Odor Pollution Control for Various Odor Emission Sources in Japan

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Abstract
Since the Law of Offensive Odor Control was enacted, many enterprises have made efforts to prevent odor nuisance. Odor survey was conducted at each factory and characteristics of odor emission for each kind of business were made clear. And many researches and developments have been carried out to confirm reliable technique. In order to remove odorants from exhaust gas, deodorizing plants have been installed at various emission sources gradually. Much information for odor control could have been stored up for these 30 years. In this paper, an outline of odor pollution control at various emission sources in Japan is introduced, that is, a number of newly installed deodorization facility, characteristics of odor emission from each type of business, efficiency of deodorizing equipment, recent trend of the development.

1. Introduction
In Japan, there are many different industries and business, which have mostly odor emission process. Residents around these factories complain for odor nuisance whenever odor leaks to the outside because of the inadequate operation. These composition and concentration of emission odor are different in each type of business. Mechanism of odor generation can be roughly divided into two groups; one is caused by raw material that is malodorous and another is caused from the manufacturing process (heating, drying, fermentation and burning) in which odorous compounds are produced. For countermeasure of odor pollution, storing method and processing condition should be improved before making the planning of deodorization. It is also important to gather odorous gas from emission sources and deodorize effectively. In order to select on adequate technique of deodorization, odor characteristics of target gas should be investigated. Main containing odorant, exhaust gas volume, gas temperature, time and frequency of odor emission and etc. have to be made clear by odor survey. Fig.1 shows concept illustration for adequate odor pollution control.

Good Idea?
Ex) Reexamination of operating process, using materials

Effective Odor Collection
Ex) duct work, suction gas volume

Planning and Selection of Deodorizing Equipment
Ex) survey of odor emission, cost, space, location, law

Maintenance & Inspection
Ex) daily check, periodical inspection, odor measurement

Fig. 1 Concept Illustration for Odor Pollution Control
In Japan, the Offensive Odor Control Law was enacted in 1972. Therefore, many kinds of surveys for odor emission and experiments of deodorization were carried out. As the results of these efforts, characteristics of odor emission at each source could be made clear and the adequate deodorizing methods for each emission sources have been developed. Current research and development are focused to high-rate deodorizing capacity and inexpensive equipment. And, the simpler and cheaper deodorizing equipments for a small scale factory and restaurant have been developed. In this paper, the outline of actual conditions of odor control in Japan is introduced with quotation of the related references.

2. Characteristics of odor emission in the various odor sources

2.1 Classification of main odor emission sources

Odor emission sources are composed of various kinds of business. These conditions of location and economic power are very different respectively. Also, values of these parameters such as odor composition, odor concentration, gas temperature, volume of exhaust gas, frequency of gas emission and etc. are varied in a wide range. Table 1 shows classification of odor emission sources by the scale of odor emission. Influence area of odor pollution shown in this table is limited only in the case of imperfect odor control.

Table 1  Classification of various odor emission sources by the scale of odor emission (OER)

<table>
<thead>
<tr>
<th>Scale of Odor Emission</th>
<th>Name of Business ( Odor Emission Sources )</th>
<th>OER (m³/min)</th>
<th>Distance of Influence (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>Pulp factory, Rendering plant, Fish-meal plant, Rayon factory, Celluloid factory</td>
<td>10⁷ ~ 10⁹</td>
<td>1,000 ~ 5,000</td>
</tr>
<tr>
<td>Middle</td>
<td>Poultry farm, Pig farm, Wastewater treatment plant, Night-soil treatment plant, Coffee baking factory, Photogravure factory, Offset Printing factory, Car coating factory, Metal coating factory, Chemical factory, Casting factory, Rubber factory, Food manufacturing factory, Composting facility</td>
<td>10⁵ ~ 10⁶</td>
<td>50 ~ 1,000</td>
</tr>
<tr>
<td>Small</td>
<td>Restaurant; Laundry, Pet shop, Bakery, Confectionery, Car Repair shop, Hairdresser, Garbage collection spot, Public lavatory, Septic tank, Drain pit of high-rise building</td>
<td>10⁴ or less</td>
<td>5 ~ 50</td>
</tr>
</tbody>
</table>

Table 2 shows classification of odor emission sources by the mechanism of odor generation. Mechanism of odor emission is similar between the 1st group and the 4th group because their handling materials have strong odor. But, the former is solid and the latter is liquid as the source of odor. In the 2nd group, odor is generated from the pyrolysis reaction which occurs by heat treatment of raw material. In the 3rd group, odor generation is partly caused by volatilization in drying process and partly by the pyrolysis of organic compound.

Table 3 shows classification of odor emission sources by the mainly odorous compounds.

Table 2  Classification of odor emission sources by the mechanism of odor generation

<table>
<thead>
<tr>
<th>Group</th>
<th>Process</th>
<th>Handled Subject</th>
<th>Name of business ( Emission sources )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transport, Storage, Fermentation</td>
<td>Night-soil, Garbage, Sludge, Industrial Waste, Gas</td>
<td>Night-soil treatment plant, a night soil truck with a vacuum hose, Garbage truck, Dumping ground of garbage, Recycling facility, Incineration Facility of waste, Industrial waste treatment plant, Landfill, Gas stand, RDF storehouse</td>
</tr>
<tr>
<td>2</td>
<td>Heat-treatment Cooking</td>
<td>Fish-meal, Oil, Bone, Food, Metal, Chemical</td>
<td>Fish-meal plant, Rendering plant, Coffee baking factory, Bakery, Food manufacturing Factory, Restaurant, Rubber factory, Casting factory, Chemical factory</td>
</tr>
</tbody>
</table>
### Table 3  Classification of odor emission sources by mainly contained odorants

<table>
<thead>
<tr>
<th>Compound</th>
<th>Main Odorants</th>
<th>Name of Business (Emission sources)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur-containing Compounds</td>
<td>Hydrogen Sulfide</td>
<td>Pulp paper Factory, Night-Soil treatment plant, Sewage disposal plant, Drain pit of high-rise building, Rubber factory, Rayon factory, Landfill</td>
</tr>
<tr>
<td>Nitrogen-containing Compounds</td>
<td>Ammonia, Trimethyl Amine</td>
<td>Poultry farm, Composting facility, Fish-meal plant, Night-soil treatment plant</td>
</tr>
<tr>
<td>Organic Solvent</td>
<td>Toluene, Xylene, Ethyl Acetate</td>
<td>Coating factory, Photogravure factory, Laundry, Adhesive manufacturing factory, Plywood factory, Car repair shop, Furniture manufacturing factory</td>
</tr>
<tr>
<td>Aldehyde Compounds</td>
<td>Acetaldehyde</td>
<td>Metal coating factory, Casting factory, Off-set printing factory, Car coating factory, Coffee baking factory</td>
</tr>
<tr>
<td>Lower fatty acid</td>
<td>n-Butyric Acid</td>
<td>Poultry farm, Pet shop, Starch manufacturing factory</td>
</tr>
</tbody>
</table>

### 2.2 Measured value of odor concentration in the odorous gas taken at typical odor emission sources

Table 4 is the list of value of odor concentration which Iwasaki summarized in his reference book<br>. Sample gas is taken at both of discharged port and borderline of each emission source. If exhaust gas device such as a chimney or a duct does not be set, sample is taken near the emission source. Maximum value is rather higher compared with mean value. It is shown that heavy pollution of odor might occur in the worst case.

### Table 4  Odor concentration at various odor emission sources (Exhaust gas and borderline)<br>
<table>
<thead>
<tr>
<th>Business Group</th>
<th>Exhaust gas</th>
<th>Borderline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car coating factory</td>
<td>41</td>
<td>490</td>
</tr>
<tr>
<td>Borderline</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Coating factory (others)</td>
<td>116</td>
<td>540</td>
</tr>
<tr>
<td>Borderline</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Metal Printing factory</td>
<td>70</td>
<td>650</td>
</tr>
<tr>
<td>Borderline</td>
<td>7</td>
<td>510</td>
</tr>
<tr>
<td>Photogravure factory</td>
<td>17</td>
<td>430</td>
</tr>
<tr>
<td>Borderline</td>
<td>6</td>
<td>63</td>
</tr>
<tr>
<td>Off-set printing factory</td>
<td>31</td>
<td>650</td>
</tr>
<tr>
<td>Borderline</td>
<td>2</td>
<td>72</td>
</tr>
<tr>
<td>Rubber factory</td>
<td>42</td>
<td>280</td>
</tr>
<tr>
<td>Borderline</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Confectionery factory</td>
<td>49</td>
<td>1,200</td>
</tr>
<tr>
<td>Borderline</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Pulp &amp; paper factory</td>
<td>45</td>
<td>8,000</td>
</tr>
<tr>
<td>Borderline</td>
<td>36</td>
<td>110</td>
</tr>
<tr>
<td>Metal plating factory</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Borderline</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Sludge Incineration</td>
<td>64</td>
<td>1,100</td>
</tr>
<tr>
<td>Borderline</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Laundry shop</td>
<td>12</td>
<td>230</td>
</tr>
<tr>
<td>Borderline</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>


3. **Actual condition of equipment installation for deodorization and its efficiency**

3.1 **Actual condition of the equipment installation**

A questionnaire survey of 200 enterprises related with deodorizing equipment is annually carried out. These results are written in annual report of odor pollution control. Though recovery rate is about 30%, main reliable enterprises always fill out a questionnaire. Therefore, the author would like to introduce the actual condition of annual equipment installation for deodorization by quoting some related information from Annual Report of Odor Pollution Control 2000.

Table 5 and Table 6 show the number of installation to each business group and the number of installation for each kinds of equipment from 1995 to 1999, respectively. One equipment is counted as one number regardless big or small. Annual total number of the installation is little varied but trends toward an increase. The number was about 830 in fiscal 1999 and increased to about 2900 in fiscal 2000. “Sanitary section” in Table 5 means the following business; sewage disposal plant, night-soil treatment plant, wastewater treatment plant for agricultural district, recycling facility, refuse disposal spot, composting facility, septic tank, drain pit of high-rise building and etc. On the other hand, “Service and public welfare section” consists of restaurant, hotel, cleaning shop, medical welfare facilities, institute, sports center and etc. Both section occupied the greater part. Fig. 2 shows the number of equipment installation for each business in fiscal 1999. The greatest number is 172 for medical welfare section and the second place is 151 for sewage disposal plant. As to the former, it was thought that setting the smaller deodorant unit at each room of facilities bought the high value. Though the number of installation for each deodorizing method was varied by year, adsorption method by activated carbon was mostly adopted in every fiscal year. Recently, biological deodorization and deodorant spray method trend
toward an increase of application. **Fig. 3** is bar graph of installation number for each deodorizing method in fiscal 2000. The numbers for both adsorption and deodorant spray method are larger and ozone catalyst method becomes popular recently. The number of the newly-installed equipment for chemical scrubbing or combustion method is decreased, but these numerous equipments were set up in many kinds of odor emission sources in the past and most of them are still useful under adequate operation and maintenance.

### Table 5  Time-course variation of the deodorizing installation number for each business

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock &amp; Food</td>
<td>28</td>
<td>5.5</td>
<td>17</td>
<td>3.1</td>
<td>28</td>
<td>5.9</td>
<td>56</td>
<td>4.9</td>
<td>30</td>
<td>3.6</td>
</tr>
<tr>
<td>Pulp &amp; Print &amp; Coating</td>
<td>20</td>
<td>3.9</td>
<td>22</td>
<td>4.0</td>
<td>15</td>
<td>3.2</td>
<td>35</td>
<td>3.0</td>
<td>20</td>
<td>2.4</td>
</tr>
<tr>
<td>Oil &amp; Organic Synthesis</td>
<td>34</td>
<td>6.7</td>
<td>27</td>
<td>4.9</td>
<td>38</td>
<td>8.0</td>
<td>25</td>
<td>2.2</td>
<td>15</td>
<td>1.8</td>
</tr>
<tr>
<td>Inorganic &amp; Metal etc.</td>
<td>19</td>
<td>3.7</td>
<td>14</td>
<td>2.5</td>
<td>33</td>
<td>6.9</td>
<td>36</td>
<td>3.1</td>
<td>39</td>
<td>4.7</td>
</tr>
<tr>
<td>Sanitary facility</td>
<td>303</td>
<td>59.3</td>
<td>368</td>
<td>66.3</td>
<td>295</td>
<td>62.1</td>
<td>470</td>
<td>40.8</td>
<td>348</td>
<td>41.9</td>
</tr>
<tr>
<td>Service &amp; Public Welfare</td>
<td>7</td>
<td>1.4</td>
<td>7</td>
<td>1.3</td>
<td>43</td>
<td>9.1</td>
<td>486</td>
<td>42.2</td>
<td>236</td>
<td>28.4</td>
</tr>
<tr>
<td>Others</td>
<td>100</td>
<td>19.6</td>
<td>100</td>
<td>18.0</td>
<td>23</td>
<td>4.8</td>
<td>43</td>
<td>3.7</td>
<td>143</td>
<td>17.2</td>
</tr>
<tr>
<td>Sum Total</td>
<td>511</td>
<td>100.0</td>
<td>555</td>
<td>100.0</td>
<td>475</td>
<td>100.0</td>
<td>1151</td>
<td>100.0</td>
<td>831</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### Table 6  Time-course variation of the deodorizing installation number by each deodorization method

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water washing (W)</td>
<td>1</td>
<td>0.2</td>
<td>7</td>
<td>1.3</td>
<td>2</td>
<td>0.4</td>
<td>12</td>
<td>1.1</td>
<td>25</td>
<td>3.1</td>
</tr>
<tr>
<td>Chemical Absorption (C)</td>
<td>20</td>
<td>3.9</td>
<td>13</td>
<td>2.3</td>
<td>17</td>
<td>3.6</td>
<td>29</td>
<td>2.6</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Adsorption (A)</td>
<td>221</td>
<td>43.2</td>
<td>208</td>
<td>37.5</td>
<td>156</td>
<td>33.3</td>
<td>287</td>
<td>25.7</td>
<td>146</td>
<td>18.3</td>
</tr>
<tr>
<td>Combustion</td>
<td>46</td>
<td>9.0</td>
<td>40</td>
<td>7.2</td>
<td>53</td>
<td>11.3</td>
<td>60</td>
<td>5.4</td>
<td>38</td>
<td>4.8</td>
</tr>
<tr>
<td>Biological treatment</td>
<td>125</td>
<td>24.5</td>
<td>129</td>
<td>23.2</td>
<td>137</td>
<td>29.2</td>
<td>180</td>
<td>16.1</td>
<td>168</td>
<td>21.0</td>
</tr>
<tr>
<td>Ozone Catalyst</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>1.6</td>
<td>5</td>
<td>0.6</td>
</tr>
<tr>
<td>Deodorant Spray (D)</td>
<td>32</td>
<td>6.3</td>
<td>45</td>
<td>8.1</td>
<td>22</td>
<td>4.7</td>
<td>386</td>
<td>34.6</td>
<td>172</td>
<td>21.5</td>
</tr>
<tr>
<td>(W) + (A)</td>
<td>5</td>
<td>1.0</td>
<td>4</td>
<td>0.7</td>
<td>1</td>
<td>0.2</td>
<td>4</td>
<td>0.4</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>(C) + (A)</td>
<td>16</td>
<td>3.1</td>
<td>17</td>
<td>3.1</td>
<td>7</td>
<td>1.5</td>
<td>28</td>
<td>2.5</td>
<td>13</td>
<td>1.6</td>
</tr>
<tr>
<td>(A) + (D)</td>
<td>7</td>
<td>1.4</td>
<td>7</td>
<td>1.3</td>
<td>5</td>
<td>1.1</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>(I) + (A)</td>
<td>5</td>
<td>1.0</td>
<td>5</td>
<td>0.9</td>
<td>4</td>
<td>0.9</td>
<td>7</td>
<td>0.6</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>(B) + (A)</td>
<td>11</td>
<td>2.2</td>
<td>30</td>
<td>5.4</td>
<td>15</td>
<td>3.2</td>
<td>30</td>
<td>2.7</td>
<td>11</td>
<td>1.4</td>
</tr>
<tr>
<td>Others</td>
<td>22</td>
<td>4.3</td>
<td>50</td>
<td>9.0</td>
<td>50</td>
<td>10.7</td>
<td>75</td>
<td>6.7</td>
<td>210</td>
<td>26.3</td>
</tr>
<tr>
<td>Sum Total</td>
<td>511</td>
<td>100.0</td>
<td>555</td>
<td>100.0</td>
<td>469</td>
<td>100.0</td>
<td>1116</td>
<td>100.0</td>
<td>800</td>
<td>100.0</td>
</tr>
</tbody>
</table>
3.2 Introduction of measured data related with deodorization efficiency in each deodorizing method

It was already shown that numerous deodorizing equipments were adapted to various odor emission sources in second chapter. But, the reports related with deodorization efficiency are unfortunately very few and poor. Ministry of the Environment in Japan published a book “Guidebook for application of deodorizing technique”, in which representative measured results were written for each type of deodorization method.

In these surveys, sample gas was taken at inlet and outlet of deodorizing equipment and was analyzed by both instrumental method and olfactory method. Only one result for one kind of deodorizing method is shown because volume of this paper is limited. So, it is desirable to use these data, just for your information. It is known that the efficiency of deodorization is influenced by various operating condition. Generally, removal rate of deodorants by charcoal adsorption and catalyst combustion is the highest immediately after the unit is installed and gradually declines as time of operation passes. On biological methods, acclimation time of about 2 weeks is necessary to get the full deodorization activity by microorganism. Off-gas has generally slight malodor especially in the combustion methods and biological methods.

Continuous measurement of odor is better to evaluate the efficiency of deodorization when inlet-gas concentration is widely varied. A semiconductor type of odor sensor or a measuring device for H₂S is sometimes used as odor monitoring instrument of outlet gas. The following tables (Table 7~Table 16) show the operating condition and its removal efficiency for each different deodorizing method.
## Chemical Scrubbing

**Table 7** Deodorization efficiency for night-soil treatment plant by chemical scrubbing method

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night-soil Treatment Plant</td>
<td>H₂S (ppm)</td>
<td>2.03</td>
<td>0.015</td>
<td>99.3</td>
<td>Acid Sol. + NaClO Washing</td>
</tr>
<tr>
<td></td>
<td>MM (ppm)</td>
<td>0.566</td>
<td>&lt;0.0005</td>
<td>&gt;99.9</td>
<td>Gas Volume : 283 m³ / min</td>
</tr>
<tr>
<td></td>
<td>DMS (ppm)</td>
<td>0.452</td>
<td>&lt;0.0005</td>
<td>&gt;99.9</td>
<td>Thickness of packing</td>
</tr>
<tr>
<td></td>
<td>DMDS (ppm)</td>
<td>&lt;0.5</td>
<td>&lt;0.0005</td>
<td>-</td>
<td>LV = 1.0 ~ 1.3 (m/sec)</td>
</tr>
<tr>
<td></td>
<td>NH₃ (ppm)</td>
<td>7.3</td>
<td>0.09</td>
<td>98.7</td>
<td>SV = 1800 ~ 3200 (1/hr)</td>
</tr>
<tr>
<td>Reservoir Tank</td>
<td>TMA (ppm)</td>
<td>0.0055</td>
<td>&lt;0.0005</td>
<td>-</td>
<td>Thickness of packing</td>
</tr>
<tr>
<td></td>
<td>n-Butyric Acid (ppm)</td>
<td>&lt;0.0002</td>
<td>&lt;0.001</td>
<td>-</td>
<td>LV = 0.3 ~ 1.0 (m/sec)</td>
</tr>
<tr>
<td></td>
<td>Odor Concentration</td>
<td>5500</td>
<td>22</td>
<td>99.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>37</td>
<td>13</td>
<td>64.9</td>
<td></td>
</tr>
</tbody>
</table>

## Charcoal Adsorption

**Table 8** Deodorization efficiency for train manufacturing factory by charcoal adsorption

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Manufacturing Factory</td>
<td>Benzene (ppm)</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>-</td>
<td>Fixed Packed Type, (Solvent Recovering by steam regeneration)</td>
</tr>
<tr>
<td></td>
<td>Toluene (ppm)</td>
<td>9.8</td>
<td>0.6</td>
<td>93.9</td>
<td>Gas Vol. : 4200 m³ / min</td>
</tr>
<tr>
<td></td>
<td>Xylene (ppm)</td>
<td>4.1</td>
<td>0.4</td>
<td>90.2</td>
<td>Thickness of packing</td>
</tr>
<tr>
<td></td>
<td>Ethyl Acetate (ppm)</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>-</td>
<td>LV = 0.3 ~ 0.5 m</td>
</tr>
<tr>
<td>Coating Process</td>
<td>Odor Concentration</td>
<td>55</td>
<td>23</td>
<td>58.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>17</td>
<td>14</td>
<td>17.6</td>
<td></td>
</tr>
</tbody>
</table>

## Direct Combustion

**Table 9** Deodorization efficiency for metal coating factory by direct combustion

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal Rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Coating Dryer Factory</td>
<td>Formaldehyde (ppm)</td>
<td>79</td>
<td>30</td>
<td>62.0</td>
<td>Gas Volume : 40 m³ / min</td>
</tr>
<tr>
<td></td>
<td>Acetaldehyde (ppm)</td>
<td>0.27</td>
<td>0.085</td>
<td>68.5</td>
<td>Furnace Condition</td>
</tr>
<tr>
<td></td>
<td>Propionaldehyde (ppm)</td>
<td>0.11</td>
<td>0.03</td>
<td>72.7</td>
<td>Temp. : 750 □</td>
</tr>
<tr>
<td></td>
<td>iso-Butyaldehyde (ppm)</td>
<td>0.041</td>
<td>0.006</td>
<td>85.4</td>
<td>Retention time : 0.7 sec or more</td>
</tr>
<tr>
<td></td>
<td>n-butyaldehyde (ppm)</td>
<td>0.013</td>
<td>0.004</td>
<td>69.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iso-valeraldehyde (ppm)</td>
<td>0.003</td>
<td>&lt;0.001</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n-valeraldehyde (ppm)</td>
<td>0.013</td>
<td>0.003</td>
<td>76.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Isobutanol (ppm)</td>
<td>6.1</td>
<td>1.0</td>
<td>83.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n-butanol (ppm)</td>
<td>0.2</td>
<td>0.09</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toluene (ppm)</td>
<td>0.14</td>
<td>0.065</td>
<td>53.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ethyl benzene (ppm)</td>
<td>0.37</td>
<td>0.065</td>
<td>82.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Xylene (ppm)</td>
<td>0.57</td>
<td>0.075</td>
<td>86.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor concentration</td>
<td>1100</td>
<td>640</td>
<td>41.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>30</td>
<td>28</td>
<td>6.7</td>
<td></td>
</tr>
</tbody>
</table>
### Catalyst Combustion

**Table 10  Deodorization efficiency for off-set printing factory by catalyst combustion**

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-set Printing Factory</td>
<td>Exhaust gas from Drying Process</td>
<td>Formaldehyde (ppm)</td>
<td>59.1</td>
<td>1.3</td>
<td>97.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acetaldehyde (ppm)</td>
<td>0.83</td>
<td>0.007</td>
<td>99.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Propionaldehyde (ppm)</td>
<td>0.39</td>
<td>0.003</td>
<td>99.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iso-Butyraldehyde (ppm)</td>
<td>0.002</td>
<td>&lt;0.001</td>
<td>&gt;50.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n-butyraldehyde (ppm)</td>
<td>0.065</td>
<td>&lt;0.001</td>
<td>&gt;98.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iso-valeraldehyde (ppm)</td>
<td>0.002</td>
<td>&lt;0.001</td>
<td>&gt;50.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n-valeraldehyde (ppm)</td>
<td>0.035</td>
<td>0.003</td>
<td>91.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acetone (ppm)</td>
<td>1.1</td>
<td>0.12</td>
<td>89.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isopropanol (ppm)</td>
<td>7.1</td>
<td>0.51</td>
<td>92.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethyl Acetate (ppm)</td>
<td>0.059</td>
<td>0.04</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBK (ppm)</td>
<td>0.076</td>
<td>0.003</td>
<td>96.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Toluene (ppm)</td>
<td>0.08</td>
<td>0.014</td>
<td>82.5</td>
</tr>
</tbody>
</table>

|                   | Odor Concentration | 14000 | 690 | 95.1 |
|                   | Odor Index | 41 | 28 | 31.7 |

**Regenerative Thermal Oxidizer**

**Table 11  Deodorization efficiency for Photogravure factory by Regenerative Thermal Oxidizer**

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photogravure Factory</td>
<td>Printing Process</td>
<td>Toluene (ppm)</td>
<td>320</td>
<td>6.0</td>
<td>98.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethyl Acetate (ppm)</td>
<td>240</td>
<td>5.0</td>
<td>97.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n-Butyl Acetate (ppm)</td>
<td>79</td>
<td>2.0</td>
<td>97.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isobutanol (ppm)</td>
<td>27</td>
<td>&lt;1.0</td>
<td>&gt;96.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Odor Concentration</td>
<td>13000</td>
<td>230</td>
<td>98.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Odor Index</td>
<td>41</td>
<td>24</td>
<td>41.5</td>
</tr>
</tbody>
</table>

**Soil Deodorization**

**Table 12  Deodorization efficiency for rendering plant by soil deodorization**

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rendering Plant</td>
<td>Processing in door</td>
<td>H$_2$S (ppm)</td>
<td>0.0061</td>
<td>0.0074</td>
<td>Gas Volume :</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MM (ppm)</td>
<td>0.0035</td>
<td>0.0018</td>
<td>1090 m$^3$ / min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMS (ppm)</td>
<td>0.00012</td>
<td>0.0001</td>
<td>48.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TMA (ppm)</td>
<td>1.4</td>
<td>0.06</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH$_3$ (ppm)</td>
<td>0.08</td>
<td>0.01</td>
<td>95.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Odor Concentration</td>
<td>3000</td>
<td>&lt;10</td>
<td>&gt;87.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Odor Index</td>
<td>35</td>
<td>&lt;10</td>
<td>99.7</td>
</tr>
</tbody>
</table>

|                   |                                  | Gas Volume : |
|                   |                                  | LV : 0.018 m/sec |
|                   |                                  | Space Area : 1000 m$^2$ |
|                   |                                  | Thickness of Soil : 50 cm |

| Rendering Plant  | Processing in door | Odor Concentration | 3000 | <10 | >99.7 |
|                   |                                  | Odor Index | 35 | <10 | >71.4 |
### Biological Packed –tower Deodorization

Table 13  Deodorization efficiency for sewage disposal plant by biological packed-tower deodorization

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal Rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage Disposal Plant</td>
<td>H₂S (ppm)</td>
<td>26</td>
<td>0.02</td>
<td>99.9</td>
<td>Gas Volume : 36 m³ / min</td>
</tr>
<tr>
<td></td>
<td>MM (ppm)</td>
<td>5.3</td>
<td>0.014</td>
<td>99.7</td>
<td>LV : 1.0 m/sec</td>
</tr>
<tr>
<td></td>
<td>DMS (ppm)</td>
<td>0.15</td>
<td>0.0005</td>
<td>99.7</td>
<td>Packed Material :</td>
</tr>
<tr>
<td>Thickener of the sludge</td>
<td>DMDS (ppm)</td>
<td>0.12</td>
<td>0.001</td>
<td>99.2</td>
<td>Porous Ceramics</td>
</tr>
<tr>
<td></td>
<td>Odor Concentration</td>
<td>31000</td>
<td>980</td>
<td>96.8</td>
<td>Thickness of Packing : 2 m</td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>45</td>
<td>30</td>
<td>33.3</td>
<td></td>
</tr>
</tbody>
</table>

### Activated Sludge Aeration Method

Table 14  Deodorization efficiency for night-soil treatment plant by activated sludge aeration method

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal Rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night-soil Treatment Plant (Wet Oxidation)</td>
<td>H₂S( ppm )</td>
<td>42</td>
<td>0.18</td>
<td>99.6</td>
<td>Gas Volume : 120 m³ / min</td>
</tr>
<tr>
<td></td>
<td>MM( ppm )</td>
<td>3.4</td>
<td>0.026</td>
<td>99.2</td>
<td>SV : 8.4 (1/hr)</td>
</tr>
<tr>
<td></td>
<td>DMS (ppm)</td>
<td>0.62</td>
<td>0.094</td>
<td>84.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DMDS (ppm)</td>
<td>0.1</td>
<td>&lt;0.005</td>
<td>&gt;95.0</td>
<td>Depth from surface :</td>
</tr>
<tr>
<td></td>
<td>NH₃( ppm )</td>
<td>0.35</td>
<td>&lt;0.01</td>
<td>&gt;97.1</td>
<td>2.0 m or more</td>
</tr>
<tr>
<td>High or Middle Level Odor</td>
<td>TMA( ppm )</td>
<td>6.1</td>
<td>0.29</td>
<td>95.2</td>
<td>Surface Area of tank :</td>
</tr>
<tr>
<td></td>
<td>Acetaldehyde (ppm)</td>
<td>1.8</td>
<td>0.37</td>
<td>79.4</td>
<td>500 m²</td>
</tr>
<tr>
<td></td>
<td>Odor Concentration</td>
<td>73000</td>
<td>310</td>
<td>99.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>49</td>
<td>25</td>
<td>49.0</td>
<td></td>
</tr>
</tbody>
</table>

### Ozone Catalyst Deodorization

Table 15  Deodorization efficiency for wastewater treatment facility of agricultural district by ozone catalyst deodorization

<table>
<thead>
<tr>
<th>Business</th>
<th>Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal Rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>wastewater treatment facility of agricultural district</td>
<td>H₂S (ppm)</td>
<td>0.35</td>
<td>&lt;0.0008</td>
<td>&gt;99.8</td>
<td>Gas Volume : 16.4 m³ / min</td>
</tr>
<tr>
<td></td>
<td>MM( ppm )</td>
<td>0.01</td>
<td>&lt;0.0005</td>
<td>&gt;95.0</td>
<td>LV : 0.4 m/sec</td>
</tr>
<tr>
<td></td>
<td>DMS (ppm)</td>
<td>0.0052</td>
<td>&lt;0.0005</td>
<td>&gt;90.4</td>
<td>SV : 700 (1/hr)</td>
</tr>
<tr>
<td></td>
<td>DMDS (ppm)</td>
<td>0.0009</td>
<td>&lt;0.0005</td>
<td>&gt;44.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Concentration</td>
<td>4200</td>
<td>25</td>
<td>99.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>36</td>
<td>14</td>
<td>61.1</td>
<td></td>
</tr>
</tbody>
</table>
Plasma Catalyst Deodorization

**Table 16** Deodorization Efficiency for amino acid manufacturing factory by plasma catalyst deodorization

<table>
<thead>
<tr>
<th>Business Subject</th>
<th>Inlet</th>
<th>Outlet</th>
<th>Removal Rate (%)</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino acid Manufacturing Factory</td>
<td>H₂S (ppm)</td>
<td>0.13</td>
<td>&lt;0.0008</td>
<td>&gt;99.2 Gas Volume: 40 m³/min</td>
</tr>
<tr>
<td></td>
<td>MM (ppm)</td>
<td>0.25</td>
<td>&lt;0.0005</td>
<td>&gt;99.6 Consumption of electric Power</td>
</tr>
<tr>
<td></td>
<td>DMS (ppm)</td>
<td>4.5</td>
<td>0.96</td>
<td>78.7</td>
</tr>
<tr>
<td></td>
<td>DMDS (ppm)</td>
<td>0.02</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NH₃ (ppm)</td>
<td>14</td>
<td>0.9</td>
<td>93.5</td>
</tr>
<tr>
<td></td>
<td>Acetaldehyde (ppm)</td>
<td>0.17</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Propionic Acid (ppm)</td>
<td>0.034</td>
<td>0.0081</td>
<td>76.2</td>
</tr>
<tr>
<td></td>
<td>n-Butyric Acid (ppm)</td>
<td>0.07</td>
<td>0.0037</td>
<td>94.7</td>
</tr>
<tr>
<td></td>
<td>Isovaleric Acid (ppm)</td>
<td>0.076</td>
<td>0.0033</td>
<td>95.7</td>
</tr>
<tr>
<td></td>
<td>n-Valeric (ppm)</td>
<td>0.0083</td>
<td>0.0002</td>
<td>97.6</td>
</tr>
<tr>
<td></td>
<td>Odor Concentration</td>
<td>17000</td>
<td>980</td>
<td>94.2</td>
</tr>
<tr>
<td></td>
<td>Odor Index</td>
<td>42</td>
<td>30</td>
<td>28.6</td>
</tr>
</tbody>
</table>

4. Conclusion

Current topics related with the development of deodorizing techniques are as follows: 1) Adoption of deodorization utilizing oxidation action by ozone or plasma is increasing, 2) Photochemical deodorization by TiO₂ is studied and developed with fervor, 3) Simpler equipments of deodorization for restaurant are actively developed. As described in the second chapter, most of deodorizing method which is charcoal adsorption or biological method, which is adopted in larger scale plant such as sewage disposal plant. On direct combustion or catalyst combustion for organic solvent treatment, heat recovery from exhaust gas is thoroughly studied. In charcoal adsorption, chemical adhesive adsorbent becomes popular than normal type and new various shapes of charcoal like honeycomb or filament are made and used as adsorbent of new deodorizing unit.

These high level of techniques related with deodorization is thought to be useful for counter plan of odor pollution in East Asian countries. But, it is necessary to be considered the economical condition and environmental strategy of foreign countries on the occasion of technical transference. Specially, I am afraid that transference of the techniques might end in failure because of the expensive price. So, we have to develop the deodorizing method toward not only high-performance but also cheaper price. Therefore, the size, cost and capacity of the equipment should be improved, as they are suitable and easily obtainable. It is important to understand well about the characteristics of each odor emission sources and its economic condition.

Reference