Operation and management of the Fukashiba treatment plant

E. Ochiai*, T. Igarashi*, S. Itou*, H. Seya* and S. Matsui**

*Kashima Prefectual Sewerage Office Kitahama 9 Kamisumachi, Kashimagun, Ibarakiken, Japan, 314–0101(E-mail: *kage@pref.ibaraki.lg.jp*)

**Graduate School of Global Environmental Studies Kyoto University, Yoshida-honmachi Sakyo-ku, Kyoto City, Japan, 606-8501(E-mail: *matsui@eden.env.kyoto-u.ac.jp*)

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Abstract Since the opening of the Fukashiba Treatment Plant in 1970, the number of industries and the amount of wastewater requiring treatment in the service area have been steadily increasing. In response to the recent economic downturn in Japan, these rates of increase have slowed, but are not decreasing. The pollution load in the wastewater from these industries has decreased and is now stable. Unlike the case of ordinary domestic sewage, the effects of the various types of substances contained in wastewaters delivered from the petrochemical complex to the treatment plant, for example, corrosion, are quite large. Measures to deal with corrosion problems, such as replacement or modification of the facilities, improvement of the efficiencies of facility operation and wastewater treatment, and improvement of measures against odours, are being implemented.

Keywords Measures against odours; modification and improvement; water quality variations

Water quality changes over the last 10 years

The volume of wastewater delivered from the petrochemical complex for treatment at the Fukashiba Treatment Plant increased from an average of 104,557 m^3/d in 1993 to 131,415 m^3/d in 2003 – a total increase of approximately 30,000 m^3/d over 10 years. Domestic wastewater accounts for approximately 10% of the total volume of wastewater treated at the plant. As shown in Table 1, there has been little change in inflow water quality on generic items such as COD_{Mn} ("COD"), BOD, SS, chloride ion and sulphate ion concentrations over the last 10 years, but there was a significant reduction in benzene, dichloromethane, total nitrogen and ammonia nitrogen with the Fukasiba Treatment plant of Kasima Rinkai Specified Sewage Works (Figures 1 and 2) (Okawa *et al.*, 1989).

A contributor to the substantial reduction of the substance concentrations is the result of continuous efforts for fine measures, such as recycling problematic chemicals, reducing the chemicals and modifying production processes in the user factories, which were subject to administrative guidance, because of which new regulations were applied to all wastewater treatment plants for the last decades.

Effluent water quality changes, as shown in Table 2. There was little change in effluent water quality on generic items such as COD, BOD, SS, chloride ion and sulphate ion concentrations, although substances in effluent also declined in concentration when influent declined:

(1) Dichloromethane: December 1992 (a discharge and removal standard for specified treatment plants is 0.2 mg/L)

(2) Benzene: February 1993 (a discharge and removal standard for specified treatment plants is normally 0.1 mg/L, but relaxes its level to 15 mg/L within the treatment area of the plant)

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Table 1 Water quality changes over the last ten years (average in each fiscal year) (mg/L)

Item\Fiscal year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
COD	109	121	116	123	124	127	120	126	121	114	118
BOD	154	131	133	154	168	156	127	118	111	110	111
SS	91	91	101	108	133	133	104	85	85	89	83
Benzene	4.80	4.25	1.80	0.81	0.92	0.753	0.456	0.485	0.222	0.107	0.048
Phenol	1.7	1.8	1.3	1.6	1.8	1.6	1.6	2.1	2.1	2.3	2
Dichloromethane	2.65	0.195	0.026	0.026	0.008	0.01	0.011	0.008	0.009	0.004	0.002
Total nitrogen	140	131	133	143	136	133	99.3	102	93.3	54	42.5
Ammonia nitrogen	127	118	118	125	119	121	90	88.1	80	42.1	28.9
Chloride ion	4,908	5,100	4,760	5,340	5,440	6,060	5,880	5,300	5,600	6,270	6,138
Sulphate ion	712	737	677	745	760	728	698	689	715	746	673

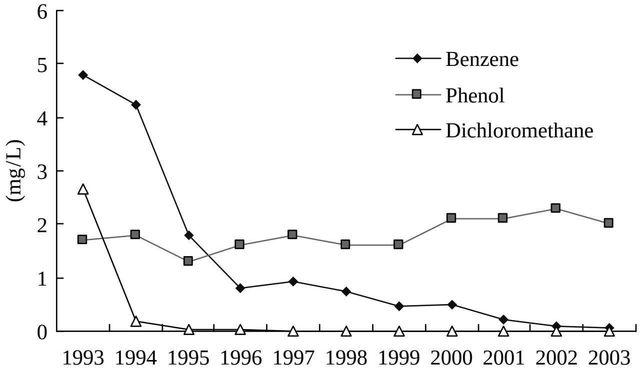


Figure 1 Inflow water quality changes (average in each fiscal year)

(3) Ammonia nitrogen etc.: July 2001 (a discharge and removal standard for specified treatment plants about a total quantity of "ammonia nitrogen," "nitrite nitrogen" and "nitrite nitrogen" is 380 mg/L, while an effluent standard for the plant is 100 mg/L).

Modification and improvement of the treatment plant processes

Overview of modification and improvement associated with upgraded treatment plant facilities

After the startup of the plant in 1970, facility replacement has been carried out in accordance with the state of deterioration of each structure and the function of each facility since 1989. The major facility replacements are discussed in the following.

Sedimentation basin. The deterioration in the functions of the sand-removal equipment and trash racks was serious, and this equipment was producing an obnoxious odour. Therefore, during 1990 and 1991 the sand-removal equipment was changed from the V-bucket type to the jet-pump type to meet the need for measures against odours. As a result, efficient sand removal, protection of the main pump unit, and prevention of sand deposition in the water treatment facility were achieved.

Primary settling tank. The sludge-collecting machine was modified step by step using stainless steel and resin-type parts during 1994, 1996, 1998 and 1999, in order to prevent deterioration in equipment function as a result of corrosion and to extend the service life of the equipment.

Aeration tank. To reduce unnecessary energy consumption from a rise in pressure in the air blower due to clogging of the aerators from equipment deterioration, the aerators

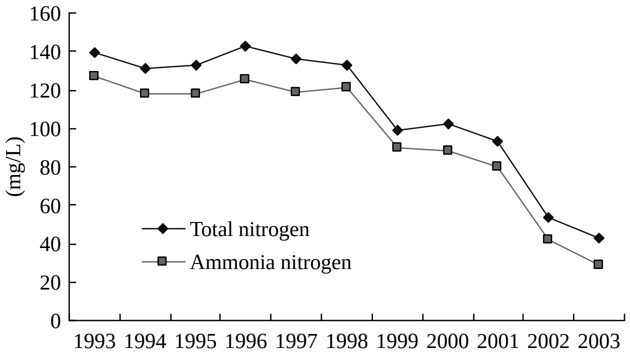


Figure 2 Inflow water quality changes (average in each fiscal year)

Table 2 Effluent water quality changes over the last ten years (average in each fiscal year) (mg/L)

Item\Fiscal year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
COD	29	31	28	28	28	27	26	28	28	25	23
BOD	4	7	6	3	3	3	2	2	3	2	2
SS	8	10	11	12	11	11	7	6	5	7	4
Benzene	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Phenol	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dichloromethane	0.205	0.040	0.011	0.010	0.003	0.003	0.003	0.003	<0.002	<0.002	0.002
Total nitrogen	130	125	118	118	119	114	88.3	90.3	72.9	36.4	26.9
Ammonia nitrogen	126	121	114	111	113	111	83.8	83.6	66.7	33.3	23.8
Chloride ion	5,409	5,090	4,930	5,310	5,540	6,020	6,050	5,220	5,360	6,050	6,244
Sulphate ion	752	741	681	734	774	730	727	706	715	724	707

began to be replaced one by one with energy-saving-type ultra-fine aerator units (panel-type aerators that have high aeration rates). A saving in electricity charges was being achieved in 2002 (see Figure 3).

In addition, the old aeration tank (which had a daily capacity of 125,000 m^3) was of the complete-mixing type (full-section inflow type and shock-load handling) which enabled the system to handle sudden water quality changes.

Because the water quality had become stable and it was necessary to improve the water treatment efficiency, the aeration tank was modified into a plug-flow type by improving the rectifier walls when the air diffusers were modified.

Sludge thickener. The sludge thickener was of the gravity condensation type. However, the concentration of hydrogen sulphide at the thickener exceeded 10,000 mg/L, and there was an odour problem. For this reason, work started on modifying the facility into the centrifugal-thickening type to shorten the retention period of sludge in 2003.

Sludge dewater. Filter-press-type sludge dewatering equipment was initially installed. However, because of the addition of dewatering assisting agents such as lime and ferric chloride, the amounts of dewatered cake had become quite large, and equipment maintenance such as filter cleaning was difficult. The equipment was altered step-by-step to the belt-press-type during 1993, 1995 and 1999. This achieved a reduction in the water content and amounts of dewatered cake.

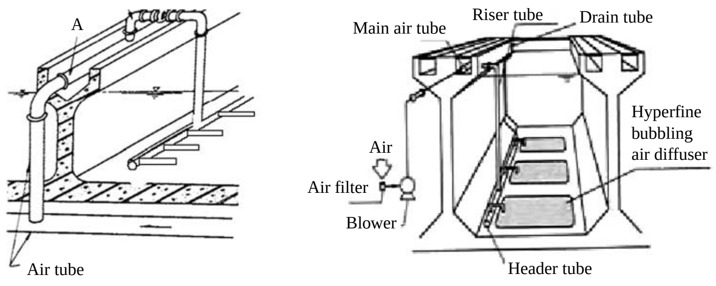
Sludge incinerator. The original multi-step-type incinerator was replaced with a fluid-bed combustion type incinerator during 1992 and 1994 due to its lack of capacity, the need to comply with strengthened emission control laws and the deterioration of equipment. As a result, the method of disposal of ash was changed from landfilling to efficient utilisation as a lightweight aggregate.

Modification and improvement of the treatment plant facilities

Aeration tank equipment

Air diffuser. Aeration power consumption in a sewage treatment plant is said to generally account for 30–60% of the overall power consumption of a treatment plant (Table 3).

The power consumption in this plant accounts for 40–46% of the total during the period of 2000–2002. Therefore, the adoption of a more efficient air diffuser leads to an efficient reduction of power consumption, so it was determined that hyperfine bubbling air diffusers (Figure 3) were employed.



Tube air diffuser

Hyperfine bubbling air diffuser

Figure 3 Air diffuser

Table 3 Rate of power consumption of blower

Item/Fiscal year	2000	2001	2002
Power consumption of overall treatment (kW)	16,564,112	15,759,680	15,159,582
Power consumption of blower (kW)	7,541,770	6,525,680	6,093,500
Rate of power consumption of blower (%)	46	41	40

The ultra-fine air bubble diffusers in the aeration tank are made of a synthetic resin base. The base is covered with a special polyurethane membrane that has small holes and is reinforced with stainless steel channel and frame to maintain air-tightness.

The size of hyper fine air diffuser is 1.2 m wide and 3.6 m long and weighs approximately 100 kg. The mechanism of producing air bubbles is as follows: when air is blown in between the membrane and the base plate, the air expands the membrane. When the membrane expands uniformly with the air pressure, aeration begins. The oxygen-transfer surface of the activated sludge increases because of the ultra-fine air bubbles produced through the membrane holes, and high oxygen transfer efficiency can be achieved.

Aeration tank operation is managed by constant control of the amount of dissolved oxygen. By adopting the use of ultra-fine air diffusers, the average amount of air supplied per tank was reduced to 37,000 Nm^3/d for both No. 1 Tank which began operation in January 2004, and No. 2 Tank which began operation in April 2004. Compared with the old aeration equipment, which required an average air supply of 87,000 Nm^3/d, a substantial reduction in the size of the air supply has been achieved (see Figure 4). As a result, electricity consumption has been reduced (see Table 4).

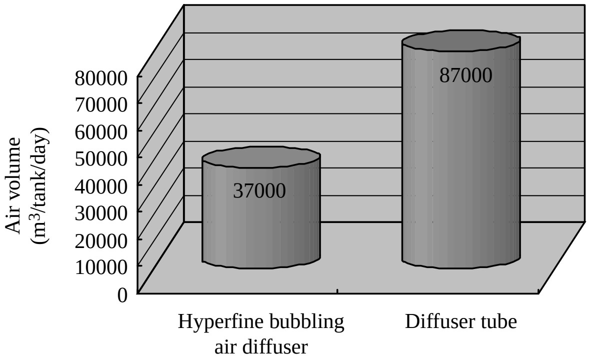


Figure 4 Air volume/tank (average, 2004 APR.–JUL.)

Table 4 Electricity and CO_2 emission reduction effect per aeration tank

Item	New system fine air bubble panel	Old system air diffuser
Amount of suction air (m^3/min)	25.7	60.4
Blower output pressure (kPa)	55	55
Blower suction pressure (kPa)	− 2	− 1.96
Adiabatic efficiency (−)	0.75	0.75
Blower shaft power (kW)	28.0	65.9
Electricity charge (yen/kW)	15	15
Annual electricity charge (1,000 yen)	3,682	8,653
Difference (1,000 yen)	4,971	–
CO_2 emission (kg CO_2/year)	93,276	219,216
Reduction in CO_2 emission (kg CO_2/year)	125,941	–

The reduction in emission was calculated on the basis of an assumed emission rate of 0.38 kg CO_2/kW

Structure. A mixing characteristic test was conducted for an aeration tank. As a result, a completely mixing type providing aeration often occurred in phases with little retention time (Figure 5), mixing performance was improved by blocking a baffle wall and forming a plug flow (Figure 6). The number of tanks that are subject to moderate aeration was increased by approximately three times (increased from $n = 1.5$ to $n = 5.9$ in the tank row model). This allowed improved treatment.

Sludge dewatering equipment. The sludge dewatering equipment has been changed from the filter-press type to the belt-press type. As the belt-press-type dewatering equipment uses polymeric flocculant as a dewatering-assisting agent, it not necessary to add lime. Thus, the amount of sludge cake produced has been dramatically reduced because of the reduction in the ratio of the amount of dewatered solid cake to the amount of solid particles in the sludge supplied to the dewatering equipment (from 1.38 to 0.89; see Figure 7).

Current situation of measures against odours

The odour-producing materials at the Fukashiba Treatment Plant are hydrocarbons and hydrogen sulphides derived from industrial wastewater. In addition, the plant receives

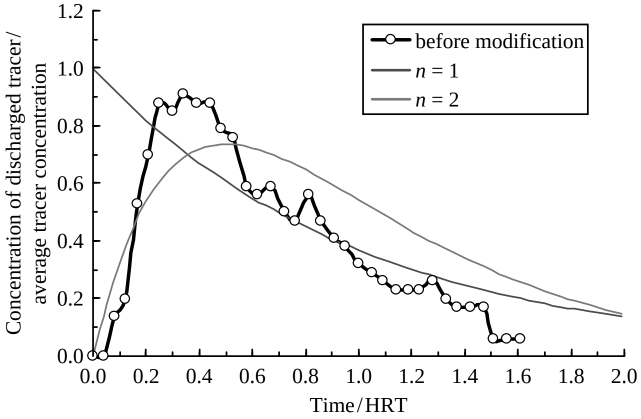


Figure 5 Mixing features of (complete mixing) AT before modification of a baffle wall

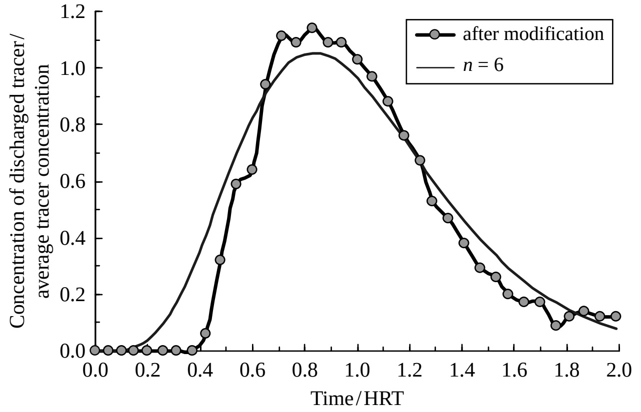


Figure 6 Mixing features of (plug flow) AT after modification of a baffle wall

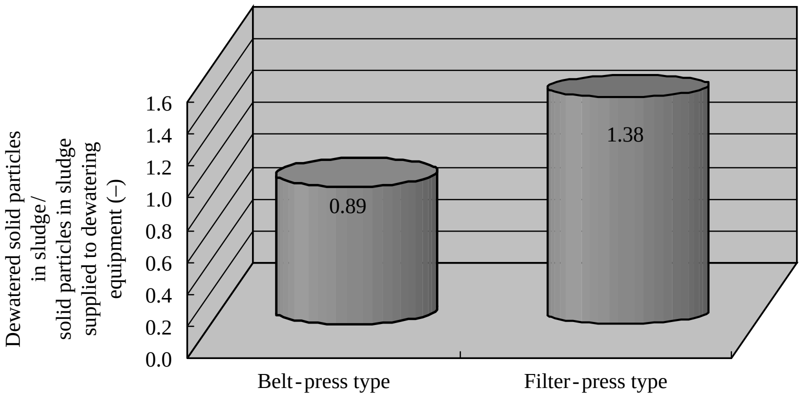


Figure 7 Ratio of amount of dewatered solid particles to amount of solid particles in sludge supplied to the dewatering equipment

influent containing sulphate in concentrations one order higher than that in public sewerage systems. It is critical to take measures against odours for compliance with laws and regulations, protection of labour environment and corrosion control of facilities.

Deodorisation equipment

Deodorisation equipment can be divided into two types, depending on offensive odour sources and odour substance concentrations. Soil deodorisation is used for relatively low concentrations of odour substances while biological deodorisation and activated carbon absorption are used for their high concentrations. The outline of the equipment is shown in Table 5 and Figure 8.

As odour-prevention measures at the three relay-pump stations, biological deodorising equipment and biological deodorising plus activated-carbon-absorbing equipment were installed.

Deodorisation effect

Both methods of soil deodorisation and a combination of biological deodorisation and activated carbon absorption provided high efficiency of removal of hydrogen sulphide and hydrocarbons, toluene and benzene, but it was difficult to remove methyl sulphide while isoprene and vinyl chloride were not removed through these methods.

Special measures must be made of the deodorising facilities which are seen at other wastewater treatment plants. These include aerated oil separators, regulating tanks,

Table 5 Outline of deodorisation equipment

Place	Odour component	Deodorisation method	Treatment conditions
Aeration and oil separation tank etc.	Petrochemical odour, hydrogen sulphide	Soil deodorisation	Airflow rate: 640 m^3/min, Area: 2,322 m^2 Ventilation velocity: 4.6 m/sec Filler: Kanto loam red soil, sand and light-weight aggregate
Grit chamber	Petrochemical odour, hydrogen sulphide	Biological deodorisation + activated carbon absorption	Airflow rate: 40 m^3/min SV = 100/h
Sludge thickener	Hydrogen sulphide		Airflow rate: 50 m^3/min SV = 60/h

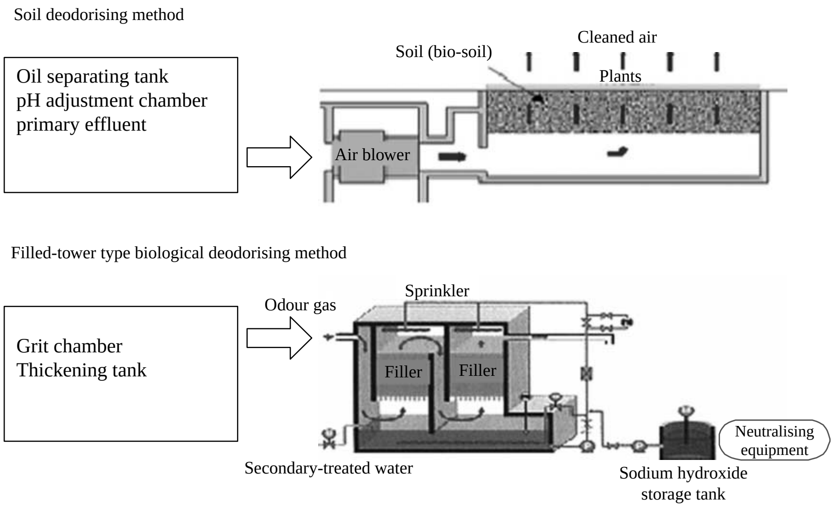


Figure 8 Schematic view of deodorising facility

Table 6 Results of odour substance treatment in aerated oil separation tank/equalising tank and coagulating basin. Unit: ppm

Measurement point/odour component	Hydrogen sulphide	Methyl sulphide	Toluene	Benzene	Isoprene	Vinyl chloride
Soil deodorisation Inlet	1.3	0.082	1.8	0.8	1.7	1.0
Outlet	< 0.001	< 0.0005 ~ 0.023	< 0.1 ~ 0.2	< 0.1	< 0.1 ~ 1.6	< 0.1 ~ 0.9

and soil deodorising equipment to remove the relatively low-concentration odoriferous materials collected by the covered chemical clarifiers. When odour gases make a short-circuit in the ground, the efficiency of removal of the odoriferous compounds dramatically declines. Thus, the soil and grass are periodically replaced. The treatment performance by the soil deodorisation in 2003 is shown in Table 6.

Conclusions

As described above, we fully reviewed efficiency and cost-effectiveness for facility upgrading and modification. In terms of cost-effectiveness, it would be important to reduce operation cost and increasing its efficiency. In addition, various characteristics (nitrification inhibitor, bio-persistency substances, etc.) of wastewater from the petrochemical factories would be taken into account for control.

From now on, it will be necessary to further replace or improve the facilities for the purposes of energy and resource saving; to preserve the work environment by providing odour prevention measures; and to continue stable wastewater treatment under close cooperation with the industries that produce wastewater.

Reference

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