)</th>
<th>Sell/Pay Status</th>
<th>Recycled Product (Future)</th>
<th>Sell/Pay (Future)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄, H₃PO₄, HF</td>
<td>51%</td>
<td>Industrial H₂SO₄</td>
<td>6% Sell, 94% Pay</td>
<td>EL grade H₂SO₄, Na₃PO₄/CaF₂</td>
<td>100% Sell</td>
</tr>
<tr>
<td>Thinner, IPA, NMP</td>
<td>14%</td>
<td>Industrial Solvent</td>
<td>100% Sell</td>
<td>Industrial Solvent</td>
<td>100% Sell</td>
</tr>
<tr>
<td>(NH₄)₂SO₄, TMAH</td>
<td>12%</td>
<td>(NH₄)₂SO₄/TMAH</td>
<td>21% Sell, 79% Pay</td>
<td>(NH₄)₂SO₄, NH₄OH, /TMAH</td>
<td>87.5% Sell, 12.5% Pay</td>
</tr>
<tr>
<td>CaF₂ Sludge</td>
<td>8%</td>
<td>Cement</td>
<td>Pay</td>
<td>Fluorite (85% CaF₂)</td>
<td>100% Sell</td>
</tr>
<tr>
<td>SiO₂ Sludge</td>
<td>5%</td>
<td>Cement</td>
<td>Pay</td>
<td>Cement</td>
<td>Pay</td>
</tr>
<tr>
<td>CuSO₄</td>
<td>4%</td>
<td>Cu CuSO₄</td>
<td>Sell/Pay</td>
<td>Copper</td>
<td>Sell</td>
</tr>
<tr>
<td>Waste Plastic Mixtures</td>
<td>2%</td>
<td>Plastic Barrel</td>
<td>Sell</td>
<td>Plastic Pellets</td>
<td>Sell</td>
</tr>
<tr>
<td>Active Carbon, Non-Toxic Waste Chemical, Waste Wiper…etc.</td>
<td>4%</td>
<td>Incineration or Landfill</td>
<td>Pay</td>
<td>Incineration or Landfill</td>
<td>Pay</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
<td><strong>Recycling Rate 95%</strong></td>
<td>~20% Sell, ~80% Pay</td>
<td><strong>85% Sell, 15% Pay</strong></td>
<td></td>
</tr>
</tbody>
</table>
Opportunities and Challenges to Connect the Future
Be a Reputable, Licensed, Specialist Company

• A **professional, responsible and sustainable** waste treatment industry is essential to success of waste treatment.

• In terms of reliability and credibility, the **state-owned treatment organizations** are currently much better than private ones, the differences of their performance are probably due to their different **business and financial models**.

• The waste treatment industry should establish **a transparent management mechanism and information platform**, such as
  – an open and public logistic information and trading process.
  – audit or verification guidelines ensure the sustainable industry.
Governance on Waste Management

• If the government is not capable to conduct the waste treatment enterprises, they should consider to transform the industry into state-owned enterprises (monopolistic sale) in order to protect the environment.

• **Profits Guarantee**: Set a minimum treatment price to avoid price competition. It can assure that the treatment plants gain fair profits, therefore they should be responsible of the legality.

• **Responsibility Guarantee**: Evaluate the performance of each treatment plant periodically. There should be a disqualification mechanism to assure the quality of treatment plants.

• **Administrative Assistance**: Amend the regulations to authorize enterprises selling their recycled wastes (B2B), so that the enterprises may dedicate to waste-recycling business.
Optimize Waste Management Program

• The first strategy of waste management is reduction, as well as prevention. The second is reuse, the last is recycling. Therefore reducing the usage from the source is the core value of the waste management.

• Bring waste treatment program to senior management level, which means to optimize the program through top-down management, is the opportunity to eliminate waste from the source i.e. reduction or prevention stage.

• Recycling and reuse can be as effective as possible only if the traditional logistic management is transformed. Facility should be requested to take more responsibility of waste reduction program and to dedicate into the new technology development.

• Encourage the suppliers to commit to waste-recycling, help the development of waste-recycling supply chain.
Recycle Your Business Waste by Yourself

• The more refined categories of wastes, the easier of recycling process and higher of recycling rate. One of the most important strategies of waste recycling is to recycle one’s own waste, so that the complexity and the process of waste recycling can be simplified.

• Designing an on-site recycling can reduce the risk of outbound transportation. When the outbound transportation is eliminated, not only the transportation can be relieved, but also the risk of illegal dumping waste can be avoided.
Summary
The Opportunities and Challenges of Waste-Recycling for Semiconductor Plants

• Treat the waste locally and avoid long distance transportation. It is suggested that the government include the treatment plants into industrial park or regional management system.

• Integrate the waste treatment plants to achieve better economic and technical scopes, so that the profits can be ensured and legal operation can be achieved.

• The waste treatment industry should assure profitability and prohibit the price competition. The logistic operation should be transparent, be watched by the society.

• High-tech industry can help to establish structured industrial chains of waste recycling and final disposal. It is suggested that the government assist and use this industrial chain to improve the waste recycling performance of general industrial area.
The Opportunities and Challenges of Waste-Recycling for Semiconductor Plants

• Same as green manufacturing and quality improvement program, each corporation should monitor the waste reduction outcome of their supply chains and encourage them to develop the waste recycling techniques and business innovation.

• Facility organizations should invest their resources, take the responsibility to solve the waste issues and to reduce operating cost through waste-recycling.

• Waste recycled as raw-materials (cradle to cradle) is happening now, it deserves effort for the enterprises to evaluate and to consider their commitments to the waste recycling.
Thank You