Odor Pollution Control for Various Odor Emission Sources in Japan

JOJI FUKUYAMA
Osaka City Institute of Public Health and Environmental Sciences
8-34 Tojohcho Tennohjiku Osaka 543-0026, 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.

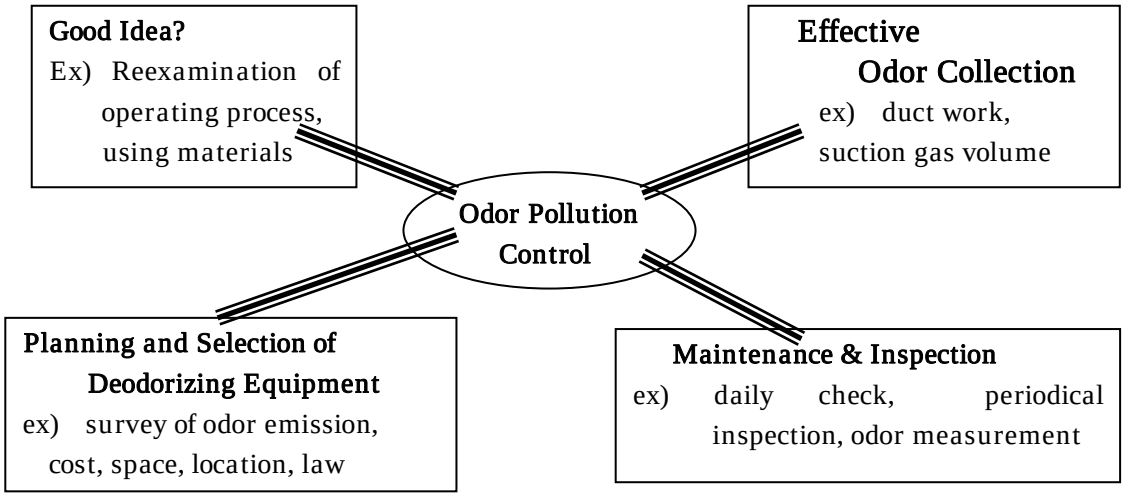

Fig. 1 Concept Illustration for Odor Pollution Control

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)

Scale of Odor Emission	Name of Business (Odor Emission Sources)	OER (m^3／min)	Distance of Influence (m)
Large	Pulp factory, Rendering plant, Fish-meal plant, Rayon factory, Celluloid factory	10^7～10^9	1,000 ～ 5,000
Middle	Poultry farm, Pig farm, Wastewater treatment plant, Night-soil treatment plant, Coffee baking factory, Photogravure factory, Off-set Printing factory, Car coating factory, Metal coating factory, Chemical factory, Casting factory, Rubber factory, Food manufacturing factory, Composting facility	10^5～10^6	50 ～ 1,000
Small	Restaurant; Laundry, Pet shop, Bakery, Confectionery, Car Repair shop, Hairdresser, Garbage collection spot, Public lavatory, Septic tank, Drain pit of high-rise building	10^4 or less	5 ～ 50

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

Group	Process	Handled Subject	Name of business (Emission sources)
Ⅰ	Transport, Storage, Fermentation	Night-soil, Garbage, Sludge, Industrial Waste, Gas	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
Ⅱ	Heat-treatment Cooking,	Fish-meal, Oil, Bone, Food, Metal, Chemical	Fish-meal plant, Rendering plant, Coffee baking factory, Bakery, Food manufacturing Factory, Restaurant, Rubber factory, Casting factory, Chemical factory

III	Drying, Incineration	Solvent, Solid Waste, Sludge Ink, Paint	Poultry farm, Printing factory, Car coating factory, Laundry, Car repair shop, Adhesive manufacturing factory, plywood factory, Crematory, Pulp paper factory, Treatment facility of industrial waste
IV	Treatment of wastewater	Sewage, Industrial Wastewater, Night-soil	Drain pit of high-rise building, Septic tank, Rayon factory, Pig farm, Starch factory, Sewage disposal plant, Sewage pumping site, Night-soil treatment plant, Food manufacturing factory

Table 3 Classification of odor emission sources by mainly contained odorants

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

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[1)]. 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)[1)]

Name of Business (Emission Sources)	Measured Point	Number of measurement	Odor Concentration	
			Mean	Maximum
Pig Farm	Emission source*	32	79*	56,000:*
	Borderline	19	26	510
Poultry farm	Emission source*	23	42*	10,000*
	Borderline	29	25	1,200
Night-soil treatment plant	Exhaust gas	70	4,100	450,000
	Borderline	25	19	370
Sewage disposal plant	Exhaust gas	23	490	9,800
	Borderline	11	100	200,000
Rendering plant	Exhaust gas	95	2,000	23,000,000
	Borderline	30	36	410
Fish-meal plant	Exhaust gas	76	2,800	310,000
	Borderline	44	81	2,900

Car coating factory	Exhaust gas	41	490	18,000
	Borderline	8	10	440
Coating factory（ others ）	Exhaust gas	116	540	230,000
	Borderline	24	15	100
Metal Printing factory	Exhaust gas	70	650	18,000
	Borderline	7	510	5,500
Photogravure factory	Exhaust gas	17	430	41,000
	Borderline	6	63	410
Off-set printing factory	Exhaust gas	31	650	41,000
	Borderline	2	72	130
Rubber factory	Exhaust gas	42	280	79,000
	Borderline	30	13	200
Confectionery factory	Exhaust gas	49	1,200	68,000
	Borderline	9	9	70
Pulp & paper factory	Exhaust gas	45	8,000	1,300.000
	Borderline	36	110	680
Metal plating factory	Exhaust gas	20	10	410
	Borderline	3	9	42
Sludge Incineration	Exhaust gas	64	1,100	14,000
	Borderline	4	5	23
Laundry shop	Exhaust gas	12	230	18,000
	Borderline	3	12	37

Reference**:** Yoshiharu Iwasaki, Olfactory measurement of odor (New version), p145~152, Japan Association on Odor Environment (2004)

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

Kind of Business	1995		1996		1997		1998		1999	
	No.	%	No.	%	No.	%	No.	%	No.	%
Livestock & Food	28	5.5	17	3.1	28	5.9	56	4.9	30	3.6
Pulp & Print & Coating	20	3.9	22	4.0	15	3.2	35	3.0	20	2.4
Oil & Organic Synthesis	34	6.7	27	4.9	38	8.0	25	2.2	15	1.8
Inorganic & Metal etc.	19	3.7	14	2.5	33	6.9	36	3.1	39	4.7
Sanitary facility	303	59.3	368	66.3	295	62.1	470	40.8	348	41.9
Service & Public Welfare	7	1.4	7	1.3	43	9.1	486	42.2	236	28.4
Others	100	19.6	100	18.0	23	4.8	43	3.7	143	17.2
Sum Total	511	100.0	555	100.0	475	100.0	1151	100.0	831	100.0

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

Deodorizing Methods	1995		1996		1997		1998		1999	
	No.	%	No.	%	No.	%	No.	%	No.	%
Water washing (W)	1	0.2	7	1.3	2	0.4	12	1.1	25	3.1
Chemical Absorption (C)	20	3.9	13	2.3	17	3.6	29	2.6	8	1.0
Adsorption (A)	221	43.2	208	37.5	156	33.3	287	25.7	146	18.3
Combustion	46	9.0	40	7.2	53	11.3	60	5.4	38	4.8
Biological treatment	125	24.5	129	23.2	137	29.2	180	16.1	168	21.0
Ozone Catalyst	-	-	–	–	–	–	18	1.6	5	0.6
Deodorant Spray (D)	32	6.3	45	8.1	22	4.7	386	34.6	172	21.5
(W) + (A)	5	1.0	4	0.7	1	0.2	4	0.4	1	0.1
(C) + (A)	16	3.1	17	3.1	7	1.5	28	2.5	13	1.6
(A) + (D)	7	1.4	7	1.3	5	1.1	0	0.0	0	0.0
(I) + (A)	5	1.0	5	0.9	4	0.9	7	0.6	3	0.4
(B) + (A)	11	2.2	30	5.4	15	3.2	30	2.7	11	1.4
Others	22	4.3	50	9.0	50	10.7	75	6.7	210	26.3
Sum Total	511	100.0	555	100.0	469	100.0	1116	100.0	800	100.0

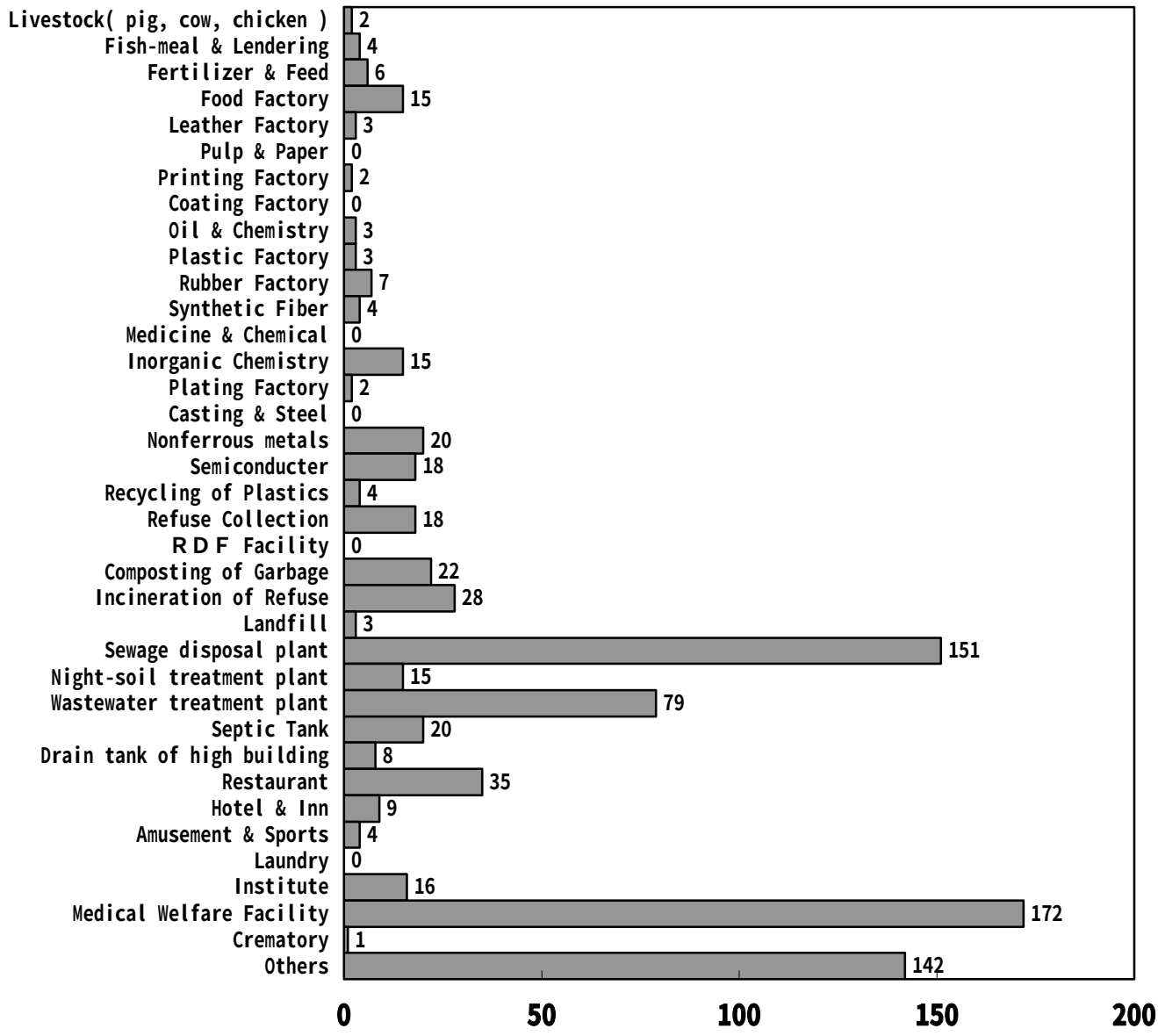

Fig. 2 Installation Number of equipment for each business in fiscal 1999

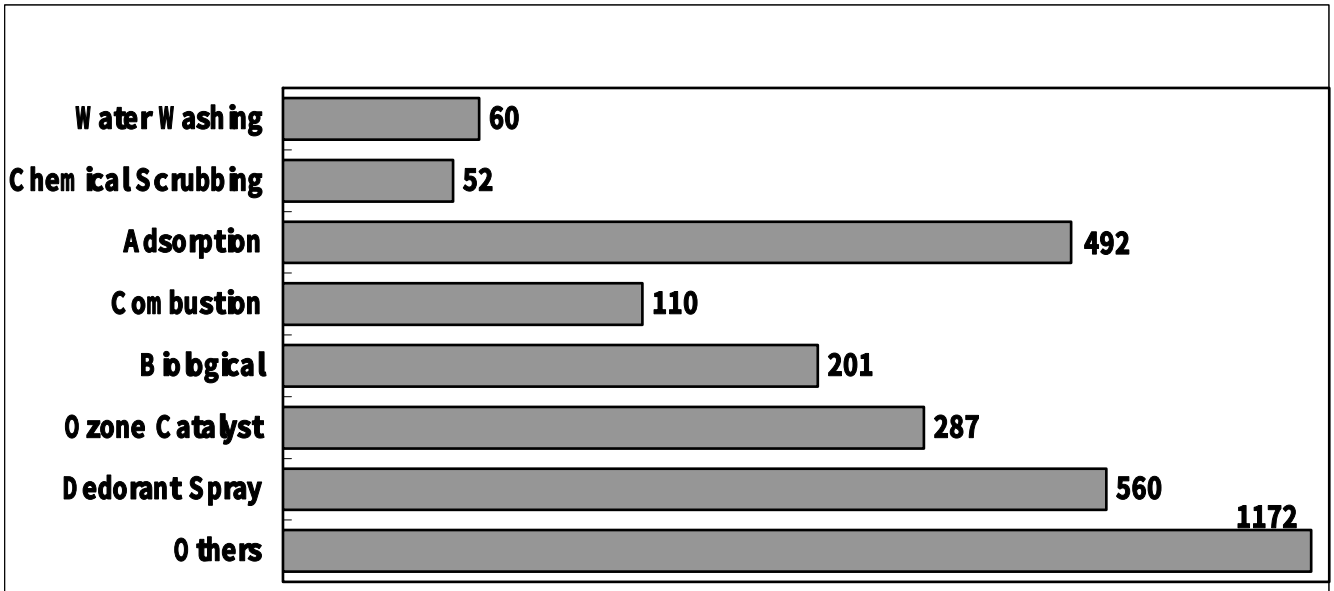

Fig. 3 Installation number of equipment for each deodorizing method in fiscal 2000 (n=2934)

3.2 Introduction of measured data related with deodorization efficiency in each deodorizing method [3)]

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 H_2S is sometimes used as odor monitoring instrument of out-let gas. The following tables (Table 7~Table 16) show the operating condition and its removal efficiency for each different deodorizing method

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① **Chemical Scrubbing**

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

Business	Subject	Inlet	Outlet	Removal (%)	Operating Condition
	H_2S(ppm)	2.03	0.015	99.3	Acid Sol. + NaClO Washing
Night-soil	MM (ppm)	0.566	<0.0005	>99.9	
Treatment	DMS (ppm)	0.452	<0.0005	>99.9	Gas Volume：283 m^3 / min
Plant	DMDS (ppm)	<0.5	<0.0005	—	
	NH_3 (ppm)	7.3	0.09	98.7	Thickness of packing
Reservoir	TMA (ppm)	0.0055	<0.0005	—	：1.5～2.0 m
Tank	n-Butyric Acid(ppm)	<0.0002	<0.001	—	LV = 1.0 ～1.3 (m/sec)
	Odor Concentration	5500	22	99.6	SV =1800 ～ 3200 (1/hr)
	Odor Index	37	13	64.9	

② **Charcoal Adsorption**

Table 8 Deodorization efficiency for train manufacturing factory by charcoal adsorption

Business	Subject	Inlet	Outlet	Removal rate (%)	Operating Condition
Train	Benzene(ppm)	<0.1	<0.1	—	Fixed Packed Type,
Manufacturing	Toluene (ppm)	9.8	0.6	93.9	（Solvent Recovering by
Factory	Xylene (ppm)	4.1	0.4	90.2	steam regeneration ）
Coating	Ethyl Acetate(ppm)	<0.1	<0.1	—	Gas Vol.：4200 m^3 / min
Process	Odor Concentration	55	23	58.2	Thickness of packing
	Odor Index	17	14	17.6	：0.3～0.5m
					LV = 0.3 ～1.0 (m/sec)

③ **Direct Combustion**

Table 9 Deodorization efficiency for metal coating factory by direct combustion

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
	Formaldehyde (ppm)	79	30	62.0	Gas Volume：40 m^3 / min
Metal	Acetaldehyde (ppm)	0.27	0.085	68.5	
Coating	Propionaldehyde (ppm)	0.11	0.03	72.7	Furnace Condition
Factory	iso-Butyraldehyde(ppm)	0.041	0.006	85.4	Temp.：750 ℃
	n-butyraldehyde(ppm)	0.013	0.004	69.2	Retention time ：
Dryer	iso-valeraldehyde(ppm)	0.003	<0.001	66.7	0.7 sec or more
	n-valeraldehyde (ppm)	0.013	0.003	76.9	
	Isobutanol (ppm)	6.1	1.0	83.6	
	n-butanol (ppm)	0.2	0.09	55.0	
	Toluene (ppm)	0.14	0.065	53.6	
	Ethyl benzene (ppm)	0.37	0.065	82.4	
	Xylene (ppm)	0.57	0.075	86.8	
	Odor concentration	1100	640	41.8	
	Odor Index	30	28	6.7	

④ **Catalyst Combustion**

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

Business	Subject	Inlet	Outlet	Removal rate (%)	Operating Condition
	Formaldehyde (ppm)	59.1	1.3	97.8	
Off-set	Acetaldehyde (ppm)	0.83	0.007	99.1	Exhaust gas
Printing	Propionaldehyde (ppm)	0.39	0.003	99.2	：110 m^3 / min
Factory	iso-Butyraldehyde(ppm)	0.002	<0.001	>50.0	
	n-butyraldehyde(ppm)	0.065	<0.001	>98.5	Pt Catalyst：150 ℓ
Exhaust gas	iso-valeraldehyde(ppm)	0.002	<0.001	>50.0	
from Drying	n-valeraldehyde (ppm)	0.035	0.003	91.4	Temp. of Furnace
Process	Acetone(ppm)	1.1	0.12	89.1	：380 ℃
	Isopropanol (ppm)	7.1	0.51	92.8	
	Ethyl Acetate (ppm)	0.059	0.04	32.2	
	MIBK (ppm)	0.076	0.003	96.0	
	Toluene (ppm)	0.08	0.014	82.5	
	Odor Concentration	14000	690	95.1	
	Odor Index	41	28	31.7	

⑤ **Regenerative Thermal Oxidizer**

Table 11 Deodorization efficiency for Photogravure factory by Regenerative Thermal Oxidizer

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
	Toluene (ppm)	320	6.0	98.1	Two tower type
Photogravure	Ethyl Acetate (ppm)	240	5.0	97.9	
Factory	n-Butyl Acetate (ppm)	79	2.0	97.5	Gas Volume：
	Isobutanol (ppm)	27	<1.0	>96.3	800 m^3 / min
Printing	Odor Concentration	13000	230	98.2	
Process	Odor Index	41	24	41.5	

⑥ **Soil Deodorization**

Table 12 Deodorization efficiency for rendering plant by soil deodorization

Business	Subject	Inlet	Outlet	Removal rate (%)	Operating Condition
Rendering	H_2S (ppm)	0.0061	0.0074		Gas Volume：
Plant	MM(ppm)	0.0035	0.0018	48.6	1090 m^3 / min
	DMS (ppm)	0.00012	0.0001	16.0	
	TMA(ppm)	1.4	0.06	95.7	LV：0.018 m/sec
Processing	NH_3 (ppm)	0.08	0.01	>87.5	Space Area：1000 m^2
in door	Odor Concentration	3000	<10	>99.7	Thickness of Soil：50 cm
	Odor Index	35	<10	>71.4	

⑦ **Biological Packed –tower Deodorization**

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

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
Sewage Disposal Plant Thickener of the sludge	H_2S (ppm)	26	0.02	99.9	Gas Volume：36 m^3 / min
	MM (ppm)	5.3	0.014	99.7	LV：1.0 m/sec
	DMS (ppm)	0.15	0.0005	99.7	Packed Material：
	DMDS (ppm)	0.12	0.001	99.2	Porous Ceramics
	Odor Concentration	31000	980	96.8	Thickness of Packing：2 m
	Odor Index	45	30	33.3	

⑧ **Activated Sludge Aeration Method**

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

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
Night-soil Treatment Plant (Wet Oxidation) High or Middle Level Odor	H_2S(ppm)	42	0.18	99.6	Gas Volume：120 m^3 / min
	MM(ppm)	3.4	0.026	99.2	
	DMS (ppm)	0.62	0.094	84.8	SV：8.4 (1/hr)
	DMDS (ppm)	0.1	<0.005	>95.0	
	NH_3(ppm)	0.35	<0.01	>97.1	Depth from surface：
	TMA(ppm)	6.1	0.29	95.2	2.0 m or more
	Acetaldehyde (ppm)	1.8	0.37	79.4	Surface Area of tank：
	Odor Concentration	73000	310	99.6	500 m^2
	Odor Index	49	25	49.0	

⑨ **Ozone Catalyst Deodorization**

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

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
wastewater treatment facility of agricultural district	H_2S (ppm)	0.35	<0.0008	>99.8	Gas Volume：16.4 m^3 / min
	MM(ppm)	0.01	<0.0005	>95.0	LV ： 0.4 m/sec
	DMS (ppm)	0.0052	<0.0005	>90.4	SV：700 (1/hr)
	DMDS (ppm)	0.0009	<0.0005	>44.4	
	Odor Concentration	4200	25	99.4	Temp.：14 ℃
	Odor Index	36	14	61.1	

⑩ **Plasma Catalyst Deodorization**

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

Business	Subject	Inlet	Outlet	Removal Rate (%)	Operating Condition
Amino acid Manufacturing Factory	H_2S(ppm)	0.13	<0.0008	>99.2	Gas Volume：40 m^3 / min
	MM(ppm)	0.25	<0.0005	>99.6	Consumption of electric
	DMS (ppm)	4.5	0.96	78.7	Power for discharge：
	DMDS (ppm)	0.02	0.04		About 15W or less
	NH_3 (ppm)	14	0.9	93.5	
	Acetaldehyde (ppm)	0.17	0.25		
	Propionic Acid (ppm)	0.034	0.0081	76.2	
	n-Butyric Acid (ppm)	0.07	0.0037	94.7	
	Isovaleric Acid (ppm)	0.076	0.0033	95.7	
	n-Valeric (ppm)	0.0083	0.0002	97.6	
	Odor Concentration	17000	980	94.2	
	Odor Index	42	30	28.6	

4. Conclusion

Current topics related with the development of deodorizing techniques are as follows: 1) Adoption of deodorization utilized oxidation action by ozone or plasma is increasing, 2) Photochemical deodorization by TiO_2 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

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3) Office of Odor, Noise and Vibration, Environmental Management Bureau, Ministry of the Environment, Government of Japan, Guide book for application of deodorizing equipments, p.79~83(2003)