Phosphorous Recycling as Green Industry

Shimonoseki Mitsui Chemicals, Inc.

Onoda Chemicals, Inc.
Phosphorus is an essential constituent for all living organisms. NO LIFE CAN EXIST WITHOUT PHOSPHORUS
Phosphorus is used in a wide variety of manufacturing industries.
Without phosphorus, there will be no biomass, no biofuel, no agriculture, nor life.
Today, phosphorus is mostly obtained from mined rock phosphate which is a non-renewable resource.

From Prof. D. A. Vaccari
Although the demand of phosphorus fertilizer is predicted to increase more than 50% by 2050, the global peak in phosphorus production is expected around 2040.

Rock phosphate is a nonrenewable resource.

No alternative to phosphorus is available for agriculture and biomass production.

The price of P fertilizer must be kept low to make foods as inexpensive as possible.
Total inflow of phosphorus to Japan is approximately 750 kt/Y. The import of rock phosphate accounts for 15%.

P Recycling for Industry

Food Industry

Vegetable oil refinery process

Sewage

Water reclamation

Eutrophication control

Wastewater treatment

Consume

P Recovered

Fertilizer Industry

P fertilizer

Food and Feed

Agriculture

Farmland

Ash

Manure

Recycle Industry

Cement Industry

The P content of clinker needs to be lower than 0.5%.

Yellow Phosphorus manufacturing

Iron ore Coke

Steel Industry

Steel-making slag

P-free slag

P-free slag can be returned to a steel manufacturing process.

P Recycling for Industry

Phosphoric acid manufacturing

High-quality phosphate

Chemical Industry

P recover through yellow phosphorus regeneration

Automobile

Semiconduct or Liquid crystal

High-tech Industry

Agriculture

Food

Manure

Phosphate production by a wet process

P fertilizer

Water reclamation

Eutrophication control

Vegetable oil refinery process

Sewage

Wastewater treatment

Food Industry

Wood Industry

Streel-making Industry

P-free slag

Steel-making slag

P-free slag can be returned to a steel manufacturing process.
Microcystis aeruginosa
cyanobacterium

Eutrophication

INCENTIVE TO EUTROPHICATION CONTROL
Genetic Engineering of Polyp Accumulation

Phosphate-specific Transport

Phosphate Inorganic Transport

Polyphosphate kinase

PST

PIT

PPK

PPX

Polyphosphate

Inducible under $P_i$ limitation

Enhanced biological phosphorus removal primarily relies on the ability of sludge microorganisms to accumulate polyphosphate.
A range of issues impede further advancement in P recovery from sewage sludge, relevant to the quality control, capital and operating costs, and the immature market for recovered P.
Phosphate can be released from polyphosphate-accumulating sludge by anaerobic sludge digestion.
Struvite often causes difficult incrustation problems in pipelines. The hard crystalline incrustations have to be removed by means of mechanical cleaning techniques.
QUALITY, COST, AND MARKET BARRIERS

Recovered phosphorus

From Mr. K. Goto, Gifu City Office
Calcium Silicate Hydrate (CSH)

Before use

After P adsorption

N and P content after P adsorption

<table>
<thead>
<tr>
<th></th>
<th>Ca/P = 2</th>
<th>Ca/P = 1.5</th>
<th>Ca/P = 1</th>
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<tbody>
<tr>
<td>N</td>
<td>0.13</td>
<td>0.12</td>
<td>0.19</td>
</tr>
<tr>
<td>P$_2$O$_5$</td>
<td>15.6</td>
<td>18.3</td>
<td>22.0</td>
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Phosphate can be recovered from the sludge digestion liquor using calcium silicate hydrate as an inexpensive adsorbent.
Business Models for P Recycling

1. **Agriculture**
   - Yellow P manufacturing
   - Chemical Industry
   - Water reclamation

2. **Food and Feed**
   - Phosphoric acid manufacturing
   - Farmland Ash

3. **Recycle Industry**
   - Cement Industry
   - Water reclamation

4. **Steel-making Industry**
   - P-free slag
   - Steel-making slag
   - P fertilizer

5. **Iron ore Coke**
   - P-free slag can be returned to a steel manufacturing process.

6. **Vegetable oil refinery process**

7. **Wastewater treatment**
   - Biosludge
   - P-free ash

8. **Sewage**
   - Eutrophication control

9. **High-tech Industry**
   - Automobile
   - Semiconductors
   - Liquid crystal

10. **Business Model 1**
    - Yellow P manufacturing
    - Phosphoric acid manufacturing
    - Phosphate production by a wet process

11. **Business Model 2**
    - Fertilizer Industry
    - P fertilizer

12. **Business Model 3**
    - Consume
    - Food

13. **Vegetable oil refinery process**

14. **P Recycling for Industry**

15. **Chemical Industry**
    - P free slag

16. **Chemical Industry**
    - P free slag

17. **P-free slag can be returned to a steel manufacturing process.**

18. **P recycle through yellow phosphorus regeneration**

19. **P recovered**
BEYOND GAPS BETWEEN SECTORS

- Hotels
- Superstores
- Food manufacturers

Waste water treatment plants (WWTP)

- P recovery (Heatphos)

Night soil treatment plant

- P recovery (Heatphos)

P recycling center

- Biogas
- Electricity
- Heat energy

Industrial Wastes

Recovered P

Sales

Fertilizer Industry

The Phosphorus Recycling Promotion Council of Japan

The model area in P recycling:

- Industry
- Academia
- Government

The Phosphorus Recycling Promotion Council of Japan

Ministry of Land, Infrastructure, Transport and Tourism

Ministry of Agriculture, Forestry and Fisheries

Ministry of Economy, Trade and Industry

Ministry of the Environment

Heatphos

Recovered P

Industrial Wastes
Phosphate rock

Yellow phosphate

P recycle technology

P depletion is a common challenge in Asia. The P recycling technology of Japan can make a great contribution to the crisis prevention.

INTERNATIONAL COLLABORATION

Efficiency of P use
P recycling
Technology improvement

Transfer of P recycle technology

China
Vietnam
Others

Japan

Stable supply of P from Asia
P fertilizer
Food and Feed
Industrial P

International cooperation for P recycling in Asia