Part 3 Examples of Food Processing Wastewater Treatment

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Chapter 1 Raw Food Material and Wastewater from Production Process

1.1. Products and Characteristics of Wastewater

The characteristics and volume of wastewater discharged from food processing factories vary with the products and production procedures. In factories like accompanying dishes makers and beverage makers, due to changes of products and/or production the wastewater fluctuates in characteristics and volume. Starch making factories in Hokkaido and sake breweries produce for a specified period of the year and only generate wastewater then. Almost all the wastewater in food processing factories is treated using a biological treatment process. The wastewater qualities and treatment methods are summarized in Table 3-1-1. The characteristics of wastewater from food processing factories are characterized by high BOD, SS, and oil concentrations as well as emitting smells from acidification. When aerobic or anaerobic biological processes are applied to wastewater treatment in food processing factories, removing oils and solids prior to the biological process is important for preventing them from disturbing the treatment.

1.2 Treatment Process Selection

When construction of a wastewater treatment plant is planned in food processing factories as well as in other industries, the wastewater properties, site conditions of the wastewater treatment plant, and economical efficiency of the treatment shall be considered for selecting the treatment process. The basic flow in food processing factories is the regulation, aeration, and settling tanks. Although activated sludge and the lagoon were the most widely used processes before the beginning of the 1990s, new processes offering improved capability, lower cost performance, and better care for the environment have taken their places in recent years. A representative type is anaerobic treatment, which has enabled economically stable treatment, owing to the development of technology for drastically upgrading the anaerobic microorganism holding density. As the result, direct discharge of effluent from the process to the sewer has been permitted where sewerage systems are available. As wastewater from food processing factories contains a high portion of organic matter, a hybrid system combining anaerobic and aerobic processes with anaerobic pre-treatment can contribute to substantial

Table 3-1-1 Typical industrial wastewater characteristics and treatment methods

Industries	Wastewater	Major pollutants									Typical treatment methods
		pH	BOD	COD	SS	Oil	N	P	Color	Others	
Food	Brewery		○	○	○						AS, AD
	Beverage		○	○							AS, AD
	Vegetable oil		○	○		◎					OS, AS, AD,
	Milk/daily product		○	○							AS
	Starch		○	○	◎						AS
	Daily dishes		○	○							AS
	Confectionary		○	○							AS
Petroleum refinery	Refinery Deforming			○		◎				smell	OS, AS, AD,
Chemistry	Petrochemistry	○	○	○							N, FL, AS, AD
	Chemical fertilizer	○	○	○	○		◎	◎			N, AS, DN, PR
	Polymer chemistry	○	○	○							N, AS, AD
	Organic chemistry	○	○	○		○					N, FL, AS, AD
	Oil/fat			○	○	○					OS, FL, AS
	Pharmaceuticals		○	○	○						AS
Steel	Blast furnace			○	○						CS, FI
	Steel, hot mill			○	○	○					OS, FI,CS, FI
	Col mill	○				○					N, FI
	Cokes		○	○		○	◎		○	phenols	N, OS, AS、FI
Paper/pulp	SKP		○	○	○				○	smell	IC, AS
	KP	○		○	○				○	smell	CS, FL, BL
	SCP, CGP		○	○	○				○	smell	CS, FL、AS, IC
	Washing/screening				○						FL, AS
Dyeing	Desizing		◎	○	○						CS, FL, AS
	Scouring			○							CS, FL, CH
	Bleaching			○							CS, FL, CH
	Dyeing			○					○		N, CS, FL、O3
Machinery	Semiconductor	○	○	○						fluoride	N, AS, CS, FI, MF, O3
	Automobile					○					FL, FI, MF
	Plating	○								cyanide	N, FL, CS, CH, O3
Fiber	Wool		○	○	○						CS, AD、IC
	Synthetic fiber	○	○	○							N, CS, FL, AS

Remarks: (1) treatment methods, N: neutralization, FI: Filtration, OS: oil separation, CS: coagulation–settling
FL: dissolved air floatation, AS: aerobic biological treatment,
AD: anaerobic biological treatment, MF: membrane separation,
CH: chemical treatment, O3: ozonation, chlorination, IC: incineration
DM: denitrification, PR: phosphorous removal, BL: black liquor recovery
(2) specifically heavily polluted items are marked by ◎
(3) in case of advanced treatment, filtration, activated carbon absorber and membrane separation are provided in addition to above unit operations

energy savings by producing methane gas. One defect in the activated sludge process is sludge bulking. New technologies, however, such as the floating media biofilm activated sludge process and the activated sludge process equipped with UF membrane instead of the settling tank, have been developed to prevent bulking problems. The effluent standards have lately become more stringent, and the nitrogen removal requirement is being specially strengthened. Denitrification processes have been dramatically improved by developing the technology of the single-phase sludge circulating denitrification process and equipment like floating medias holding high-density anaerobic microorganisms. Advanced treatment including coagulation-sedimentation, high-rate sand filtration, and dissolved air floatation is used for removing BOD, COD, and SS. For removing color, coagulation-sedimentation, ozonation or ozonation with ultra violet radiation, and activated carbon adsorption are used. For treating excess sludge, which has a rapidly rising disposal cost, biological wastewater treatment processes, which generate almost no sludge, have been put into use. Where wastewater qualities and effluent standards are conditioned favorably, sludge generation can be made close to zero. Figure 3-1-1 shows the conceptual relations among the effluent qualities, site conditions, purpose of treatment, and process flow.

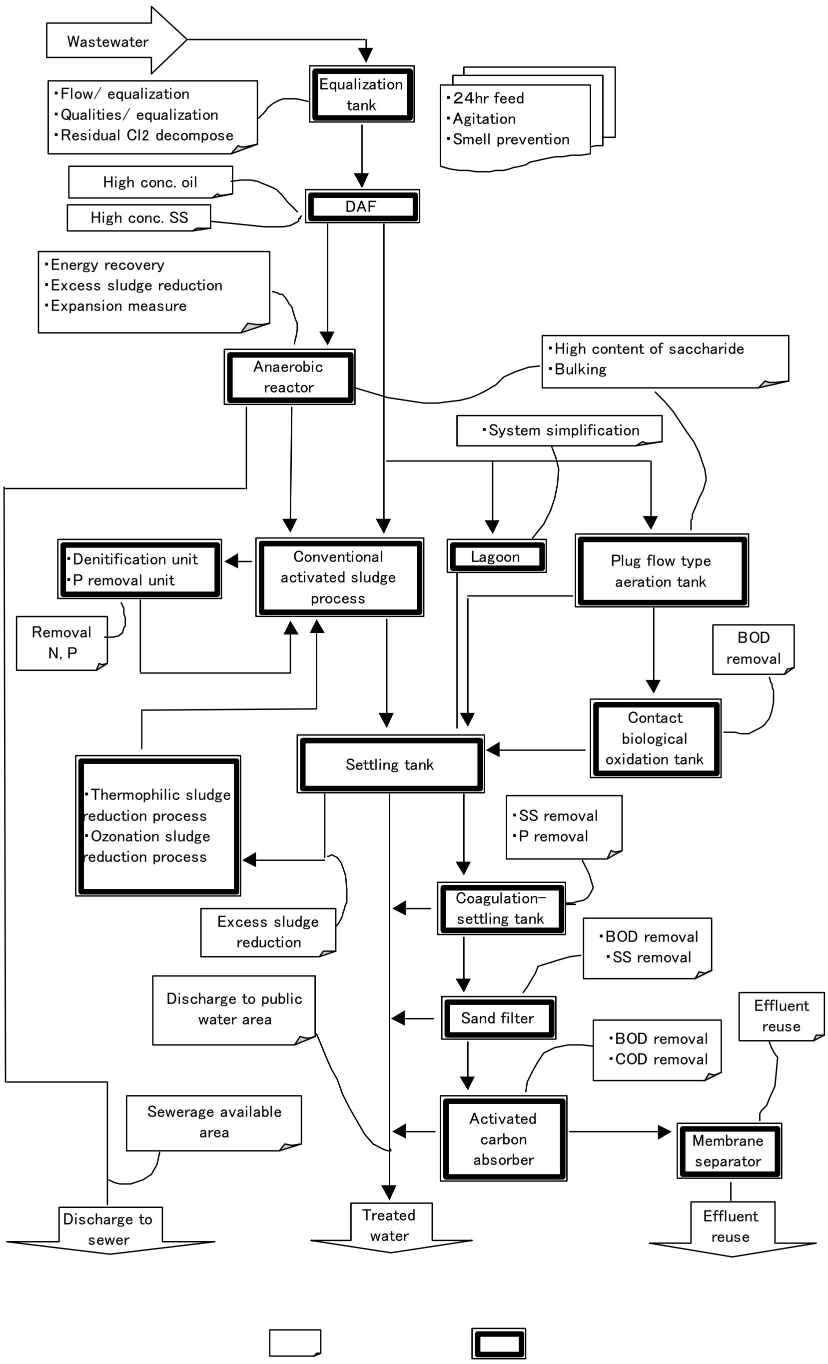

Figure 3-1-1 Treatment systems and treatment requirements in food processing wastewater

Chapter 2 Beverages

2.1 Wastewater Volume and Qualities

As the raw water qualities used in beverage factories significantly affect the products, better quality water than tap water is used as the raw material, after being treated by chemical dosing coagulation, sand filtration, activated carbon filtration, degasification, and other processes. As shown in Figure 3-2-1, carbon dioxide gas, sweeteners like sugar or syrup and flavors are dissolved into the water. Much of the wastewater comes from washing and rinsing cans, bottles, cleaning equipment, containers, floor, etc. Although wastewater volume varies with the products and factories, water 10 times the product ingredients is generally needed and has to be treated. As a standard[1] , the wastewater volume is about 50 m^3 for producing 1,000 standard containers. Carbonated drink ingredients are shown in Table 3-2-1[2] . Wastewater qualities are shown in Table 3-2-2[2] . As the table clearly shows, wastewater is alkaline because alkaline detergents are used in washing. Since BOD and SS concentration are high, direct discharge into public waters without treatment causes environmental pollution.

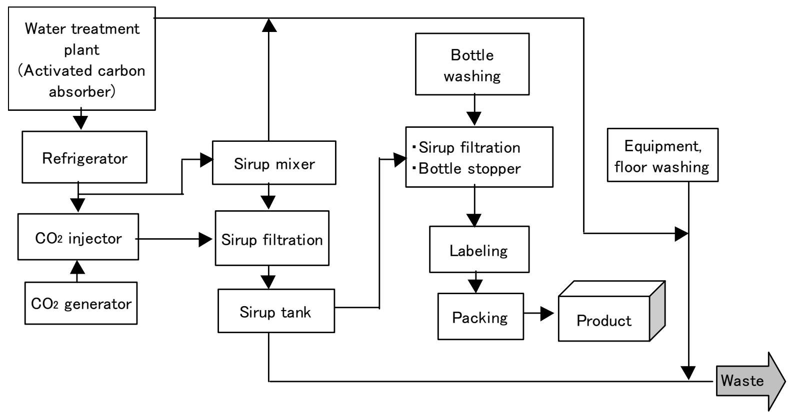

Figure 3-2-1 Carbonated beverage manufacturing process and wastewater

Table 3-2-1 Properties of carbonated drink

Carbonated drink	BOD (mg/ℓ)	Total solids (mg/ℓ)	Total acidity (mg/ℓ)	pH
Coke	67,400	114,900	1,526	2.4
Pepsi Cola	79,500	122,000	1,466	2.5
Canada Dry	64,500	101,300	3,150	2.4

Table 3-2-2 Wastewater properties in carbonated drink factories

Factories	pH	Total alkalinity (mg/ℓ)	BOD (mg/ℓ)	SS (mg/ℓ)
A	１０．６～１１．４	390	380	170
B	１０．０～１１．２	250	660	160
C	１０．４～１１．２	220	250	340
Average		290	430	220

2.2 Example of Actual Treatment[3)]

1. Design Condition

Main product	Coke	
Containers	Glass bottles, plastic bottles, cans	
Wastewater volume		4,000 m^3/d, hourly peak flow 300 m^3/h
Wastewater qualities	BOD	400 mg/ℓ (daily average)
	pH	5.8~11.0
	SS	50~70 mg/ℓ
Effluent qualities	BOD	30 mg/ℓ (daily average)
	pH	7.0~8.0
	SS	20~30 mg/ℓ

2. Process

As this factory was located in an area where the effluent standards were lenient and sufficiently wide space was available for wastewater treatment plant, the lagoon process was adopted due to the ease of operation and limited sludge generation. Figure 3-2-2 shows the wastewater treatment scheme. After large floating solids are removed in the grid-oil separator tank, the raw water flows into the lagoon, where it is oxidized and decomposed by the activated sludge therein. As the lagoon is 20,000 m^3 in total capacity and uses 5 days detention time, the BOD-MLSS load is 1/5~1/10 of the conventional activated sludge process. The endogenous respiration is accelerated and limited excess sludge is generated. The lagoon is divided into four parts, and the aerator in each part is intermittently operated for supplying oxygen and agitating the water. The last part of the lagoon plays a dual role, the final upgrading of the quality by aeration and removing the sludge by settling. Aeration is given for 4~7 hours a day and the supernatant, relieved of sludge, is discharged from a gate taking 12 hours during the aeration halt, while part of the finally settled sludge is returned by pumping to the first part of lagoon. As the wastewater tends to be short of nitrogen and phosphorous, nutrients for activated sludge, urea, and phosphate ammonium are dosed as supplements.

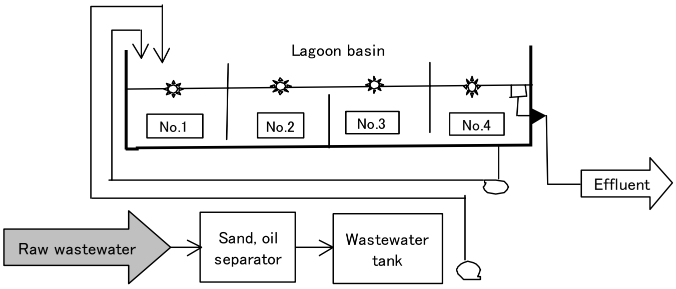

Figure 3-2-2 Schematic flow of Carbonated beverage manufacturing wastewater treatment

3. Performance Results

Although this wastewater treatment facility is located in Sapporo where the outdoor temperature goes down to nearly -15℃ in winter, the water in the lagoon is kept at 8℃ due to the high raw water temperature. Good treatment is achieved throughout the year. Typical raw wastewater quality is shown in Table 3-2-3. The average, maximum, and minimum effluent qualities of the year are shown in Table 3-2-4. No sludge has been drained since 1974 when the operation started.

Table 3-2-3 Raw wastewater properties (monthly average)

Line	pH	COD (mg/ℓ)	BOD (mg/ℓ)	SS (mg/ℓ)
1,2	10.1	320	162	3.8
3,4	10	175	151	16.6

Table 3-2-4 Treated water quality in carbonated drink wastewater treatment

Items	Temp. ℃	Water temp. ℃	pH	COD (mg/ℓ)	BOD (mg/ℓ)	DO (mg/ℓ)	SS (mg/ℓ)	Trans-parent	Coli form (No./1mℓ)
Yearly average	10.7	16.7	7.3	9	2.6	4.5	4.3	40	105
Maximum	33	25.4	7.6	11.3	5.4	9.2	11.3	50	279
Minimum	−15	8.5	7.1	7.8	1.6	1.7	2.4	20	2

2.3 Considerations in Operation and Maintenance

Though the lagoon process is operated easily, sludge bulking tends to occur. It is important to maintain a well-balanced ratio of BOD, N, and P control the bulking. As the process is operated under low BOD-MLSS load conditions, the nitrogen in raw wastewater is oxidized into nitrate and then reduced to nitrogen gas under anoxic condition in the final part of the lagoon. Micro fine nitrogen bubbles adhering to sludge particles cause poor settling and carry-over of the sludge. This sometimes results in effluent quality deterioration and performance degradation due to MLSS reduction.

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Chapter 3 Breweries

3.1 Beer

3.1.1 Wastewater Volume and Qualities

In the beer brewing process, malts, rice, and cornstarch are fed as supplemental raw materials into the breeding tank and saccharized. The malt liquid, then dosed with hops, is filtered. The filtrate, after heat-processed in a boiling caldron, cooling down to 7~10 ℃, and being dosed with yeast, is fermented for 7~10 days before becoming the final product. The quality and volume of wastewater vary with the brewing process and if there is a malt producing process because some beer breweries now use dried malt mass-produced at malt-producing factories elsewhere. Figure 3-3-1 shows all the production lines and wastewater discharge points. A large volume of wastewater containing high BOD and SS is discharged from the stage of screw-press-dewatering filtered residues after the breeding tank, and the dewatered residue is fed to livestock because of high nutrient contents. Wastewater with high BOD and SS comes out of the hop separation tank too. After fermentation in the main fermentation tank, yeast is separated, washed, and reused. Part of it is also reused for food, medicine, and other uses. These processes, consuming water for washing and rinsing, are a main source of wastewater. Beer is aged in the after-fermentation tank washed after periodical draining of settled yeast, discharging wastewater. In the final filtration process residual yeast, insoluble proteins, tannins, and other items are removed from the brewed beer. Diatomite used in the process is washed out into the washing water of filter equipment, separated at the inlet of the wastewater treatment plant, and disposed of as solid waste. Heat sterilization is not applied for draft beer production. Therefore, a large quantity of wastewater is generated from washing filter equipment, as it is very important for microbial control of the product. The last production stage is bottling. The recovered bottles and casks are washed with alkaline and acid detergents, and residual beer and labels come out into the wastewater. The standard wastewater volume is generally about 10~20 times the beer produced[1)].

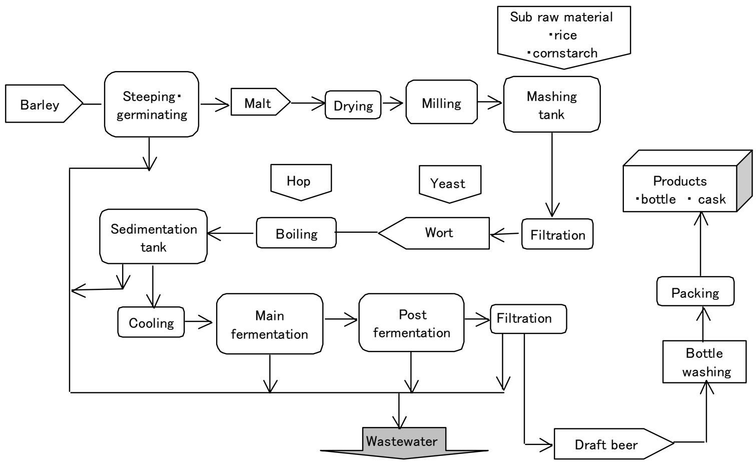


Figure 3-3-1 Beer brewery and wastewater discharges

3.1.2 Example of Actual Treatment

1. Design Condition

Wastewater volume		7,000 m^3/d (brewing=5,400 m^3/d, bottling=1,600 m^3/d)
Wastewater qualities	BOD	1,500 mg/ℓ(brewing=1700 mg/ℓ, bottling=300 mg/ℓ)
	SS	65 mg/ℓ(brewing=800 mg/ℓ, bottling=150~300 mg/ℓ)
Effluent qualities	BOD	＜20 mg/ℓ(anaerobic effluent <200 mg/ℓ, activated sludge effluent ＜20 mg/ℓ)
	SS	＜20 mg/ℓ(anaerobic effluent <200 mg/ℓ, activated sludge effluent ＜20 mg/ℓ)

2. Process

This factory had treated previously wastewater with the activated sludge process and, when expanding production and after reviewing the performance, added an anaerobic treatment process in order to cope with the increased production and reduce the wastewater treatment cost. Figure 3-3-2 shows the schematic flow diagram. In the screening chamber, floating solids are removed from the 7,000 m^3/d wastewater, mixture of wastewater from the brewing, bottling, and canning processes, and the wastewater flows into the equalization tank. There it is divided into two parts, a part of 6,400 m^3/d for the newly built anaerobic treatment plant and another part of 600 m^3/d for the old activated sludge plant. Wastewater for the anaerobic treatment is removed of SS with the dissolved air floatation unit (DAF), neutralized by sodium hydroxide or hydrochloric acid, and then fed into an anaerobic treatment reactor where the inner temperature is kept at 36℃ by steam heating. Methane gas generated in the anaerobic treatment reactor is desulfurized, stored in a gas holder, and used for fueling the boiler. Scum separated by DFA is returned to the aeration tank to reduce the volume. While 600 m^3/d wastewater for aerobic treatment flows into the aeration tank, the sludge is removed from the settling tank, mixed with the effluent from the anaerobic process, and then discharged into the sewer. Excess sludge (granule sludge) generated in the anaerobic treatment reactor is stored for making up the loss due to granule runoff. Excess sludge from the activated sludge process is thickened in the thickener, dehydrated, and then hauled out as industrial waste.

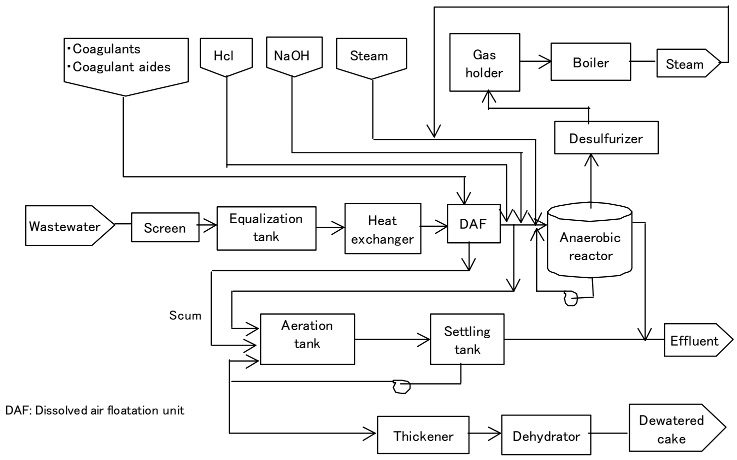


Figure 3-3-2 Schematic flow of beer brewery wastewater treatment

3. Performance Result[1)]

As the anaerobic process plays the main part of the wastewater treatment here, explanation of the aerobic process is omitted. Specifications of the anaerobic treatment facility are described in Table 3-3-1. The sludge load in the table means the BOD load of the sludge (granules) in the anaerobic treatment reactor, which is an important indicator for operation performance. Figure 3-3-3 shows the relations between the BOD-sludge load, temperature, and BOD removal rate. It is seen that if the temperature in the reactor drops, then the BOD removal rate falls down by about 5%. The figure also shows that if the temperature in the reactor is kept at 28℃ or above, stable performance will be secured up to 0.6 BOD - sludge load (kg BOD/kg VSS・d). The BOD-sludge load in this plant is usually around 0.3 (kg BOD/kg VSS・d) and more than 90% of BOD removal is stably achieved at all times. Figure 3-3-4 shows the effluent quality under the influent's fluctuating load for 3 months, and it clearly indicates the stability of performance in spite of the fluctuations.

Table 3-3-1 Performance of anaerobic treatment in beer brewery wastewater

Items	Specifications
Temperature in reactor	35. 5℃
pH in reactor	7.2
Sludge load	0. 31kg BOD/kg VSS/d
Influent BOD	1, 420mg/ℓ
Effluent BOD	104mg/ℓ
Influent SS	117mg/ℓ
Effluent SS	135mg/ℓ
BOD removal rate	93%

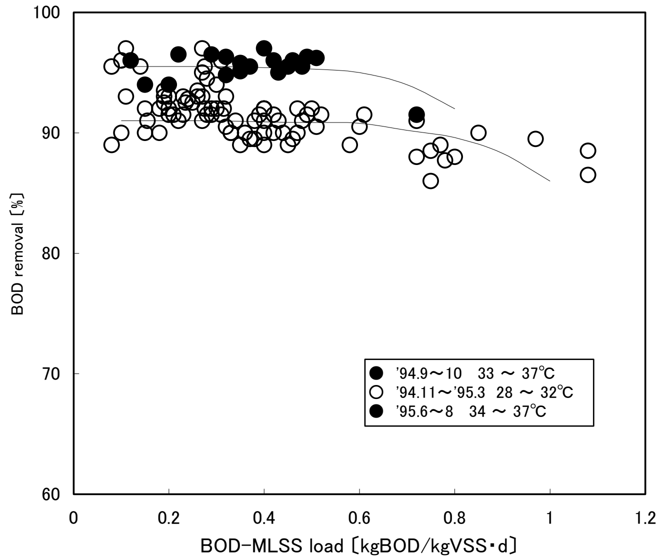


Figure 3-3-3 BOD-MLSS versus over BOD removal rate

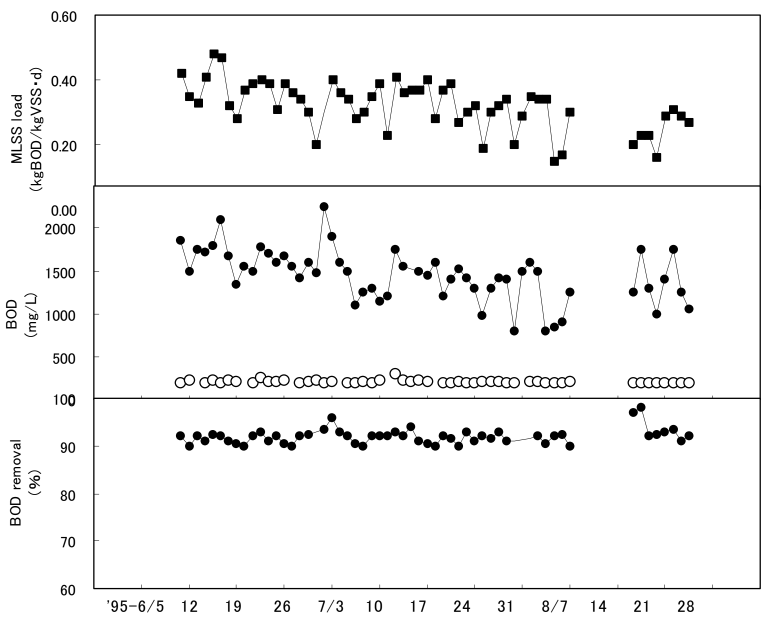


Figure 3-3-4 BOD-MLSS load and BOD removal rate in beer brewery wastewater treatment

3.1.3 Considerations in Operation and Maintenance

Two anaerobic methods are used in treating industrial wastewater. They are the UASB (Up-flow Anaerobic Sludge Blanket) process using microbial granulation and the fixed bed process using microbial biofilm on the surface of media. Though the UASB process can hold more anaerobic microorganisms per volume than the fixed bed process and makes a higher loading rate operation possible, it contains the risk of granule runoff. The major cause of granule runoff is that adherence of SS in raw wastewater to the granules makes it difficult to separate the gas bubbles from the granules. The relation between SS in influent raw wastewater and granule runoff from the reactor is shown in Figure 3-3-5. The allowable SS weight in influent raw wastewater shall be less than the weight of the multiplying granules in the reactor, which is 400 mg/ℓ in this case.

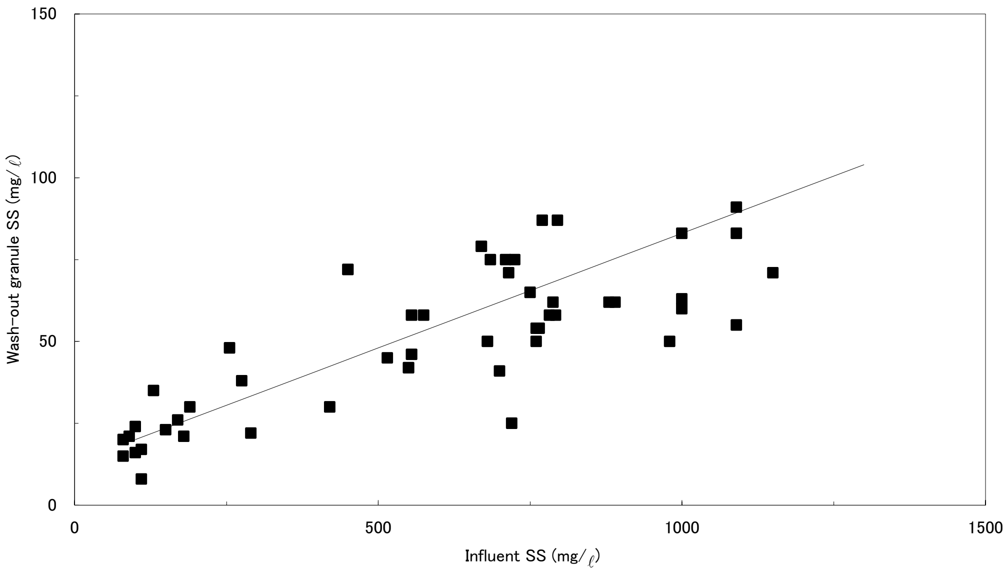


Figure 3-3-5 Relations between influent SS and wash-out granule SS

3.2 Sake

3.2.1 Wastewater Volume and Qualities

The relation between the process of brewing sake and generating wastewater is shown in Figure 3-3-6. Rice polisher washes rice bran off from polished rice, and starch flows out from the operation. As the major pollutant portions in sake breweries are discharged here, the pollutants for the wastewater treatment depend significantly on the volume of water used in the washing operation. Efforts to remove rice bran from polished rice by rotary shifters or dry rice polishers prior to washing have been made lately in order to reducing the wastewater volume and concentration. Wastewater re-circulation, definitely contributing to reducing the volume and load for the settling tank, makes operating wastewater treatment easier, although it raises the concentration. Other wastewater comes from the bottling process and washing equipment. As washing recycled bottles is outsourced now and the BOD of wastewater from washing bottles is as low as a few mg/ℓ, it can usually be discharged after pH adjustment. The wastewater volume is generally about 20~30 times the sake as a rough standard[2)].

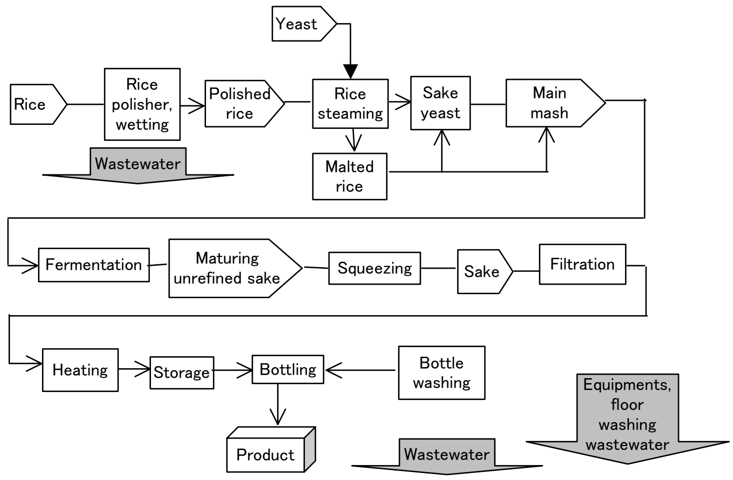


Figure 3-3-6 Sake brewing process and wastewater

3.2.2 Example of Actual Treatment

1. Design Condition

Wastewater volume	250 m³/d (rice-wash-wastewater: miscellaneous wastewater= 120 m³/d: 130 m³/d)		
Wastewater qualities	BOD	750 mg/ℓ	(rice-wash-wastewater 4,000 mg/ℓ)
	SS	120 mg/ℓ	(rice-wash-wastewater 5,000 mg/ℓ)
Effluent qualities	BOD	＜20 mg/ℓ	
	SS	＜30 mg/ℓ	

2. Process

The wastewater treatment plant is located in an area surrounded by a good natural environment, and advanced treatment is incorporated into the plant. The schematic flow is shown in Figure 3-3-7. Solid contents in the wastewater from rice washing are separated in the coagulation-sedimentation tank and the supernatant is sent, together with miscellaneous wastewater, to the aeration tank. The effluent from the activated sludge process, after separating SS in the coagulation-sedimentation and sand filtration tanks, is processed through activated carbon and chlorinated before it is discharged into the river. As the sake brewing wastewater tends to be short of nitrogen and phosphorous, urea and phosphate ammonium are dosed as supplement nutrients. Sediment materials from rice-wash-wastewater are used for livestock feed after being coagulated, thickened, and dehydrated by dosages of harmless coagulants.

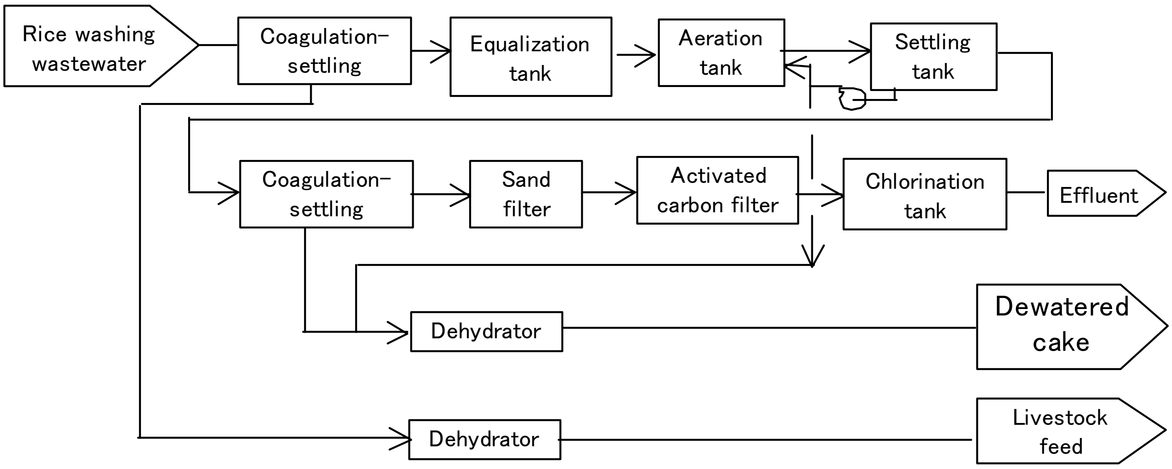


Figure 3-3-7 Schematic flow of rice washing wastewater

3. Performance Results

BOD and COD in the wastewater from washing rice can be substantially removed by coagulation–sedimentation. The test results of the properties of sampled wastewater and settlability are respectively shown in Table 3-3-2 and Table 3-3-3. The wastewater was sampled just after washing the rice and the removal rates of BOD and COD by coagulation-sedimentation were about 85% and 80%. The rates are lowered as time elapses, due to fast putrefaction of the wastewater. When the same testing was made for samples collected 48 hours after washing the rice, the removal rates of BOD and COD were down to 35% and 56%. These changes were caused by the solid contents in the wastewater being solubilized, and changing to soluble BOD and COD, and they made coagulation difficult. A test result of coagulating the wastewater is shown in Figure 3-3-8[3)] . The results show that SS coagulated with PAC 250 as a coagulant, and nonionic polyelectrolyte as a coagulant aid settles it very speedily. In this factory, the effluent BOD of activated sludge process is around 10 mg/ℓ, and then it is lowered down to a few mg/ℓ through the advanced treatment system.

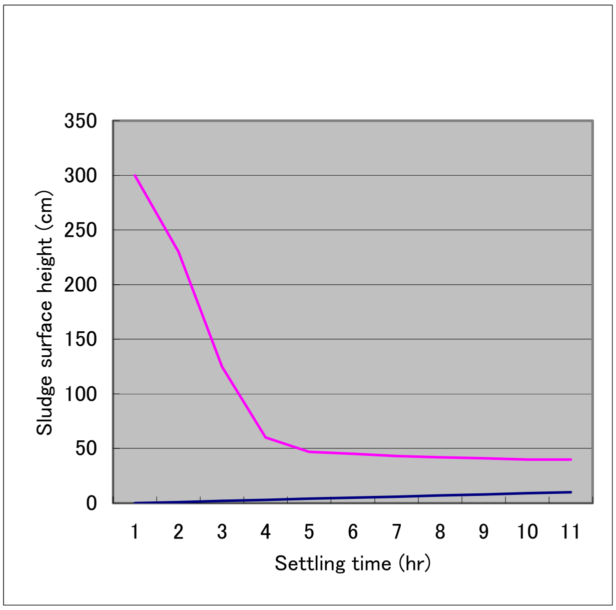
Table 3-3-2 Rice-wash-wastewater properties for experiment

Appearance	pH	SS (mg/ℓ)	COD (mg/ℓ)	BOD (mg/ℓ)
Cloudy	6.6	717	990	1,250

Table 3-3-3 Coagulation-settling test result for rice-wash-wastewater

Run	Chemical dosage volume (mg/?)				Coagulation states			Effluent qualities			
	Alum	PAC 250A	Noah	Konan-Floc	Floc stability	Settle-ability	Floc volume	pH	SS (mg/?)	COD (mg/?)	BOD (mg/?)
1	200	—	58	10	C	C	10	6.8	<50	230	215
2	300	—	105	10	C	C	12	6.7	<50	209	216
3	400	—	150	10	B2	B2	15	6.8	<30	196	215
4	500	—	200	10	B1	B1	16	6.8	<30	191	208
5	1,000	—	365	10	B3	B3	26	6.8	<30	179	185
6	—	200	15	10	C	C	10	7	<50	213	232
7	—	300	25	10	C	C	12	6.8	<30	219	232
8	—	400	42	10	B	B	15	6.9	<30	213	232
9	—	500	58	10	B	B	16	7	<30	213	221
10	—	1,000	94	10	C	C	23	6.8	<30	196	212

Remarks: coagulation states, settlability: B: good, B1: better than B, B3 best, C: normal



Condition: pH 7.0, PAC250A 390mg/ℓ, Konan Floc 3000S 10mg/ℓ

Figure 3-3-8 Settling test result of coagulated rice-washing-wastewater

3.2.3 Considerations in Operation and Maintenance

The important factor for securing continuous and stable performance in wastewater treatment is pre-treatment by coagulation-sedimentation. As described above, SS shall be coagulated, settled, thickened, and taken out of the treatment system before the wastewater starts putrefying. Moreover, the settlability of activated sludge in sake brewing factories is inherently poor. This is due to the dispersion, poor settlability, and poor compaction of sludge caused by the viscosity from delayed polysaccharide decomposition, which originates from the nitrogen shortage in the wastewater. This phenomenon is called sludge bulking. Sludge bulking in sake brewing wastewater treatment is different from other bulking as the number of filamentous bacteria is few and viscous froth forms in the aeration tank. Adding nitrogen and bulking inhibitor effectively solves the problem. As most sake production is limited seasonally, wastewater is not generated for many months. For ready re-starting of wastewater treatment, molasses and rice bran are fed as nutrients during the off seasons to maintain the sludge activity. If a sewage treatment plant or wastewater treatment plant using activated sludge is located nearby, another method is importing live sludge a few days before start up, putting it in the emptied aeration tank, and acclimatizing it by feeding nutrients like rice bran to prepare it for receiving wastewater.

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Chapter 4 Oils and Fats

4.1 Wastewater Volume and Qualities[1)]

Vegetable oils are produced from rapeseed, corn, and soybean by the processes shown in Figure 3-4-1. The production line consists of two processes, extracting oils from raw materials and refining the extracted oils. The vegetable oil expression methods of industrial scale are classified into the expression, extraction, and expression-extraction methods. The expression method squeezes oils out of dried and heat-treated raw materials, leaving 4~7% oil content. The extraction method extracts oils from heat-treated raw materials using normal hexane as solvent. The expression-extraction method is a series of the expression and extraction methods. In the refining process, dust, saccharides, proteins, gummy substances, fatty acids, pigments, smelling substances, and other such items are removed. Phosphoric acid, sodium hydroxide, and water are used in the process. Filtration aid is also dosed to improve filtration and refining. Water consumption volume per unit of raw material varies with the production capacity level of the vegetable oil manufacturing factory. Table 3-4-1 shows the annual production capacity level, percentage of consumption classified by different water sources (drinking, industrial, recirculated, sea, etc.), and the consumption volume per unit of raw material. The consumption volume per raw material unit varies from 30~80 m^3/ton. Table 3-4-2 shows the annual production capacity level as well as the percentage of consumption classified by different processes and usages (cooling, production process, bottle washing, boiler, sanitary, etc.). Consumption in the production processes is relatively low percentage-wise except for cooling, and most of the wastewater comes from deacidifying and deodorizing operations in the refining process. Wastewater qualities generated by deacidifying and deodorizing operations are shown in Tables 3-4-3 and 3-4-4.

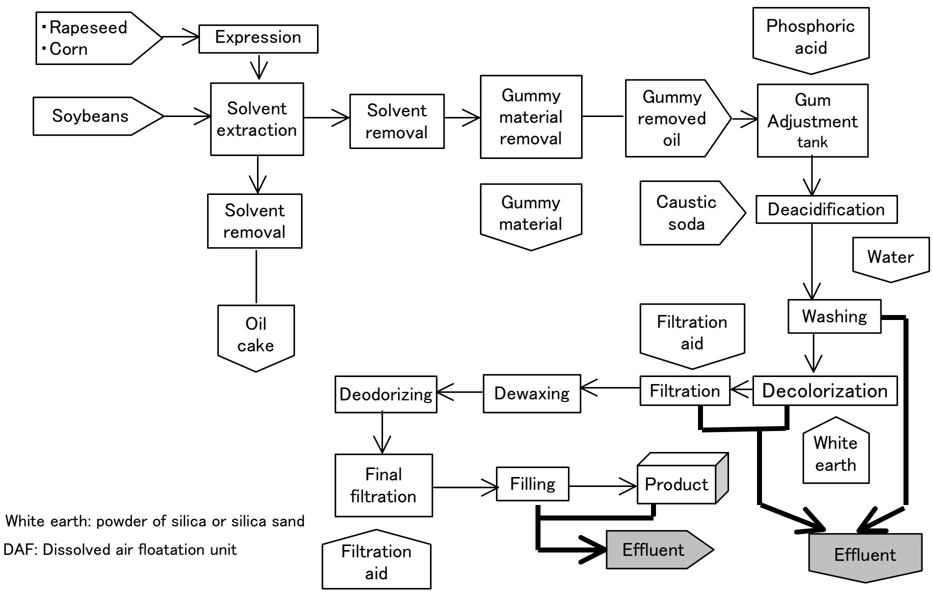

Figure 3-4-1 Schematic flow of vegetable oil processing and wastewater

Table 3-4-1 Plant scales and water consumption in vegetable oil manufacturing

Raw materials consumption (1,000 ton/year)	Service water usage ratio (%)					Water (m^3) per raw material (ton)
	Tap water	Industrial water	Recycle water	Sea water	Others	
＜10	5	18.5	12.1	0	64.4	35.9
10～50	2.1	8.7	45.3	25.1	18.8	36.7
50～100	1	8.5	11	73.4	6.1	83.1
100～300	0.8	2.5	70.6	26	0.1	62.2
≧300	0.5	7.3	56	36.2	0	31
Average	0.8	6.1	53.9	36.2	3	41.9

Table 3-4-2 Water consumption rate at each process in vegetable oil manufacturing (%)

Raw materials consumption (1,000 ton/year)	Expression, extraction process		Refining process		Bottle washing	Boiler feed	Sanitary, others
	Cooling	Process	Cooling	Process			
＜10	25.9	0	54.1	7.2	1.6	4.6	6.6
10～50	29.4	0.7	51	5.8	0.6	3.5	9
50～100	31.5	0.2	42.5	1.3	0.1	2.8	21.7
100～300	41.5	0.1	56.4	0.3	0.1	1.1	0.5
≧300	51.1	0	41.2	3.4	0.1	2.8	1.4

Table 3-4-3 Wastewater qualities of deacidification process

pH	6～7
COD	400～7, 400 mg/ℓ
N-hexane extract	1, 000～10, 000 mg/ℓ

Table 3-4-4 Wastewater qualities of deodorizing process

pH	neutral
COD	50～100 mg/ℓ
N-hexane extract	50～100 mg/ℓ
SS	30～400 mg/ℓ

4.2 Example of Actual Treatment

4.2.1 Example of Dissolved Air Floating Unit[1)]

When wastewater discharged from vegetable oil manufacturing is mixed with sea water, coagulation takes place. In Japan, many factories are located in coastal areas because imported raw materials are transported in bulk by sea, and the location facilitates using sea water for wastewater treatment. Table 3-4-5 shows reducing COD in soybeans oil wastewater by dosage with salt. When 30 g of salt is dosed for one liter of wastewater and agitated, floc is formed by coagulation and settles. This removes 90% of COD in the supernatant.

Table 3-4-5 Salting-out test result for vegetable oil manufacturing wastewater by dosing synthetic sea water

Run	Wastewater(mℓ)	synthetic sea water (mℓ)	COD in treated water (mg/ℓ)
1	100	200	574
2	100	300	193
3	100	400	133
4	100	100	447
5	100	100	275
6	100	200	247

COD in raw wastewater is 7,400 mg/ℓ

1. Process

The schematic flow of two-stage dissolved air floatation units (DFA) are shown in Figure 3-4-2. Almost the same amount of sea water as wastewater is added in the first stage DFA. The condensed scum is dewatered and carried out as industrial waste. The effluent from the first-stage DAF is adjusted for pH and dosed coagulant, and then treated in the second-stage DAF before being discharged. The second stage scum is dewatered similarly as the first stage scum. The volume is about 20% wastewater and contains 5% solids.

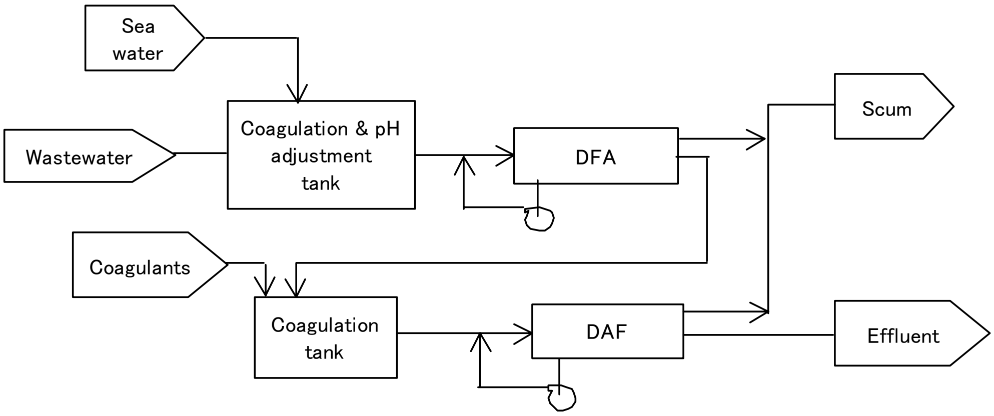

Figure 3-4-2 Dissolved air floatation (DFA) treatment of vegetable oil processing factory

2. Performance Results

More than 90% of COD is removed at the first stage DAF and 80~90% of remaining COD is further removed at the second stage DAF.

4.2.2. Example of Biological Treatment

1. Design Condition

Wastewater volume		600 m³/d
Wastewater qualities	BOD	8,000 mg/ℓ
	TOD	14,000 mg/ℓ
	SS	1,700 mg/ℓ
	N	400 mg/ℓ
Effluent qualities	BOD	＜280 mg/ℓ
	SS	＜280 mg/ℓ

2. Process

This treatment plant can concurrently recover methane from organic materials in the wastewater, reduce the load on the activated sludge process, save energy consumption, and reduce excess sludge generation. The schematic flow of the treatment plant is shown in Figure 3-4-3. The raw wastewater is adjusted for the temperature by heat exchanger and fed to the anaerobic treatment reactor, where the temperature is kept at around 36℃, and the floating media are fully filled. Anaerobic microorganisms held on the surface of the media generate methane by decomposing organic materials. Then the effluent is fed to the upstream denitrification tank where nitric acid in the returned sludge water from the settling tank is reduced to generate nitrogen gas. After denitrification, organic materials in the effluent from the denitrification tank are oxidized and nitrified in the aeration tank. Then, the effluent is fed to the downstream denitrification tank where nitrogen is removed again by reducing the nitric acid. The effluent from the denitrification tank is separated from the sludge at the settling tank, and finally discharged. Settled sludge in the settling tank is returned to the upstream denitrification tank. Methane gas generated in the anaerobic treatment reactor has hydrogen sulfide removed by the desulfurizer and is used for the fueling boiler. Generated steam is used for heating the anaerobic treatment reactor.

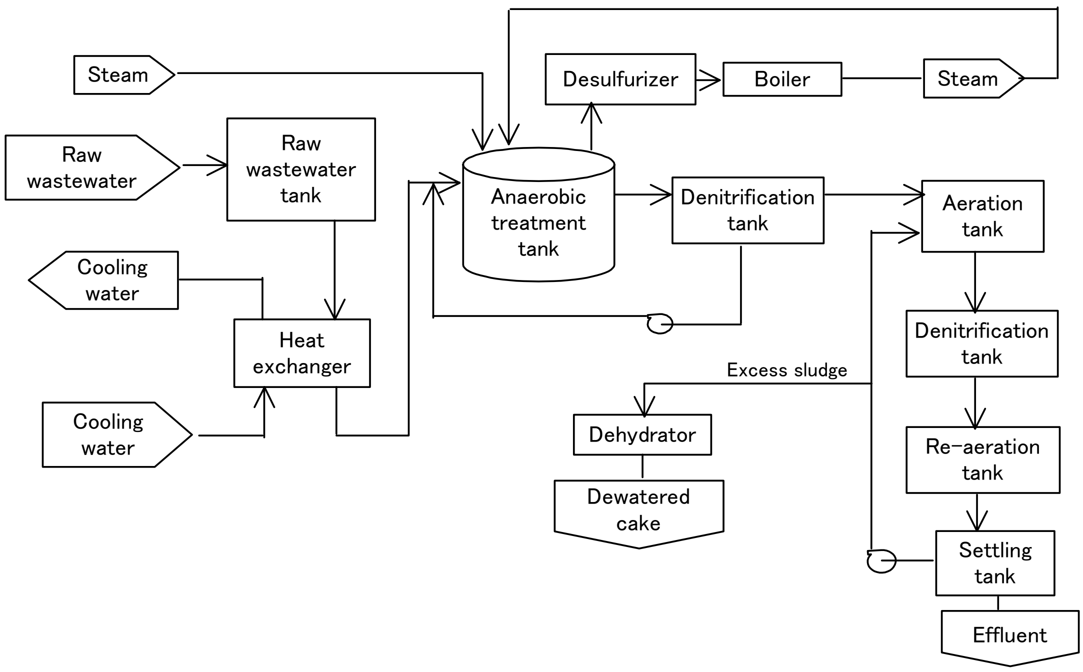

Figure 3-4-3 Schematic flow of vegetable oil processing wastewater treatment

3. Performance Results

It took some time before the anaerobic microorganisms adhered, grew, and held on to the media surface in this fixed bed type anaerobic treatment reactor. Since then, however, the reactor has maintained stable operation, maintaining over a 70% removal BOD rate, despite the unexpected and sudden substrate changes in the wastewater and load conditions. The activated sludge process downstream keeps the BOD reduction stable at more than 90%. The volume of generated gas varies affected by pH in the anaerobic treatment reactor. When the pH goes on the alkaline side, the volume decreases due to the higher solubility of the carbon dioxide, and when the pH inclines to the acid side, the volume increases. If pH is kept at 6~8, the methane gas content in the generated gas is almost equal to the theoretical value. The volume of generated excess sludge is 1/3~1/5 of the aerobic biological process. Energy savings and sludge volume reduction, goals of introducing the processes, have been attained in this plant.

4.3 Considerations in Operation and Maintenance

Although the wastewater volume in vegetable oil factories is relatively small and fluctuates less, removing oil sufficiently in the oil separator for pre-treatment is important because of the high oil content. Especially in the case of anaerobic and activated sludge treatment, much attention is paid to the oil removal. In the case of two stage dissolved air floatation, the effects of coagulants in the second-stage coagulation are influenced by alkalinity and salt concentrations in the wastewater. Therefore, coagulating conditions shall be optimized by using jar testing. The coagulating conditions of wastewater differ for raw materials like rapeseeds and soybeans and understanding them is important for sludge management.

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Chapter 5 Milk and Dairy Products

5.1 Wastewater Volume and Qualities [1)]

The production lines of milk and dairy products are shown in Figure 3-5-1. In the milk and dairy product processing factories, water is used for washing, cooling, air conditioning, boilers, sanitation, etc. The wastewater originates from washing equipment, machines, floor, etc.; accidental leakage of raw materials and products; and dumping off-spec products and contaminated raw materials and products. Figure 3-5-2 shows, in percentages, the water consumption by various processes. About 60% of wastewater comes from washing. After production works terminate, the equipment used is cleaned by chemicals and, before and after the cleaning, washed and rinsed with water. Thus, the wastewater is generated. Table 3-5-1 shows the properties of wastewater and the generated volume per unit of product, classified by the products. As production of milk and dairy products peaks in the summer, so does the wastewater volume. Depending on the degree of production activities, the volume and pollutant concentration of wastewater fluctuates within a 3 to 1 range by the hour and 2 to 1 by the day. The pollution load is especially high on the weekends.

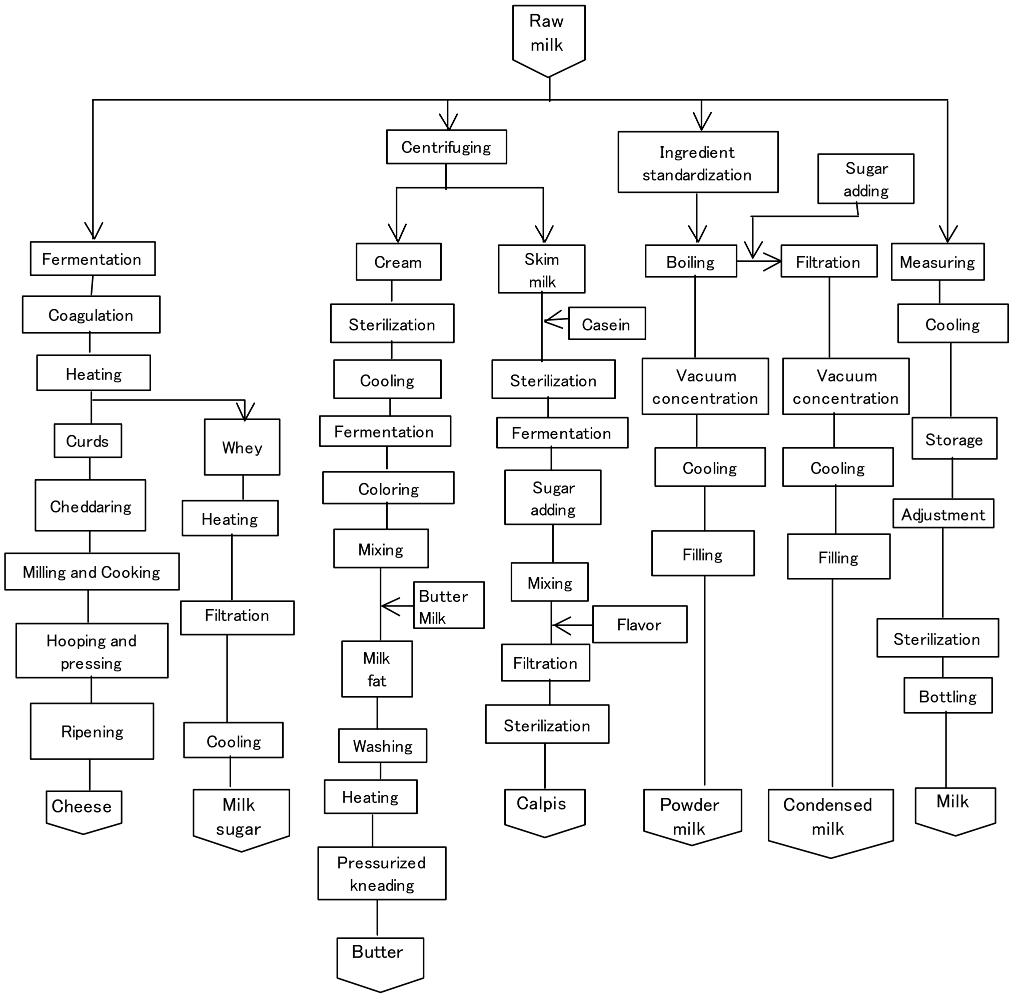

Figure 3-5-1 Schematic flow of milk and dairy products

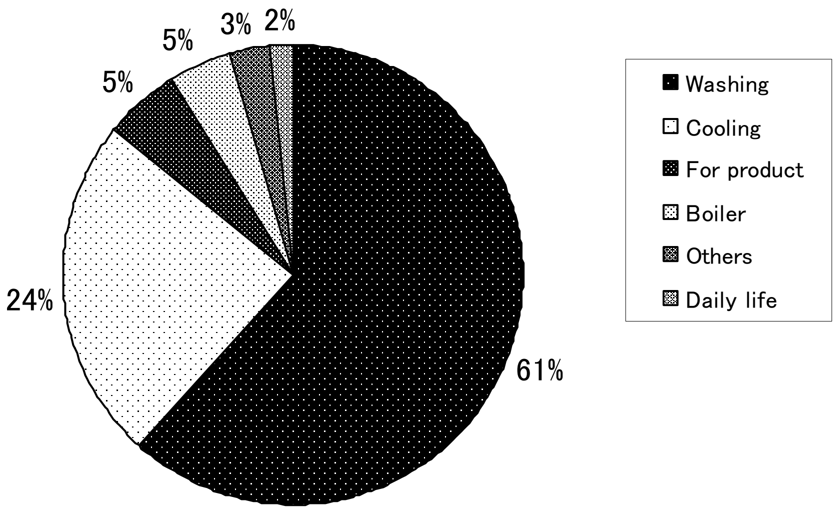

Figure 3-5-2 Water consumption rate by various processes

Table 3-5-1 Wastewater volume and qualities in milk and dairy product processing factory

Product	pH	BOD mg/ℓ	COD mg/ℓ	SS mg/ℓ	Oil※ mg/ℓ	Water/product m^3/ton
Milk, milk drink	11	750	400	150	90	10
Dairy products	10	600	300	100	60	3
Desserts	11	750	350	250	130	13
Cold cakes	11	800	400	200	200	20

※ N-hexane extract

5.2 Example of Actual Treatment

A conventional activated sludge process in milk and dairy product processing factories is applied to this factory[2)].

1. Design Condition

Wastewater volume 540 m^3/12 hr. /d (factory; 12 hours operation)

Wastewater qualities pH 8.4

BOD 200 mg/ℓ

Effluent qualities pH 6~8

BOD 20mg/ℓ

SS 20 mg/ℓ

COD 20 mg/ℓ

Coli No. ＜330/mℓ

2. Process

As the hourly and daily fluctuations of volume and pollutant loads of wastewater are large, it is desirable for the conventional activated sludge process that the wastewater be sent to the aeration tank after equalization of the fluctuating quantity and quality in the equalization tank. Although an extended aeration process is sometimes adopted for stability against load fluctuations and easy operations, it needs more space than the activated sludge process. In this example, the activated sludge process was adopted. Nutrient supplements are not needed because the wastewater contains BOD, nitrogen, and phosphorous in a well-balanced ratio. Although excess sludge generation in the activated sludge process is generally higher than in the extended aeration process, the excess sludge in this plant was reduced to the same volume as in the extended aeration process by aerobic digestion of thickened sludge. The schematic flow of this plant is shown in Figure 3-5-3. The raw wastewater is screened for floating solids, equalized in the equalization tank, and fed to the aeration tank. After separating the sludge in the settling tank, it is sterilized by chlorine, and then discharged. Excess sludge is oxidized, and the volume is reduced in the aerobic digestion tank.

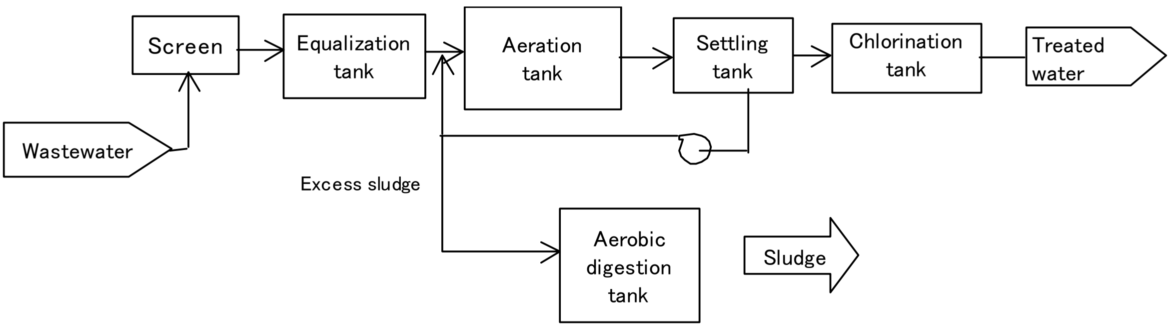

Figure 3-5-3 Schematic flow of wastewater treatment of milk and dairy product factory

3. Performance Results

The operation results in this plant are shown in Table 3-5-2. In spite of the pollutant concentrations in the raw wastewater being lower than the design figure, the BOD in the effluent sometimes exceeded 20 mg/ℓ of the design figure during the period just after start-off when the MLSS concentration is low. BOD in the effluent, however, has decreased responding to the increase of MLSS. Excess sludge is aerated for 10~20 days in the aerobic digestion tank, oxidized, reduced in volume, and then returned to the aeration tank. By this operation, the processed excess sludge balances, in weight, the SS carried out into the effluent, and eliminates the need for sludge transportation to the outside.

Table 3-5-2 Milk and dairy wastewater treatment result by activated sludge process

Date	Raw wastewater				Aeration tank		Treated water			
	pH	BOD (mg/ℓ)	COD (mg/ℓ)	SS (mg/ℓ)	MLSS (mg/ℓ)	DO (mg/ℓ)	pH	BOD (mg/ℓ)	COD (mg/ℓ)	SS (mg/ℓ)
1-May	7.6	121	41	6	1,200	4.2	7.1	19	7	22
5-May	7.3	134	46	17	1,110	4.6	7.1	22	7.4	16
10-May	7.4	110	36	8	1,308	3.2	7.2	16	5.1	18
10-Jul	7.1	140	47	5	2,100	3.6	7	11	3.4	8
10-Sep	6.8	96	31	3	1,860	2.8	7	14	5.2	6
10-Oct	7.4	126	40	6	2,460	3.2	7.1	18	6.1	10
10-Nov	7.6	118	40	4	3,120	3.8	7.2	12	4.2	8
10-Dec	7.2	180	58	9	3,080	3.8	7	12	4.8	20

5.3 Considerations in Operation and Maintenance

In wastewater treatment of milk and dairy products, sludge settlability sometimes becomes poor and accordingly SS concentration in the effluent rises. It is caused by the over-aeration of activated sludge. Over-aerated sludge floc becomes less coagulable, disperses in water, and does not settle. Relations between the MLSS concentrations and SV_{30}, an indicator of sludge settlability (height of the settled sludge blanket after 30 minutes settling, %) for both the activated sludge process and extended aeration process are shown in Figure 3-5-4[1)] . When the MLSS concentration rises, the DO concentration falls, and the treatment performance deteriorates. In this case, MLSS shall be lowered by extracting sludge to resume the DO level at 1~2 mg/ℓ.

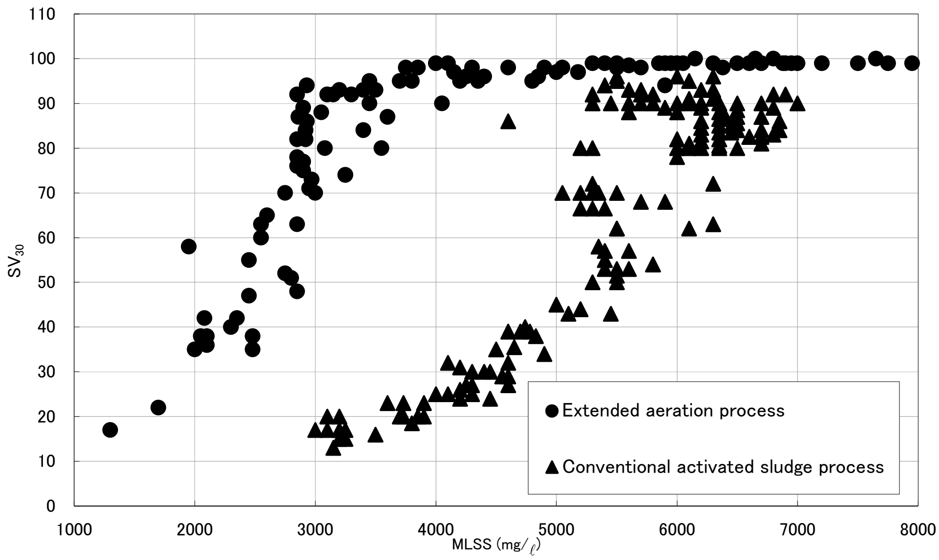

Figure 3-5-4 Relations between MLSS concentration and SV30 in activated sludge process and extended aeration process

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Chapter 6 Agriculture Product Processing

6.1 Wastewater Volume and Qualities

The industries consuming a lot of water in agriculture product processing include producers of wheat starch, potato starch, sweet potato starch, and sugar. Potato starch processing factories are located in the main potato producing area in Hokkaido, while wheat starch processing factories and sugar factories are located where sufficient water and convenient sea transportation are available because they import their raw materials from overseas. The wastewater treatment processes are, therefore, characterized by these geographical locations. Water used in wheat starch processing is 7~15 times, by weight, of the raw wheat, and the water consumption varies depending on the production methods. Main pollutants in the wastewater are BOD and SS, and they become putrid easily. The wheat starch production process and the wastewater generation points are shown in Figure 3-6-1[1)]. The typical wastewater qualities of wheat starch processing are shown in Table 3-6-1. Water used in potato starch processing is 13~44 m^3 per ton of potatoes[2)]. The difference in water consumption per raw material unit (unit water consumption) depends on the starch recovery rate in the separation process, in which starch, milky liquid, and lees are separated from the smashed potatoes and some ingredients are refined and condensed. This separation process is the major source of wastewater. Potato starch processing factories are generally small scale and discharge a large volume of wastewater with high BOD and SS concentration. These factories are mostly operated in the seasons between the end of summer and early winter. The typical wastewater qualities of potato starch processing are shown in Table 3-6-2. The unit water consumption in sweet potato starch processing is about half of potato starch processing, but the amount of generated BOD is nearly equal. In Japan, sugar industries previously used sugarcane and beet as raw materials, but sugarcane has faded out, and they now focus production on refining imported crude sugar. Cane sugar production consumes 15~20 times the water per ton of raw material and discharges high concentrations of BOD and SS, while water consumption as well as the concentration of BOD and SS are low when using imported crude sugar. In beet sugar processing, wastewater of 8~10 times the weight base of raw materials is discharged from the flume-process in which beets are transported and washed in the flowing water, occupying 50~60% of the total wastewater. Other major sources of wastewater are the lime-cake process for extracting sugar from the beets, the Steffen process for recovering sucrose from spent molasses, and the ion exchange process which has lately replaced the Steffen process. Although the wastewater volume ratio per unit of raw material varies in different factories, generally it is about 1.3 times for the lime-cake wastewater, 30~40% for the Steffen wastewater, and 25~30% for the ion exchanger wastewater [3]. Wastewater qualities in beet sugar processing are shown in Table 3-6-3.

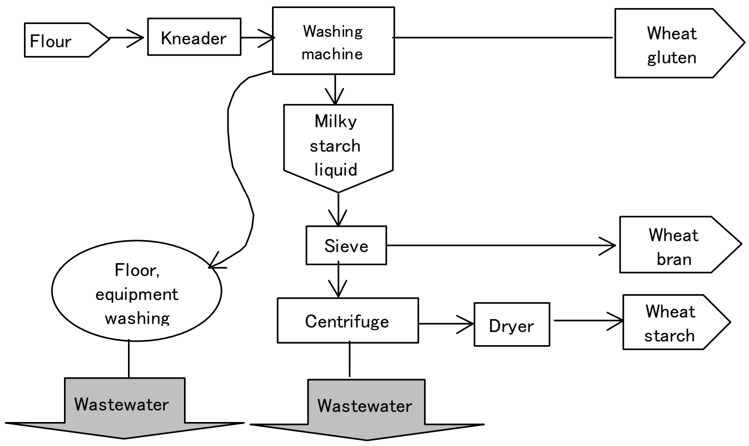

Figure 3-6-1 Schematic flow of wheat starch manufacturing process and wastewater

Table 3-6-1 Wastewater qualities of wheat starch processing

Items	Max.	Min.	Aver.
pH	4.4	5.4	–
TS (mg/ℓ)	12,800	16,400	14,600
DS (mg/ℓ)	10,140	12,000	11,100
SS (mg/ℓ)	2,600	4,400	3,500
CODcr (mg/ℓ)	–	20,600	18,750
BOD (mg/ℓ)	9,400	13,200	11,300
TOC (mg/ℓ)	4,600	5,800	5,200
T–N (mg/ℓ)	500	600	550
T–P (mg/ℓ)	170	190	180

Table 3-6-2 Wastewater volume and pollutants load of potato starch processing (per ton of raw materials)

Items	Flume–process wastewater	Separation–process		Total	
		Conventional	Concentration	Conventional	Concentration
Wastewater volume (m^3)	4. 4～31	7～4	–	13～44	–
BOD (kg)	0. 1～2. 0	13～15	6. 2～16	14～56	17～40
SS (kg)	1. 3～57	10～44	0. 6～12	12～67	8～22

Table 3-6-3 Wastewater qualities of beat sugar processing

Items	Flume process	Lime -cake process	Steffen process
pH	6.7～7.4	–	12.5
BOD (mg/?)	200～630	1,420	4,000
SS (mg/?)	700～3,090	2,860	1,300
TDS (mg/?)	–	3,313	7,000

6.2 Example of Actual Treatment (wheat starch)[1), 4)]

A wastewater treatment plant in factories manufacturing wheat starch and wheat gluten from flour is described here. Being introduced for the pre-treatment of the existing activated sludge process, this plant has contributed to energy savings, reducing excess sludge generation, and stabilizing operation of the activated sludge treatment plant.

1. Design Condition

Wastewater volume maximum 550 m^3/d, average 500 m^3/d

Wastewater qualities CODcr maximum 20,000 mg/ℓ, average 16,000 mg/ℓ

Effluent qualities CODcr removal rate: >80 %, effluent of anaerobic treatment reactor

2. Process

The schematic flow diagram is shown in Figure 3-6-2. The raw wastewater flows from the equalization tank, through the heat exchanger, to the anaerobic treatment reactor. The anaerobic treatment reactor is filled inside by floating plastic media, and 7 pH and 36℃ temperature are maintained. The pH is adjusted by sodium hydroxide dosages. Heating is done by steam. The gas generated in the anaerobic treatment reactor is desulfurized, stored in a gas holder, and used for drying products. The effluent from the anaerobic treatment reactor is treated by the activated sludge process and then discharged.

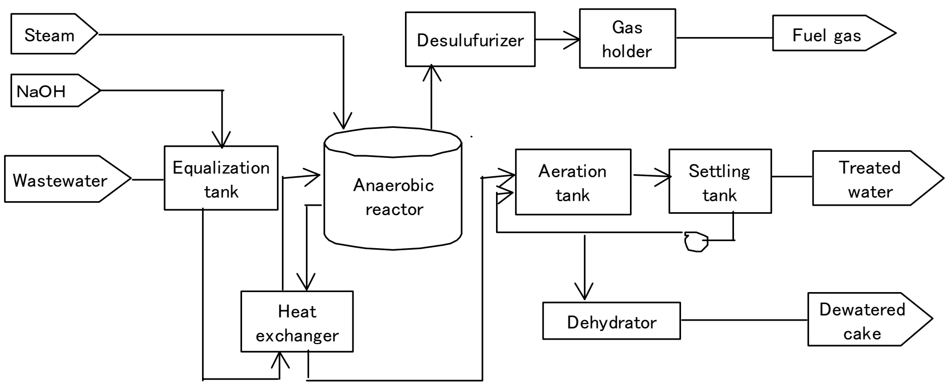

Figure 3-6-2 Schematic flow of wastewater treatment in wheat starch factory

3. Performance Results

Start-up of the anaerobic treatment reactor took 3 months due to the slow growth rate of anaerobic microorganisms. Operating data in the start-up period is shown in Figure 3-6-3. During this period, the loads were increased, monitoring the relation between CODcr load input and methane gas volume generation output as well as organic acid concentrations in the effluent. When the load-increase exceeds the growth rate of methanogenic microorganisms, low fatty acids such as acetic acid and propionic acid start to increase. Therefore the load-increase was controlled so that the fatty acid concentrations did not exceed several hundreds mg/ℓ. The treatment results from the anaerobic process are shown in Table 3-6-4. The effluent qualities in the activated sludge process are shown in Table 3-6-5.

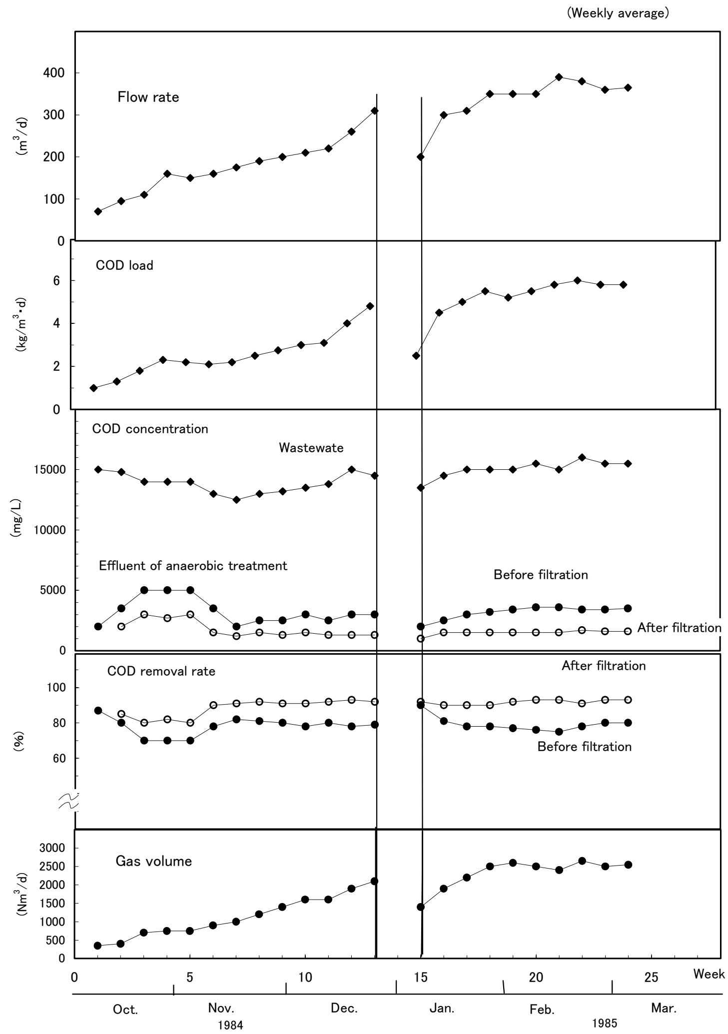

Figure 3-6-3 Operating results at start-up-period in anaerobic treatment process

Table 3-6-4 Anaerobic treatment result of wheat starch processing

Items	Apr	Jun	Aug	Oct	Dec	Feb
Wastewater (m^3/d)	386	359	343	395	400	424
Influent TOC (mg/ℓ)	4,860	5,063	5,350	4,602	5,495	5,382
Effluent (mg/ℓ)	2,252	1,785	1,874	1,650	2,029	2,135
pH	7.1	7.2	7	7	7.1	7.1
Generated gas (m^3/d)	1,569	1,781	1,810	1,615	2,012	1,688
Methane conc. (%)	67	71	72	71	71	71

Table 3-6-5 Effluent qualities in anaerobic treatment in wheat starch processing wastewater (as post activated sludge treatment)

COD (mg／ℓ)	15～56
BOD (mg／ℓ)	22～46
pH	7．0～8．0
T-N (mg／ℓ)	40～70
T-P (mg／ℓ)	60～80

6.3 Considerations in Operation and Maintenance (wheat starch)

Though the fixed bed anaerobic treatment reactor is very stable in operation, the media interspace tends to be clogged by microorganisms, and periodic purging with nitrogen gas from the bottom of the reactor is essential. In this operation, peeled anaerobic sludge flows into the aeration tank, and the load on the treatment process increases temporally. Therefore this purging operation is carried out once or twice a year, during the off-period in summer and/or the end-of-the-year in winter. By introducing the anaerobic treatment for pre-treatment, the bulking problems of the activated sludge process ceased, and sludge settlement in the settling tank was improved, but nitrogen in the effluent increased. The nitrogen, however, was easily reduced by making part of the aeration tank anaerobic or by intermittently stopping aeration.

6.4 Example of Actual Treatment (potato starch)

Potato starch processing factories in Hokkaido operate seasonally from the end of summer to early winter. The lagoon process is often adopted because operation start-up is easy, tolerance for load fluctuations is high, and large areas are available in Hokkaido. A typical example is introduced below.

1. Design Condition

Wastewater volume 3,600 m^3/d

Wastewater qualities BOD 1,800 mg/ℓ

Effluent qualities pH 5.8~8.6

BOD ＜120 mg/ℓ

SS ＜150 mg/ℓ

2. Process

Wastewater from this starch factory is fed directly into the aeration tank (lagoon) without using an equalization tank. The aeration tank is a pond built by excavating earth with a holding capacity of 30,000 cubic meters. It is equipped with 5 surface floating aerator units of 37 kilowatts, and the detention period is about 8 days. The liquid in the aeration tank is pumped to the settling tank through a flow control device, separated from the sludge, and then discharged as treated water. As the effluent standards for SS is generous, detention time in the settling tank is designed at 6 hours. Settled sludge is returned to the aeration tank similarly as in a usual activated sludge process.

3. Performance Results

The operation results for the month of October in the year following the startup are shown in Table 3-6-6. Part of the settled sludge at the bottom of the lagoon is drawn out to use as fertilizer after the suspension of production in early winter, and the lagoon is usually left as it is until startup the next year. The leftover sludge is used for restarting treatment. The average influent BOD and SS at the peak operation in October are 85% and 80% of the design basis. The effluent BOD is always lower than the design limit, although SS exceeds the design limit temporarily due to the carryover of inactive sludge just after restarting. Even when temperature in the aeration tank drops to zero deterioration of the effluent water quality is not recognized, because BOD-MLSS load is designed at the low rate of 0.05 (kg BOD/ kg MLSS・d).

Table 3-6-6 Treatment result of potato starch processing wastewater

Items	Wastewater			Treated water		
	Aver.	Max.	Min.	Aver..	Max.	Min.
Wastewater (m^3/d)	3,040	3,360	2,760	–	–	–
pH	–	6.8	5.7	–	7.5	7
SS (mg/ℓ)	602	3,730	176	119	188	54
CODMn (mg/ℓ)	939	2,440	409	85	116	60
BOD (mg/ℓ)	1,440	2,230	873	68	91	42
Water temp. (°C)	–	17	2	–	17	2

6.5 Considerations in Operation and Maintenance (potato starch)

When septicity of the sludge proceeds due to suspension of activated sludge treatment for a long time, sludge bulking caused by filamentous bacteria tends to occur. This is especially true for potato starch, which contains about 100 mg/ℓ of sulfides that abnormally accelerate the growth of filamentous sulfur bacteria. Due to the abnormal change of the microorganic phase, it takes a long time to restore operations to the original state for restarting operation. The following will prevent this problem. First, provide a minimum level of aeration to control the progress of the sludge septicity. Then store thickened wastewater in the equalization tank and intermittently feed it during suspended operation. When restarting, dose coagulant to coagulate dispersing activated sludge floc so that a minimal concentration of MLSS is maintained by preventing the carryover of floc, and transport sludge from a sewage treatment plant if necessary. Furthermore, it is desirable to start aeration and nutrient dosages, such as remaining wastewater or spent molasses, a few days before restarting treatment in order to acclimatize the activated sludge. If a big load is applied to immature sludge at the initial stage, SS carryover from the settling tank will be heavy. In a lagoon where wastewater is treated by activated sludge, sludge is digested aerobically. The aerobic digestion leads to sludge dispersion and deterioration of sludge settlability, which cause carry-over of SS from the settling tank. If the carry-over of SS is serious, continuous dosing of coagulants to the center well in the settling tank will effectively correct it.

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Chapter 7 Takeout Dishes

7.1 Wastewater Volume and Qualities

The size of daily dish processing factories varies in a wide range from relatively small factories that prepare specific dishes to large ones that manufacture 400 products including cakes, breads, and noodles. This chapter introduces a wastewater treatment plant at a large factory that manufactures various products with only one day off at New Year's Day every year[1]. The water consumption per unit of raw material varies widely depending on products, so data for each raw material is not obtainable. This factory, for example, uses raw materials of 9,800 tons of flour, 3,600 tons soybeans, and 137 tons alimentary yam paste powder to produce 6,842 tons of noodles, 5,900 tons loaf bread, 4,600 tons sweet bun, 2,700 tons alimentary yam paste, 8,500 tons soy bean curd, and 1,400 tons fried bean curd. The factory uses 350,000 m^3 of water a year, discharging 80% as wastewater. Calculations based on the above-mentioned figures lead to average unit figures of about 20 m^3 per ton of raw materials and about 9 m^3 per ton of products, indicating that this is definitely a water-oriented industry. The production processes of boiling beans, natto, and tamago-tofu (egg-bean curd), which discharge high concentration wastewater, are shown in Figure 3-7-1, and those wastewater qualities are shown in Table 3-7-1.

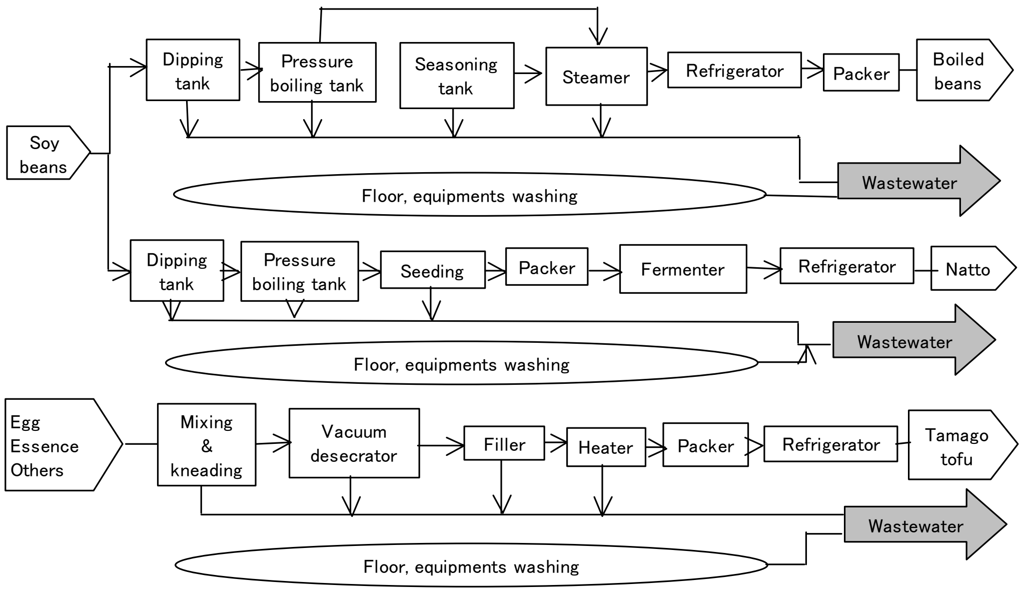

Figure 3-7-1 Schematic flow of large scale daily dishes processing and wastewater

Table 3-7-1 Wastewater qualities in each process in daily dishes processing factory (mg/ℓ)

Items	Tamago-tofu			Natto			Boiling beans		
	High conc.	Middle conc.	Low conc.	Boiling	Subme-rged	Pot washing	Subme rged	Vacuum pot	Cleaning
BOD	6,260	486	82	814	100	117	2,370	358,000	2,220
TOC	3,340	272	29	572	96	90	1,360	222,000	1,470
S-TOC	1,450	175	22	499	93	102	1,290	196,000	780
SS	2,720	143	212	195	5	73	78	675	63
N-hexane extract	4,780	689	<5	<5	<2	<5	<5	6	<5
T-N	438	38	2	84	8	41	52	799	13
T-P	22	4	1	8	1	10	20	152	4

7.2 Example of Actual Treatment

1. Design Condition

Wastewater volume 1,600 m^3/d (high concentration wastewater: 1,505 m^3/d, low concentration wastewater: 650 m^3/d)

		high concentration wastewater	low concentration wastewater
Wastewater qualities	pH	4.3	6.3
	BOD (mg/ℓ)	2,310	760
	SS (mg/ℓ)	550	130
	n-hexane extract (mg/ℓ)	110	50

Effluent qualities	pH	5~9
	BOD	＜200 mg/ℓ
	SS	＜200 mg/ℓ
	n-hexane extract	＜ 30 mg/ℓ

2. Process

As this factory is located in an area where a sewerage system is available, wastewater is collected and treated separately according to high and low concentrations, before being discharged to the sewer, as shown in Figure 3-7-2. The low concentration wastewater is screened of floating large solids, treated through coagulation dissolved flotation process, neutralized, and then discharged. The high concentration wastewater is also screened of floating large solids and goes through the equalization tank and heat exchanger to the anaerobic treatment reactor. The anaerobic treatment reactor is equipped with floating plastic media inside and kept at 7 pH and about 36 ℃. The pH is adjusted by sodium hydroxide. Heating is provided by steam. Methane gas generated in the anaerobic treatment reactor is desulfurized, stored in a gas holder, and used for drying products. The effluent from the anaerobic treatment reactor is treated by the aerobic biological treatment plant with floating media. At the next step, in order to remove SS peeled off from the media surfaces and SS in influent raw wastewater, the effluent is coagulated by ferric chloride and polyelectrolyte, treated in a DAF unit and, after pH adjustment, discharged into the sewer.

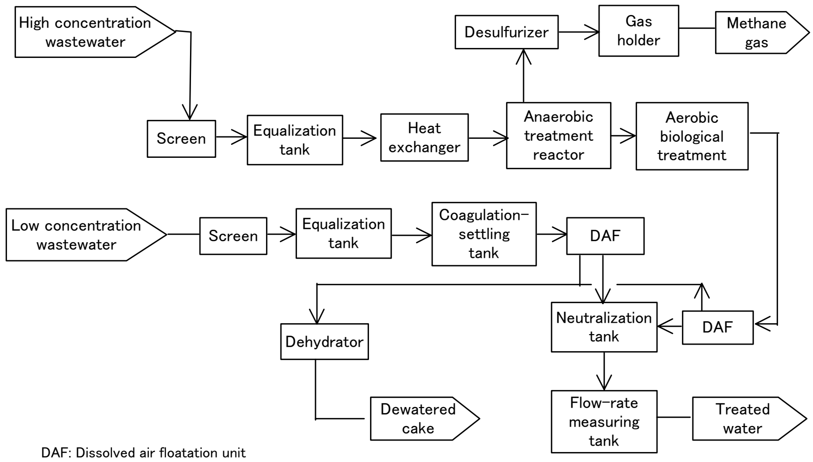

Figure 3-7-2 Schematic flow of wastewater treatment in daily dishes processing (discharge to sewer)

3. Performance Results

The raw wastewater quality data, averaged for every half month throughout a year, are shown in Figures 3-7-3 and 3-7-4 for the high and low concentration wastewater. The seasonal changes of quality, designated as the ratio of maximum to minimum, are 2 times for BOD and 3 times for SS, concerning both high and low concentration wastewater. Figure 3-7-5 shows the performance of the high concentration treatment system incorporated with advanced treatment process, indicated by one year's average of BOD through the sequential steps. As seen in the figure, 1,860 mg/ℓ in raw water is reduced to a stable 650 mg/ℓ by anaerobic treatment, then to 250 mg/ℓ by latter bio-film aerobic treatment, and finally to 6 mg/ℓ by coagulation-floatation. This effluent is mixed with treated water of low concentration wastewater and discharged into the sewer. The quality is shown in Figure 3-7-6.

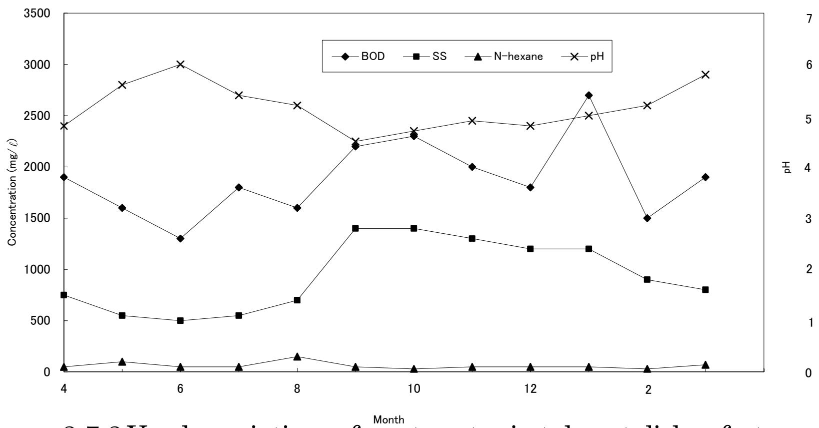

Figure 3-7-3 Yearly variations of wastewater in takeout dishes factory (high concentration stream)

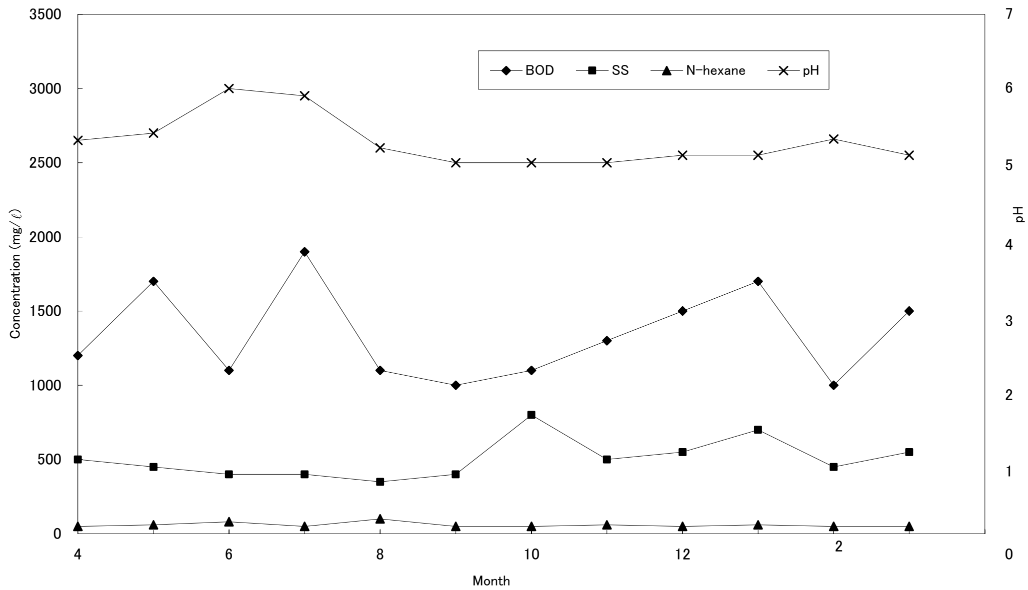

Figure 3-7-4 Yearly variations of wastewater in takeout dishes factory

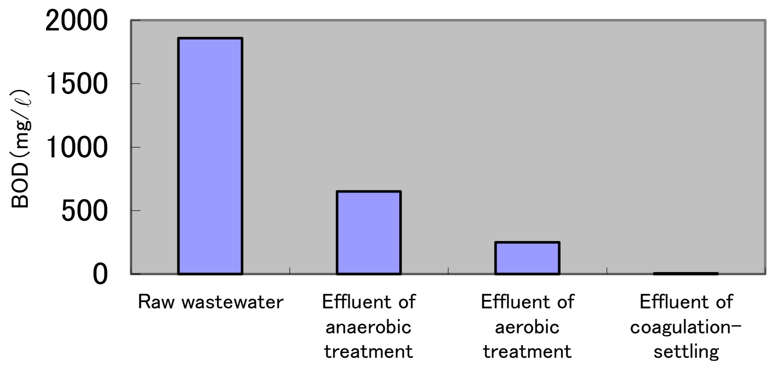

Figure 3-7-5 Treatment result of high concentration wastewater

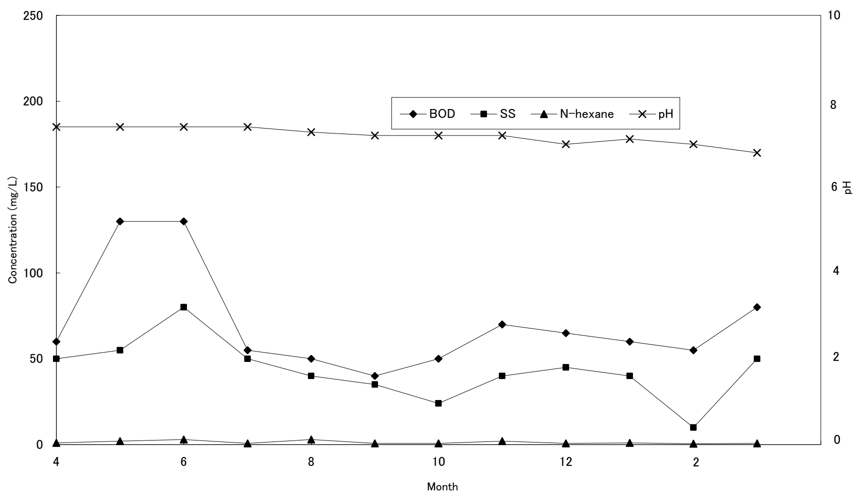

Figure 3-7-6 Wastewater treatment result in takeout dishes factory

7.3 Considerations in Operation and Maintenance

Detergents and disinfectants are used for cleaning equipment in food processing factories. If these chemicals are overused due to mistakes or leaks, it causes abnormal foaming in the anaerobic and aerobic treatment plants. As disinfectant leakage temporally decreases biological activity of the anaerobic and aerobic treatment plants and deteriorates the effluent quality, serious attention must be paid to such leakage. As the deposited solids at the bottoms of tanks go rotten and emit offensive smells, periodical cleaning of the wastewater pits, equalization tank, DAF, and other items are desirable.

REFFERENCES

1. Soejima T. Daily Dishes, *The Best Treatment of Food Processing Wastewater Handbook*, p 318 (Science Forum, 2002).

Chapter 8 Confectionaries

8.1 Wastewater Volume and Qualities

The wastewater properties in confectionary factories vary widely depending on the products and are also influenced by seasonally changing demands. This chapter introduces wastewater treatment processes for jellied fruit and sponge cake (Castella) factories[1]. Jellied fruit is jelly with pieces of fruit such as loquats, oranges, and peaches inside. To make it, liquid sugar, syrup, flavor, and pigment are blended, and the mixture is filled into cups filled with pieces of fresh fruit. The main streams of wastewater are from washing the equipment, syrup spilling from opened cans, and overflows of blended liquor from sealing machines. Figure 3-8-1 shows the production process of jellied fruit and the wastewater sources. Sponge cake (Castella) is made in a way that raw materials of egg, sugar, flour, and other ingredients are blended and baked in a baker. Then, the baked cake is packed in a wooden box. The Castella production process is in Figure 3-8-2. The main streams of wastewater are from washing the egg-crusher, blender, filler, and wooden box.

8.2 Example of Actual Treatment

1. Design Condition

Wastewater volume 160 m^3/d

Wastewater qualities BOD 4,000 mg/ℓ

	COD_{Mn}	2,500 mg/ℓ
Effluent qualities	BOD	10 mg/ℓ (daily average)
	COD_{Mn}	20 mg/ℓ (daily average)

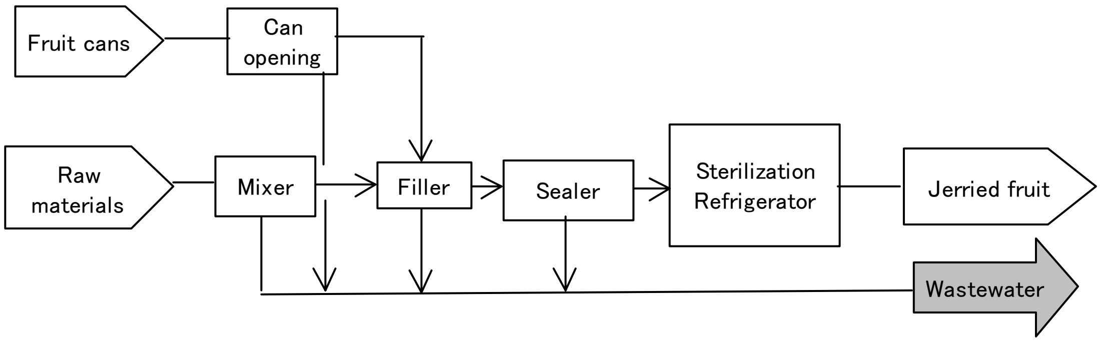

Figure 3-8-1 Schematic flow of Jerried fruit processing and wastewater

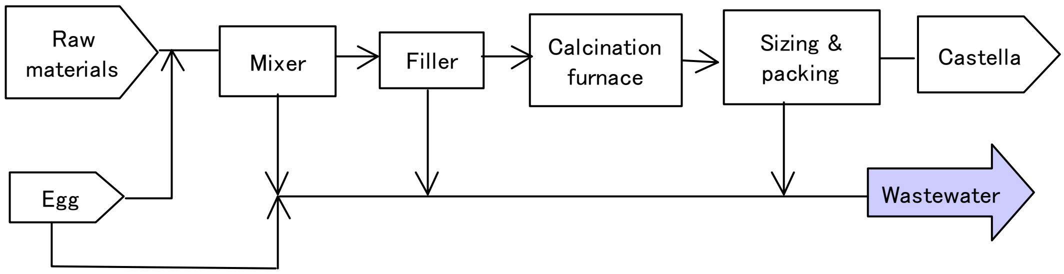

Figure 3-8-2 Schematic flow of Castella processing and wastewater

2. Process

As this factory is located in an area where the effluent standards are strict, the wastewater is treated in two stages, which are a conventional activated sludge process and an aerobic biofilm process. A coagulation-sedimentation tank is provided to cope with emergency cases involving effluent quality deterioration. The schematic flow diagram is shown in Figure 3-8-3. The influent wastewater is adjusted to equalize the flow rate in the equalization tank and dosed with nitrogen and phosphorus to cover shortage. Then, it is fed into the aeration tank and separates the sludge in the settling tank. After further removal of BOD and COD_{Mn} in the contact stabilization tank, the wastewater goes through the coagulation-sedimentation tank for emergencies, and it finally flows out after chlorination. To prevent sludge bulking, a 10 stage plug-flow is provided for the aeration tank. Excess sludge is thickened in the thickener, stored in the sludge storage tank, periodically dewatered by a mobile dehydrator on a truck, and then carried out.

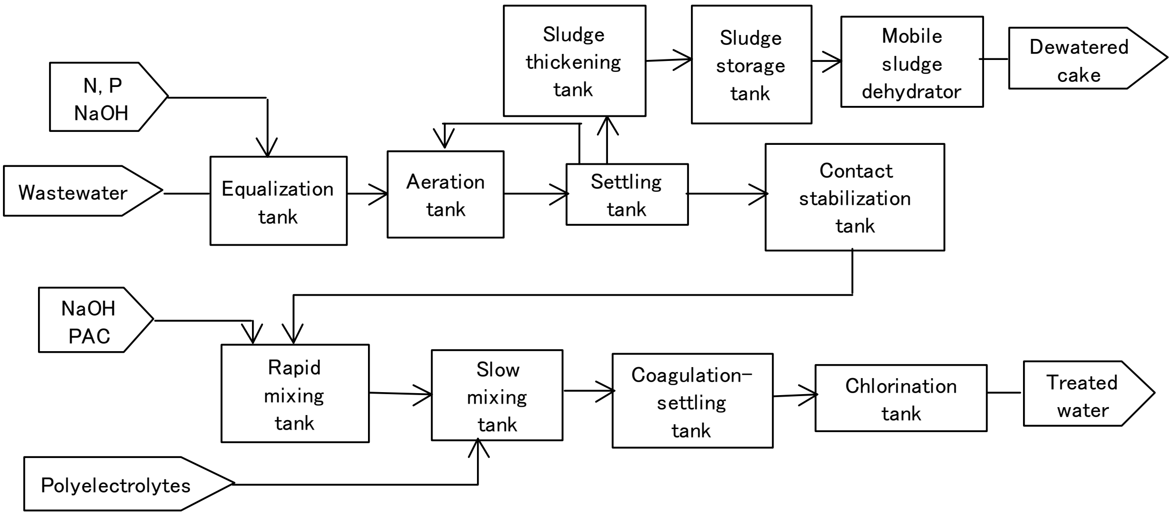

Figure 3-8-3 Schematic flow of confectionary factory wastewater treatment

3. Performance Results

This wastewater has major seasonal fluctuations in volume and concentration. Although BOD in the outflow of the equalization tank fluctuates from 2,000 to 4,500 mg/ℓ, BOD 5~30 mg/ℓ and COD_{Mn} 20~40 mg/ℓ are maintained in the effluent from the settling tank. There have not been any emergencies using the coagulation-sedimentation tank. The nutrient balance in the wastewater is BOD: N: P=100: 0.4: 0.1 for the jellied fruit factory and BOD: N: P=100: 0.2: 0.1 for the Castella (sponge cake) factory. As these figures show, nitrogen and phosphorus are short in both cases. Instead of using chemical compounds, however, treated water from the septic tank for domestic sewage in the factory is mixed into the wastewater, as it contains both nitrogen and phosphorous. In addition, saving operation costs and preventing eutrophication have been achieved by managing the dosages of nitrogen and phosphorous based on the data of relations between the BOD-sludge converted ratio and the nutrient requirements. For instance, if the BOD-sludge conversion rate decreases below 0.2 in normal operation, no nutrients are dosed.

8.3 Considerations in Operation and Maintenance

Viscous sludge bulking generally tends to occur in wastewater containing much saccharide, due to the accumulation of polysaccharide, and it makes separating the sludge difficult in the settling tank. Measures to prevent bulking in the aerobic treatment of wastewater from factories making cake, bread, fruit juice, and other products are conceivable in relation to two aspects. The first aspect related to the equipment is introducing the plug-flow to the aeration tank which causes the gradient of BOD concentration and also introducing a batch-wise activated sludge process involving partial anaerobic process. The second aspect related to the operation is adjusting the MLSS concentration to maintain an appropriate BOD-MLSS load (0.2~0.4 kg BOD/kg MLSS・d) to delay the growth rate of bulking-exciting filamentous microorganisms and to adjust the DO concentration in the aeration tank within an appropriate range. Actually, in this plant, bulking has been successfully prevented since it adopted plug flow and tapered aeration for keeping a determined level of DO concentration at each stage in the aeration tank. In the aerobic biofilm process in the second stage, bulking-exciting filamentous microorganisms are attached, held by the media, and prevented from flowing out to the settling tank. It is also considered effective.

REFFERENCES

1. Ohnishi M. Confectionary, *The Best Treatment of Food Processing Wastewater Handbook*, p 351 (Science Forum, 2002).