Air Pollution Control Technology
In
Fertilizer Manufacturing Industry

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Overseas Environmental Cooperation Center, Japan
Air Pollution Control Technology in Fertilizer Manufacturing Industry

Committee Members

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Urea Plant in Bangladesh
# 1. Air Pollution in Fertilizer Plant

## Fertilizer

<table>
<thead>
<tr>
<th>Nitrogenous F.</th>
<th>Phosphate F.</th>
<th>Potassium F.</th>
<th>Coated F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonia, Chilean saltpeter, limestone + N₂</td>
<td>phosphate rock</td>
<td>ore (ingredient ; KCl + NaCl), KCl</td>
<td>N, P, K + <strong>thermo plasticity resin</strong></td>
</tr>
</tbody>
</table>

## Pollutants

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Origins of Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soot, SOx, NOx</td>
<td>Boiler, Dryer, Calcining furnace, etc.</td>
</tr>
<tr>
<td>Dust</td>
<td>Raw material stock yard, Raw material feed equipment, Belt conveyer, Bucket conveyer, Crusher, Mill, Sieve</td>
</tr>
<tr>
<td>HF</td>
<td>Phosphate fertilizer plant------ Reactor, Calcining furnace, Melting furnace, Phosphoric acid concentration plant</td>
</tr>
<tr>
<td>NH₃</td>
<td>Pelletizer, Dryer</td>
</tr>
<tr>
<td>Solvent</td>
<td>Coated fertilizer manufacturing process</td>
</tr>
</tbody>
</table>
2. Soot & Dust Collection
2-1 Gravitational, Inertial & Centrifugal Dust Collector

**Stokes’ Law**

\[
V = \left( \frac{g}{18 \eta} \right) \left( \frac{\rho_1 - \rho}{\rho_2} \right) D^2 \quad \text{(cm/s)}
\]

- \( V \): settling velocity (cm/sec)
- \( \eta \): gas viscosity (kg/ms)
- \( g \): gravitational acceleration (cm/s^2)
- \( \rho_1 \): particle density (g/cm^3)
- \( \rho_2 \): gas density (g/cm^3)
- \( D \): particle diameter (cm)

**Principle of dust collection:**

Centrifugal force \( F = \frac{mv^2}{R} \), (N)

- \( m \): particle mass (kg)
- \( V \): particle velocity (m/s)
- \( R \): cyclone radius (m)

Gravity

Centrifugal

Inertia
2. Soot & Dust Collection

2-2 Scrubbing Dust Collector

**Mechanisms of Separation**
- Adhesion of dust to water drops & water film by inertia force
- Adhesion by diffusion force among dusts
- Increase of coagulation force of particles by increasing moisture
- Moisture condensation triggered by dust as a nucleus
- Particle adhesion by bubbles

**Typical Types of Scrubbers**

<table>
<thead>
<tr>
<th>Type</th>
<th>Velocity m / s</th>
<th>L/G l / m³</th>
<th>□ P kPa</th>
<th>Th. ★ m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray</td>
<td>1~2</td>
<td>2~3</td>
<td>0.1~0.5</td>
<td>★ 3</td>
</tr>
<tr>
<td>Packed</td>
<td>0.5~1</td>
<td>2~3</td>
<td>1~2.5</td>
<td>★ 1</td>
</tr>
<tr>
<td>Jet</td>
<td>10~20</td>
<td>10~50</td>
<td>0~ -1.5</td>
<td>★ 0.2</td>
</tr>
<tr>
<td>Venturi</td>
<td>60~90</td>
<td>0.3~1.5</td>
<td>3~8</td>
<td>★ 0.1</td>
</tr>
</tbody>
</table>

Th. ★: Particle size of threshold to allowing 50 % removal

*Packed tower*
2. Soot & Dust Collection

2-3 Filter Type Dust Collector

Filtration Action in Filter Cloth

Flue gas → Clean gas
0.5~3 cm / s
dust
primary layer

Filter cloth

Dusting frequency
- intermittent
- continuous

Dusting drive
- vibration
- reverse air

Dusting frequency: 150 mg Hg dusting

Clean gas

Bag filter

Fan

Flue gas
2. Soot & Dust Collection
2-4 Electrostatic Precipitator

Principle of dust collection:

Structure of EP:
- discharge electrode
- high voltage DC generator
- manhole
- hammering drive
- gas distribution plate
- hammering device
- collecting electrode
- hopper
2. Soot & Dust Collection

2-5 Selection of Dust Collector

**Factors affecting Dust Collection:**
dust concentration, particle size distribution, temperature of dust, apparent electric resistance rate, due point, gas temperature, composition of flue gas, gas volume, etc.

**Applicable Range of Dust Collector**

<table>
<thead>
<tr>
<th>Type</th>
<th>Particle ($)</th>
<th>Working ($)</th>
<th>Cutback Level (%)</th>
<th>Pressure Drop (mm H₂O)</th>
<th>Equipment Cost</th>
<th>Running Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity</td>
<td>1000~50 d.p. ~ 400</td>
<td>40~60</td>
<td>10~15</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Inertia</td>
<td>100~10 d.p. ~ 400</td>
<td>50~70</td>
<td>30~70</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Centrifuge</td>
<td>100~3 d.p. ~ 400</td>
<td>85~95</td>
<td>50~150</td>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>Scrubbing</td>
<td>100~0.1 no-limit</td>
<td>80~95</td>
<td>300~800</td>
<td>M</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Filtration</td>
<td>20~0.1 no-limit</td>
<td>90~99</td>
<td>100~200</td>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>20~0.05 d.p. ~ 400</td>
<td>90~99.9</td>
<td>10~20</td>
<td>L</td>
<td>S~M</td>
<td></td>
</tr>
</tbody>
</table>

L: expensive  M: average  S: cheap
3. SOx Reduction Technology

**Sources of SOx: Fuel SOx**
- Boiler
- Dryer
- Calcining furnace
- Melting furnace

**Wet Type Absorption**

\[
\begin{align*}
\text{Mg(HSO}_3\text{)}_2 + \text{Mg(OH)}_2 & \rightleftharpoons 2\text{MgSO}_3 + 2\text{H}_2\text{O} \\
\text{H}_2\text{SO}_3 + \text{Mg(OH)}_2 & \rightleftharpoons \text{MgSO}_3 + 2\text{H}_2\text{O} \\
\text{MgSO}_3 + \frac{1}{2}\text{O}_2 & \rightleftharpoons \text{MgSO}_4
\end{align*}
\]

\[
\begin{align*}
\text{SO}_2 + \text{H}_2\text{O} & \rightleftharpoons \text{H}_2\text{SO}_3 \\
\text{H}_2\text{SO}_3 + \text{Mg(OH)}_2 & \rightleftharpoons \text{MgSO}_3 + 2\text{H}_2\text{O} \\
\text{MgSO}_3 + \text{H}_2\text{SO}_3 & \rightleftharpoons \text{Mg(HSO}_3\text{)}_2 \\
\text{Mg(HSO}_3\text{)}_2 + 12\text{O}_2 & \rightleftharpoons \text{MgSO}_4 + \text{H}_2\text{SO}_3 \\
\text{MgSO}_3 + \frac{1}{2}\text{O}_2 & \rightleftharpoons \text{MgSO}_4
\end{align*}
\]
4. NOx Reduction Technology

4-1 NOx Generation in Fertilizer Plant

Air ratio ~ Retention time ~ Thermal NOx

**NOx concentration increases at:**
- higher temp. in combustion
- higher $O_2$ conc.
- longer retention in high temp. zone
## 4. NOx Reduction Technology

### 4-2 NOx Control Methods

<table>
<thead>
<tr>
<th>NOx Reduction Methods</th>
<th>Decreasing effect</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Improving operating condition</strong></td>
<td>Thermal NOx</td>
<td>Fuel NOx</td>
</tr>
<tr>
<td>Lower air ratio combustion</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Lower heat load</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Decreasing pre-heat air temp.</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td><strong>Improving equipment configuration</strong></td>
<td>Thermal NOx</td>
<td>Fuel NOx</td>
</tr>
<tr>
<td>2-stege combustion</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Rich-lean burner</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Exhaust gas recirculation</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Steam or water injection</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Low NOx burner</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>mixing accelerate type</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>flame-divided type</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>self-circulate type</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>stepwise combustion type</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Emulsion combustion</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
5. Dust Scattering Prevention

**Dust generating equipment & location designated by air pollution control law**
- belt conveyer
- bucket conveyer
- crusher, mill
- sieve
- ore stock yard

**Equipment protected work shop environment from dust scattering**
- silo, hopper for raw material & product
- transporting equipment except belt & bucket conveyer
- packing machine, etc.

**Measures**
- outdoor stock with sheet cover (phosphate rock)
- indoor allocation
- closed cover, negative pressure
- Sealed dust collecting cover
- dust collecting hood

- cyclone
- bag filter
6. NH₃ Removal Technology

1. **Permissible NH₃ emission:**
   1~ 5 ppm at boundary of premise (set forth by prefecture governors)

\[
Q = 0.108 \times H_e^2 \times C_m
\]

- **Q**: gas volume (Nm³ / h)
- **He**: effective height of exhausting outlet (m)
- **C_m**: concentration at boundary line of premise (ppm)

2. **In compound fertilizer plant:**

<table>
<thead>
<tr>
<th>Process</th>
<th>Origin</th>
<th>Abatement</th>
</tr>
</thead>
<tbody>
<tr>
<td>pelletizer &amp; drying</td>
<td>(NH₄)₂SO₄</td>
<td>reservoir type wet scrubber</td>
</tr>
<tr>
<td></td>
<td>(NH₄)₃PO₄</td>
<td>pressurized water scrubber</td>
</tr>
<tr>
<td></td>
<td>CO(NH₂)₂</td>
<td>packed bed water scrubber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(NH₄ removal 70<del>90%, 20</del>50ppm)</td>
</tr>
</tbody>
</table>

3. **In urea plant**

- Fan
- Demister
- Rectification plate
- Guide vane
- Pelletizing tower
- NH₃ ≤ several 10 ppm

Water
7. F Removal Technology

Generation of F

- reaction & condensation process for H₃PO₄ production
- reaction process for Ca(H₂PO₄)₂ production
- reaction furnace for fused P and calcined P production

HF, SiF₄
(with greater hydrophile property)

1st Absorption tower
2nd Absorption tower

water
exhaust gas
NaOH (2 %)
to wastewater treatment
## 8. Odors Abatement technology

### 8-1 Abatement Processes

<table>
<thead>
<tr>
<th>Deodorizing Method</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incineration method</strong></td>
<td>decompose to $CO_2$, $H_2O$ by heat</td>
</tr>
<tr>
<td>direct incineration</td>
<td>at $\approx 800^\circ$</td>
</tr>
<tr>
<td>regenerative thermal oxidizer</td>
<td>regeneration, heat efficiency $&gt; 80%$</td>
</tr>
<tr>
<td>catalytic incineration</td>
<td>using catalysis at $200\sim 350^\circ$, rem. $&gt; 99%$</td>
</tr>
<tr>
<td><strong>Scrubbing method</strong></td>
<td>scrubbing by chemical solution</td>
</tr>
<tr>
<td>water, acid, alkaline, oxidant, etc.</td>
<td></td>
</tr>
<tr>
<td><strong>Adsorption method</strong></td>
<td>activated carbon, steam regeneration</td>
</tr>
<tr>
<td>recovery type</td>
<td>activated c., heat regeneration by $N_2$ gas</td>
</tr>
<tr>
<td>fixed bed</td>
<td>separating odor from low concentration gas</td>
</tr>
<tr>
<td>fluidized bed</td>
<td>replacing saturated adsorbent or oxidant</td>
</tr>
<tr>
<td>concentration type</td>
<td></td>
</tr>
<tr>
<td>honeycomb</td>
<td></td>
</tr>
<tr>
<td>replacement type</td>
<td></td>
</tr>
<tr>
<td><strong>Biological method</strong></td>
<td>biodegradation by microorganisms</td>
</tr>
<tr>
<td>soil bed</td>
<td>using soil bacteria</td>
</tr>
<tr>
<td>packed tower</td>
<td>using bio-film on the media</td>
</tr>
<tr>
<td><strong>Deodorizer, masking agent</strong></td>
<td>deodorize or easing offending gas</td>
</tr>
</tbody>
</table>
## 8. Odors Abatement technology

### 8-2 Troubles in Abatement Processes (examples)

<table>
<thead>
<tr>
<th>Deodorizing Method</th>
<th>Trigger</th>
<th>Trouble</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combustion method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>direct incineration</td>
<td>NOx ✓</td>
<td>permission level ✓</td>
</tr>
<tr>
<td>regenerative thermal ox.</td>
<td>mixture of Cl₂, paint, etc.</td>
<td>HCl ✓, clogging</td>
</tr>
<tr>
<td>catalytic incineration</td>
<td>mixture of Cl₂, paint, S, etc.</td>
<td>catalyst deterioration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adsorption method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recovery type</td>
<td>mixture of ketone, high B.P.</td>
<td>firing, deterioration of activated carbon</td>
</tr>
<tr>
<td>fixed bed</td>
<td>substance</td>
<td>A.C. deterioration</td>
</tr>
<tr>
<td>fluidized bed</td>
<td>high temp. of exhaust gas</td>
<td></td>
</tr>
<tr>
<td>concentration type</td>
<td>mixture of cyclohexane</td>
<td>firing</td>
</tr>
<tr>
<td>honeycomb</td>
<td>conc. &gt; several ppm</td>
<td>short term A.C. replacement</td>
</tr>
<tr>
<td>replacement type</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biological method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>soil bed</td>
<td>drying of soil</td>
<td>malfunction</td>
</tr>
<tr>
<td>packed tower</td>
<td>slow acclimatization</td>
<td>slow starter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scrubbing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>less sprinkling water</td>
<td>malfunction</td>
</tr>
<tr>
<td></td>
<td>dust in gas</td>
<td>clogging internals</td>
</tr>
</tbody>
</table>
9. Solvent Recovery & Abatement technology

1. **Sources of Generation**
   coated fertilizer (thermoplasticity resin)

2. **Abatement**
   recovery of solvent brings profit  → production cost reduction
   residual solvent value  → recovery cost  → pollution control

3. **Abatement Process**
   - cooling condensation method
     cool down flue gas below vapor pressure
   
   - absorption & dispersion method
     absorbing of solvent to absorbent with lower vapor pressure
   
   - adsorption & dispersion method
     applicable to compositions with low vapor pressure and non-
     existence of antagonist. Adsorbed at under pressure or lower temp..
     adsorber: fixed bed, moving bed, fluidized bed
     adsorbent: A.C., silica gel, molecular sieve, aluminum gel
     regeneration method: heated gas, steam, heat transfer,
     extraction under decompression
10. Environmental Management System

1. Environmental Management System
   - Organization for Environmental Control
   - ISO 14000 series—— PDCA cycle
   - Responsible for environmental protection

2. Environmental Control Manual
   - Operation Standard Manual

3. Education & Training
   - legally qualified expert of environment control
   - training program and preparation of manual

4. Environmental Control at Work Shop

5. Environment Monitoring
   - maintaining monitoring system
   - monitoring of air pollution state
   - legal emission permissible level