A CASE STUDY ON WASTE MINIMIZATION AND WASTEWATER TREATMENT IN STARCH AND NOODLE FACTORIES

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Abstract : A medium scale Mung Bean starch factory was taken in this study to assess the pollution caused by various streams in starch and noodle factories, and to provide the basic information for wastewater management in them. This study shows that the wastewater from starch processing unit with 46~54 tons production capacity is the main polluting source, contained high values of COD_f and SS. Also the specific water consumption to process one ton Mung Bean in 16~25 m^3 is higher than theoretically required one. Methods have been proposed for minimizing and treating the wastewater produced by the factory to overcome the pollution problems. One of the alternatives is to use water in a controlled way by marking optimum flow rates on the tab valves, in which water consumption can be brought down. However, bio-treatability of wastewater can be used for treating the total wastewater due to the suitability in characteristics.

Key Words : starch factory, wastewater treatment and management, water consumption

INTRODUCTION

Pollution from industries is becoming an alarming problem especially in developing countries. Large-scale industries are managing to control effluent qualities within the standards set by respective countries. But small and medium scale industries are unable to meet the effluent quality required by the authorities mainly due to the lack of technical knowledge of wastewater treatment plants and a shortage of technicians.[1,2] Pollution problems can be solved according to the "end-of-pipe" principle but more efficiently if they are considered from the starting point of the process.[3]

A field-scale study was carried out to resolve the practical pollution problems of small and medium scale industries by Carl Duisberg Gesellschaft (CDG), which is Germany's oldest and largest non-profit association for international professional training and personnel development. This study is a part of the project in which a medium scale Mung Bean starch factory in Bangkok was chosen to analyze the pollution problems and to provide suggestions to reduce the problems. Data collected from

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two small scale starch and noodle factories were analyzed for comparison. In this study, as a first step, investigation of the existing situation was made. It focussed on wastewater characteristics, fluctuations and documentation of different wastewater streams of the factories. Process modifications and waste reuse and recycling were suggested to reduce the pollution.[4~6]

The starch factory uses Mung Bean as raw material. Protein is produced as by-product and sulfur dioxide uses as a blenching agent. The noodle factory produces wide and thin noodle using rice as raw material. Those two factories face the following problems; (i) effluent wastewater quality does not meet the Thailand Standards, (ii) bad odor due to treatment processes, and (iii) high water consumption. The main part of the study was finished in the Mung Bean starch factory.[7]

Manufacturing Process of the Mung Bean Starch Factory

The Mung Bean starch factory consists of a location for starch processing, two locations for vermicelli production, processing was carried out by laborers and it was called old vermicelli process. Other location employed machines together with laborers, which was called new vermicelli process. All the waste produced was discharged into a pond system through open channels.

Starch process : Figure 1 shows the process flow chart of starch production from Mung Bean. The process which produce polluted waste streams are wet cleaning, soaking and refinery starch process. In the Mung Bean starch factory, the wet cleaning has two stages. The first stage is washing in a tank and the second stage is sieving using a rolling sieve. The second washing water was collected in a sedimentation tank under the sieve and pumped back to the first washing tank since the settleability of waste of wastewater is very good. The flow rate was measured once when wastewater flow is small, and it was 6.8 m^3/h.
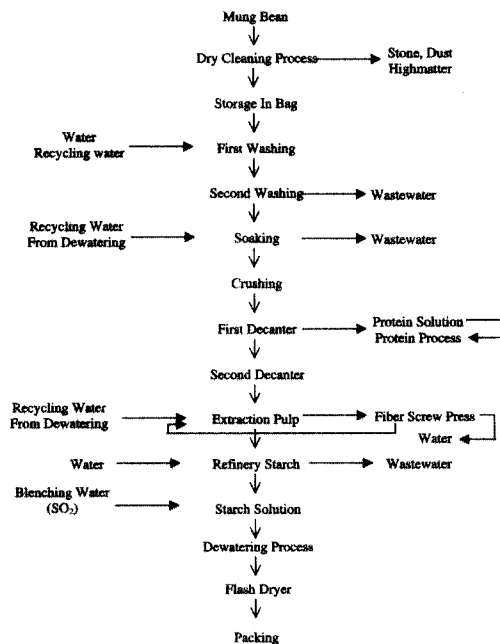

Figure 1. Process flow chart for starch production.

Wet cleaning water mainly contained earth and Mung Bean scraps as well as protein and starch. Mung Bean was made soft by soaking in water. In order to prevent fermentation and sprouting, SO_2 is used as preservation in soaking water. Mung Bean was soaked soaking tank about 10~12 hr at 30℃. To soak 50 ton of Mung bean, 115 m^3 water was needed of which about 55 m^3 soaking water was discharged finally. Soaking was carried out in a tall tank and needed more water to make the Mung Bean float. The soaking water mainly contained protein and starch that produced a bad smell after being discharged into the wastewater stream. Crushing machines are used to reduce the size of Mung Bean. Decanters are used to separate protein from starch and fiber because protein has a better dissolvability in water than starch and fiber. Protein solution is sent to protein process. Rotary sieves are used to separate fiber from starch. Starch can pass the sieves easily and fiber attach to the wall of the rotary sieves. Coarse fiber is sent to a screw press, then sold as animal feed. The fine fiber was discharged into the waste stream

since it cannot be dewatered if it goes with the coarse fiber to the filter press. The water flow rate was $4 \sim 40$ m^3/d, here. Then, bleaching water (SO$_2$ water solution) is added into the starch solution and to bleach the starch. A centrifuge is used to separate starch from fluid streams. Starch is dried by a flash drier and, then packed in bags.

Vermicelli manufacturing process : Vermicelli is a kind of noodle but much thinner. About $9 \sim 10\%$ of starch is put into hot water to make gelatinized starch. Mix it with rest of starch to make paste by adding water. The paste is transferred to a perforated container and drops in hot water ($100\,^{\circ}$C). Then vermicelli is kept in a water bath for $3 \sim 4$ min. Fresh vermicelli is refrigerated at -10°C for 10 hr, and then the frozen vermicelli is passed into bleaching tanks with $200 \sim 300$ ppm SO$_2$ water for 3 hr. After that the bleached vermicelli is thawed with water, which is still frozen. Then the vermicelli is dried either by natural air or in an oven, finally packed in polyethylene bags. In old vermicelli process, waste streams from the following processes were considered for analysis; (i) cooling water, (ii) boiling water, (iii) bleaching water, and (iv) total wastewater. In new vermicelli process, waste streams from the following processes were considered for analysis; (i) cooling and boiling water together, (ii) drying and bleaching water.

Protein manufacturing process : In protein manufacturing process, waste is mainly from a decanter and it contains a lot of foam. A high pressure water gun was used there to destroy the foam by shooting anti-foam. Setting up a

weir for flow measurement in the stream of the wastewater from protein process gave problems for two reasons. They are as follows: The hot water in the stream softened the clay which was used to fill the cap between the weir and the channel walls. Setting up the channel in hot water (more than 60°C) was not so easy even if rubber gloves were used. The gloves became hot very soon. The measurement was made difficult further by the foam in the channel which prevented measuring the water depth accurately. Finally accumulation of foam due to the weir installation was found to disturb the operation.

The Existing Situation

Mass balance : In starch production $14.5 \sim 21.5$ tons of starch a day were produced from 50 tons of Mung Bean. For this $800 \sim 1,250$ m^3 water was used. As a by-product $230 \sim 290$ m^3 of protein solution was produced. The following mass balance can be set for the process of Mung Bean starch. The material that goes to wastewater streams from processing of Mung Bean is about $5.7 \sim 10$ tons per day that includes 3% moisture contained in Mung Bean. The results were got from the data provided by the Mung Bean starch factory in a statistic way. Coarse fiber was assumed to be 23% of Mung Bean in dry form. It is 26% of Mung raw material with 3% earth and 13% moisture out of one ton Mung Bean enters in wastewater streams. The old vermicelli process and new vermicelli process are processing $3 \sim 6$, $2 \sim 5$ tons of starch per day, respectively.

Every day, about $30 \sim 140$ kg starch or short noodle enters into wastewater streams from

Table 1. Water consumption in the Mung Bean starch factory

	Water cons. (m^3/d)	Water cons. of raw material processed* (m^3/d)
Total	$1,100 \sim 1,700$	-
Starch process	$800 \sim 1,250$	$16 \sim 25$
Protein process	$3 \sim 35$	-
New vermicelli	$170 \sim 360$	$48 \sim 80$
Old vermicelli	$200 \sim 440$	$54 \sim 80$

* The raw material for starch process is Mung Bean and for vermicelli process starch.

each process. 970~990 kg vermicelli is obtained from one ton starch, 10~30 kg starch with moisture 13% enters in wastewater streams.

The values of water consumption were read from water meters installed in each process. The specific water consumption is 9 m^3 and about 30 m^3 differences between the minimum values and the maximums in the starch production process and two vermicelli processes respectively. The great difference between the maximum and the minimum specific values are probable due to uncontrolled water usage and clean up. Processing little amount of starch needs the same amount of clean up water, which causes extreme high specific water usage. The water consumption in starch process is approximately as follows:

The amount of water used in old vermicelli process, consumed in starch process due to leakage, overflow and clean-up was estimated in following ways. For cleaning, it was assumed that one hose be used in both old

vermicelli process and starch process. Then the amount of clean up water used was about 10~14 m^3/d (1 hose×6.8~9 m^3/h×0.5 h/time×3 times/d). Two hoses were used for thawing in old vermicelli process. The amount of water was about 40~85 m^3 (2 hoses×6.8~9 m^3/h×1~1.5 h/time×times/d). The total amount was 50~100 m^3/d. It was estimated that the water used for clean-up was about 120~160 m^3/d if 3 hoses were used to clean three times a day, and for 3 hr each time. It was difficult to estimate the amount of the leakage. By assuming that the leakage be like a hose flowing 24 hr a day the amount of the leakage could be calculated, and the amount of this part of consumption was about 200 m^3/d.

Wastewater composition : The composite samples of total wastewater is given in Table 3. From the results, it was obvious that the total wastewater was acidic in nature with high organic contents. Since BOD$_f$: COD$_f$ = 0.72~0.79 and COD : TKN : TP = 100 : 30 : 1, the

Table 2. Water consumption in starch process

Water used in Mung Bean starch process	m^3/d	M^3/t of Mung Bean
Washing	140	2.8
Soaking	155	2.3
Protein solution	230~290	4.6~5.8
Went with coarse fiber	10	0.2
Discharged with fine fiber	4~40	0.1~0.8
Clean up	120~160	2.4~3.2
Leakage and overflow	200	4
Used in old vermicelli	50~100	1~2

Table 3. The characteristics of total wastewater in the Mung Bean starch factory

Characteristics	Unit	Range	Characteristics	Unit	Range
BOD$_5$	(mg/L)	2,240~3,210	BOD$_f$	(mg/L)	1,680~2,530
COD	(mg/L)	3,210~5,050	COD$_f$	(mg/L)	2,330~3,250
SS	(mg/L)	1,070~1,570	TS	(mg/L)	3,900~5,450
VS/TS	(%)	76~79	VSS/SS	(%)	92~95
TKN	(mg/L)	108~244	NH$_3$-N	(mg/L)	20~30*
TP	(mg/L)	31~46	OP	(mg/L)	<10**
H$_2$SO$_3$	(mg/L)	5~8	pH***	(-)	4.0~5.4
Temperature	(℃)	31~39	Conductivity	(s/cm)	410~2,400
Settleable solids	(mL/L)	2~194			

* reference 2, ** reference 8, *** The values of pH, temperature, settleable solids and conductivity were got from grab samples.

wastewater could be treated biologically by adjusting the pH. Care must be taken for the high TKN content since this might produce ammonia concentration which could be toxic to the microorganisms. The theoretical methane production could be $810 \sim 1,140$ m^3/d, which have a heat value of 3.7×10^6 kcal or 370 m^3 heavy oil (about 1,100 Baht in 1992; 25 Baht = 1 US$). If the wastewater flow is 1,500 m^3/d, around 600 kg solids in dry form could be obtained at 40% recovery from 1,000 mg/L SS concentration, which could be sold at 2 Bath/kg. VS/TS is about $76 \sim 79\%$. The following table shows the COD, SS and TS got from 5 days total wastewater.

For total wastewater in the Mung Bean starch factory it was found that the range of (COD-COD$_f$)/SS is $0.76 \sim 1.16$ and the average 1.01. The COD/TS values given above seem to be constant with in the range of $0.81 \sim 0.99$ and the average 0.92. To identify the details of the salts, acids or basis existing in wastewater streams, the conductivity combined with pH measurement is measured. The wastewater

from the Mung Bean starch factory has a high conductivity value which mainly caused by SO$_2$, acetic acid and propionic acid. Table 5 shows the characteristics of wastewater in different streams from starch and protein processes. Starch process produces the largest amount of wastewater and high COD$_f$ and SS which is the main pollution source. Soaking water has a higher COD$_f$ than washing. But the washing water may have higher load because of its higher flow rate. Fine fiber discharged from refinery starch process has a high SS contents as well as high settleable solids. Washing water sometimes is acidic because soaking water is occasionally added into it during wet cleaning. The value of conductivity of soaking water are great as it contains SO$_2$. And the content of acetic acid becomes higher with soaking time will also increase its acidity.

Fluctuations in wastewater characteristics :
In total wastewater characteristics, the values of COD$_f$ are lower (less than 400 mg/L) before 9 o'clock and during lunchtime. This might be

Table 4. Comparison of COD, SS and TS from 5 days total wastewater sampling

	03/01	07/01	09/01	15/01	27/01
COD (mg/L)	3,212	4,464	5,049	4,568	3,783
COD$_f$ (mg/L)	2,336	2,796	3,251	3,002	2,657
SS (mg/L)	1,074	1,436	1,570	1,352	1,490
(COD-COD$_f$)/SS (-)	0.82	1.16	1.15	1.16	0.76
TS (mg/L)	3,944	4,788	5,450	4,624	4,046
COD/TS (-)	0.81	0.93	0.93	0.99	0.94
WW (m^3/d)	920	1,530	1,450	1,450	-

Table 5. Wastewater characteristics at starch and protein process

	Starch				Protein
	Washing	Soaking	Refinery starch	Total	
Flow rate (m^3/d)	140	55	$4 \sim 40$	$500 \sim 900$	$40 \sim 70$
COD$_f$ (mg/L)	$506 \sim 955$	$575 \sim 1,139$	$656 \sim 1,344$	$653 \sim 4,047^*$	$9,300 \sim 16,316$
SS (mg/L)	$198 \sim 1,404$	$630 \sim 1,130$	$15,000 \sim 17,000$	$2,512 \sim 2,786$	$3,220 \sim 3,530$
Settleable solids (mL/L)	$20 \sim 70$	$40 \sim 50$	$670 \sim 820$	-	$0 \sim 150$
TKN (mg/L)	-	-	-	330	1,120
pH (-)	$4.8 \sim 6.6$	$4.4 \sim 5.8$	$6.4 \sim 6.7$	$4.6 \sim 5.6$	$4.5 \sim 4.6$
Temperature (℃)	32	32	$32 \sim 41$	$30 \sim 39$	$60 \sim 70$
Conductivity (μs/cm)	$379 \sim 494$	$422 \sim 1,920$	$350 \sim 493$	$570 \sim 1,065$	$2,230 \sim 2,510$

* COD

due to less starch dissolved in wastewater with less hot water discharge. COD_f is about 400~800 mg/L after 9 o'clock. It is lower when water flow is high and vis verse. SS appear peak values during clean up time which are above 400 mg/L most time.

EXPERIMENT

Soaking Test

A soaking test was carried out in transparent containers in AIT's laboratory in order to find a way to reduce material entering wastewater stream. The conditions of the soaking test were kept as those in the factory. COD_f of the soaking water with and without adding SO_2 was observed at 5 hr interval along with other properties such as soaking and change in color, as shown in Table 6. Analysis was followed by the guideline in Standard Methods.[9]

Another soaking test was conducted to find out if soaking water can be reduced. Mung Bean to water ratio 1:1 was used instead of 1:2 and found that the Mung Bean in the bottom part of the 1,000 mL cylinder could not swollen even if there was still water in the top part of the cylinder.

Table 7 shows the results obtained in a batch test: formation of volatile fatty acids with time in the soaking water without adding SO_2. After

Table 7. Accumulation of volatile fatty acids in soaking water

Time (hr)	Acetic acid (mg/L)	Propionic (mg/L)	i-Butyric acid (mg/L)
0	15	0	0
5	92	66	0
10*	91	62	0
15	686	632	4
20	778	982	6
25	1,481	2,239	14
30	1,959	2,487	8
40	4,376	3,418	20

* The value of 10 hr was obtained from discharged soaking water.

20 hr concentrations of acetic acid and propionic acid increase rapidly.

Toxicity of SO_2 and Anti-foam on Methane Production

Table 8 and 9 show the characteristics of sludge and wastewater and substance and substrate used in test, respectively. A batch test was carried out to find the toxicity of methane production at difference concentrations of SO_2 and anti-foam.

The result in Table 10 was shown that SO_2 concentration 100 mg/L become toxic for methane production but anti-foam does not affect.

Table 6. Detail of soaking test

| Time (hr) | Without SO_2 | | With SO_2 | | Soaking |
	COD_f (mg/L)	Remarks	COD_f (mg/L)	Remarks	COD_f (mg/L)
0	100	Light yellow	243	White color	493.5
5	873	Almost all mung bean swallen	1,320	Most of them are still hard	950
10	4,055	Lot of foam on top; gas bubble come up from bottom to top and stay there as foam	1,967	Light yellow; less foam compared with SO_2 water	2,872
15	5,029	-	4,227	Lot of foam	-
20	8,250	-	9,313	-	9,180
25	-	Solution become opaque	-	-	13,320
30	10,515	-	10,443	Solution become opaque	18,300
30	18,741	-	16,953	-	23,025

Table 8. Characteristics of sludge and waste-
water

Item	Sludge	Wastewater
COD (mg/L)	-	3,783
COD$_f$ (mg/L)	51	2,657
MLSS (mg/L)	22,780	-
MLVSS (mg/L)	12,680	-
pH (-)	7.2	6.5

SO$_2$ Evaporation Test

A test was carried out to find SO$_2$ concentration at 30℃ with time. Table 11 shows the result obtained.

SO$_2$ was evaporated from the soaking water and after 8 hr more than 60% of the concentration was lost.

Bleaching Test

The aim of the test was to reduce the energy consumption of the chiller which was used to frozen vermicelli after dropping, cooling and hanging. According to a literature, freezing should give more transparency to the noodle. It was found that freezing did not improve

transparency of the noodle during the experiments but it can drive the water out and prevent stickiness of the noodle. And also show that bleaching for 5 min after thawing can give the desirable whiteness to the noodle. This can reduce the long period of time used for bleaching.

RESULTS AND DISCUSSION

Starch Process

Water consumption per ton Mung Bean could be brought down from $16 \sim 25$ m^3 to 12 ~ 15 m^3 by controlling water flow rates at minimum used by the factory and could be further brought down to $8 \sim 10$ m^3 by process modification.

As mentioned before, water consumption of wet cleaning, soaking, refinery starch and clean up are 140 m^3/d (assuming 20 h/d washing), 115 m^3/d, $4 \sim 40$ m^3/d and $120 \sim 160$ m^3/d (6.8 ~ 9 m^3/h, 3 times a day), respectively. For finding optimum condition, mark the valve position and keep the water flow enough and

Table 9. Substance and substrate used in test

Bottle No.	Sludge (mL)	WW (mL)	Acetate (g/L)	SO$_2$ (mg)	Anti-foam (mg)
1	20	20	0.1	0	0
2	20	20	0.1	10	0
3	20	20	0.1	100	0
4	20	20	0.1	0	1,000
5	20	20	0.1	0	c*

*Where c = 1 L of anti-foam in 1,000 m^3 of wastewater

Table 10. CH$_4$ production and CH$_4$-COD at different SO$_2$ and anti-foam concentrations

Time (hr)	Methane production at 30℃(mL)					Methane-COD (mg) at 30℃				
	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
8	1.3	4.7	0	0.8	1.3	3.4	12.2	0	2.2	3.4
24	9.2	10.9	0	10.8	10.2	23.6	28	0	27.7	26.2
48	24.5	24.6	9.8	24.5	24.5	63.1	63.3	25.1	63.1	63.1
72	36.6	38.8	13.8	39.2	38.7	94.2	100	35.6	101	99.7

Table 11. SO$_2$ water evaporation rate at 30℃

Time (hr)	0	4	8	6	20	24
SO$_2$ concentration as SO$_3^{2-}$ (mg/L)	355.4	206	137	49.4	9.4	0

as small as possible. More water and energy can be saved if washing water is not pumped to the first washing tank at the beginning.

The water consumption for process one ton Mung Bean is $12 \sim 15$ m^3. This will reduce the money for water payment and energy consumption. The water consumption of the factory was $800 \sim 1,250$ m^3/d. Therefore $100 \sim 650$ m^3 water could be saved. As mentioned before, soaking water was mainly starch and protein. To prevent materials from going to waste stream and causing pollution the following process modification is suggested to eliminate soaking water discharge. Wash Mung Bean carefully and crush it by dry method. By removing the seed coat water can disperse into starch granule easily. Consequently, soaking time can be reduced and water will not produce bad odor. Then, the supernatant of soaking water can be sent to protein process. By using this method there would be no material loss into the waste stream in soaking.

Discharging the fine fiber into the waste stream could be prevented by collecting the fine fiber attached onto the walls of the rotator sieve in semi-solid form. This can be sold to factories, which make cakes. Using systematic clean-up methods could save more water. Cleaning should be done from the top to the end and cleaning one place frequently should be avoid. Cleaning could be finished within half an hour if a systematic cleaning way is used and 40 m^3 water will be enough and 91.8 m^3 water could be saved.

Comparing the Table 12 with Table 5, recycling water has higher COD and SS than wastewater from washing, soaking and refinery. Therefore, recycling water overflow from storage tanks will cause product reductions and will burden the wastewater treatment system. Adjusting the water flow rate or storing

automatic valves should prevent water overflow from storage tanks. Removal of seed coat after soaking is suggested if the process modification of reusing soaking water is not adopted. This could be helpful to reduce the odor and color problem in protein process. It will also reduce the SO$_2$ water usage in bleaching vermicelli.

Vermicelli Process

It is important to reduce bleaching water discharge and cooling water consumption in vermicelli process. About 45 kg per day of sulfur is used in the factory to make SO$_2$ water. The concentration of SO$_2$ water is made from about $200 \sim 300$ ppm to 500 ppm when it is used for bleaching vermicelli. After freezing vermicelli is put into bleaching tank and bleached for 3 hr. One tank of bleaching water is used three times a day and then discharged. It was found that the concentration of discharged bleaching water is more than 200 ppm. One suggestion is to discharged only half tank of used bleaching and mix 500 ppm fresh SO$_2$ water in used bleaching water and use it again.

Using SO$_2$ gas for bleaching instead of SO$_2$ water solution is an option to eliminate water pollution from SO$_2$. But caution has to be taken for air pollution. Changing a less pollution chemical such as H$_2$O$_2$ as bleaching agent is also a possible alternative. Another alternative is to stop bleaching and produce the noodle with natural color, which can reduce the waste strength from bleaching process. Water from a cooling tower is used for cooling the noodle. The temperature of water in the tower is 28℃ and becomes 30℃ when it reaching the location where cooling takes place. This consumes more water for cooling. Frozen vermicelli from the chiller can be used to cool the water which can be served in vermicelli

Table 12. Characteristics of recycling water

	COD$_f$ (mg/L)	SS (mg/L)
Crushing water from second decanter	6,300	9,930
Recycling water from dewatering	585	9,290
Recycling water from screw press	400	4,690

process and reduce cooling water consumption. There could be two ways.

i. Keep the pipe, which carries the cooling water at lower temperature by providing a passage through the thawing area.
ii. Use the water from cooling process for thawing and reuse it for cooling.

Cooling water: Present water consumption = $120 \sim 220$ m³/day in old vermicelli process.

At present the water used for cooling is at 30℃ and rises to 34℃ after cooling. If thawing water is used for cooling which is at 20℃ there will be a reduction in water consumption. This reduction can be calculated by equation the heat energy gained by both waters.

Mass of cooling water (at present) × Specific heat × (34-30) = Mass of cooling water × heat × (34-20)

Mass of cooling water necessary
= (4/14) mass of water used at present.
Therefore $85 \sim 150$ m³ can be saved per day.

Every day, about $30 \sim 140$ kg starch was going to the waste stream from each vermicelli process. To prevent this a container had been placed under the effluent pipe from new vermicelli process. The water comes out through the holes in the circumference of the container. Short noodle is retained in the container. During clean up period in the vermicelli processing unit, water flow became very high and caused overflow of wastewater from the container. This allowed the short noodle to escape into the waste stream. A weir or a screening could be considered to recover short noodles and starch by setting a weir or a screening in the open channel. Recovered starch can be a source for modified starch factories or factories which make chemicals from starch. It can also by use as flocculent in wastewater treatment.

Starch is lost two places. One is while transferring gelatinized starch to mixing bucket,

and the other is while transferring the starch manually for boiling. The first loss can be eliminated by using small basins to transfer gelatinized starch to the mixing bucket or bring the mixing bucket down to the lower position where gelatinized starch is placed. Transferring the starch manually for boiling can be replaced by using buckets. Starch can be taken to where boiling take place with provision of stirrer for mixing.

Lot of water is used to clean up starch. If a spatula is used to remove the starch from buckets then the starch can be used while the amount of water required will be reduced. Bleaching water can be reused by adding SO_2. After reusing SO_2 water several times it can be discharged separately to avoid shock loading to the treatment process. A cover could be used to prevent the emission of SO_2 from the tank. Using some other reagents such as H_2O_2 for bleaching is another option.

The hot water discharged from dryer could be used to preheat the water, which goes to the boiler. Part of the cooling water can be used for washing and the rest can be used for mixing.

Finally, there are two additional suggestions,
i. Close valves when no operation eq. during lunch times.
ii. The energy could be saved if the temperature of the chiller brought down from -10℃ to -4℃.

CONCLUSIONS

1. Wastewater from starch processing unit with $46 \sim 54$ ton production capacity is the main polluting source in the Mung Bean starch factory. The water consumed by this process is $800 \sim 1,250$ m³/d which takes up over 70% of total water consumption of $1,100 \sim 1,700$ m³/d and the wastewater from this process has high values of COD_f and SS. The value of the specific water consumption which is measured $16 \sim 25$ m³ for one ton Mung Bean is higher, compared with other

starch productions (maize: $9 \sim 10$ m^3 and potato: $14 \sim 23$ m^3). Wastewater from protein process has the highest values of COD$_f$ and SS which are $9,300 \sim 16,300$ mg/L and $3,220 \sim 3,530$ mg/L respectively, but the amount is very little, only $40 \sim 70$ m^3/d. The two vermicelli processes have similar specific water consumption and wastewater characteristics. The COD$_f$ and SS values of wastewater from vermicelli processes are much lower than those from starch and protein processes.

2. Total wastewater from Mung Bean starch factory is acidic and contains high level of BOD$_5$ and SS, up to $2,200 \sim 3,200$ mg/L and $1,070 \sim 1,770$ mg/L respectively. On the analyses of total wastewater characterized by BOD$_f$, COD$_f$, TKN and TP, it is estimated that the wastewater has a good bio-treatability and that $810 \sim 1,140$ m^3/d of methane can be obtained, which is equivalent to 3.7×10^6 kcal or 370 kg heavy oil (about 1,100 Baht in 1992). If the wastewater flow is 1,500 m^3/d, around 600 kg solids in dry form could be obtained at 40% recovery from 1,000 mg/L SS concentration. 1,200 Baht can be obtained from the solids if they can be sold 2 Baht/kg.

3. SO$_2$ and anti-foam are not toxic to anaerobic biological treatment under normal operation condition. But the bleaching water with the content of SO$_2$ up to 100 ppm is toxic.

4. The value of COD$_f$ and the concentrations of acetic and propionic acids in soaking water increase with the soaking time which causes more material dissolved into water and lost when discharged with soaking water together.

5. The most effective and reasonable way to reduce pollution is to cut down the water consumption, which can easily be done by marking the optimum flow rates on the tab valves and repeating the use of soaking water.

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