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# A CASE STUDY ON WASTE AUDITING IN AN ICE CREAM FACTORY

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**Abstract**: The management of the ice cream factory concerned in this study strongly felt the importance of undertaking a waste audit of its biggest waste generator, the ice cream plant. Ice cream wastewater constitutes as much as 74 % of the total volume of wastewater discharged by the company to the central treatment plant of the Industrial Estate in which the factory is situated. Generation of ice cream wastes is attributed to the high consumptive use of water in the plant for washing and cleaning operations. As a result of waste auditing, methods were proposed to save water and to segregate the waste, and to modify the existing wastewater treatment system of the ice cream plant for better treatment efficiency.

**Key Words**: waste auditing, ice cream wastewater, treatment plant

## BACKGROUND INFORMATION

The enterprise considered in this paper is situated in an industrial estate which belongs to the Industrial Estates Authority of Thailand (IEAT) and the estate has a total land area of 2,515 rai presently occupied by 160 different industries. These industries include textile making, food processing, pharmaceutical product manufacturing, and car assembling ones. IEAT receives untreated and partially treated wastewater discharged from all the factories within the estate. It employs an activated sludge process for biological treatment of the industrial wastewater. It has a central wastewater treatment plant composed of two separate plant units. Total capacity of the central treatment plant is 16,800 $m^3$/d.

Authorities from IEAT established a set of effluent wastewater standards (Table 1) for the waste discharge from the factories in order to regulate the discharge of pollution (BOD and COD) into the receiving water channel. Industries are accordingly required to pay trade effluent charges based on the volume of the

Table 1. IEAT effluent wastewater standards

| Paramenter | Allowable Limit |
|---|---|
| BOD (mg/L) | 900 |
| Suspended Solids (mg/L) | 600 |
| Temperature (℃) | 45 |
| Oil and Grease (mg/L) | 30 |
| Synthetic Detergent (mg/L) | 30 |
| pH | 6~9 |

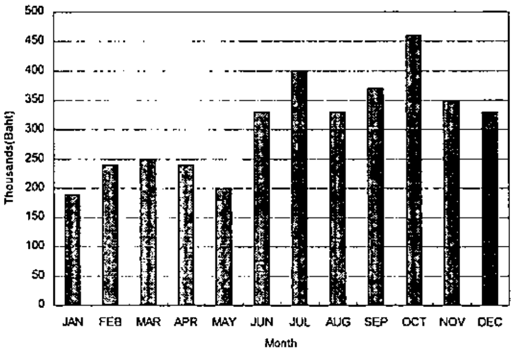


Figure 1. Cost of treated wastewater sent for treatment charged by IEAT.

wastewater and associated BOD and suspended solids (SS) loads.

The concerned enterprise produces several consumer items including ice cream. For the year 1993, the company has a total consumption of 490,129 $m^3$ of raw water as gathered from the Engineering Department utility records. The corresponding total treated effluent, as recorded, is 228,429 $m^3$. The 1993 monthly expenses incurred by discharging treated effluents to IEAT shown in Figure 1 at the average cost of 12.57 Baht per cubic meter of wastewater discharged.

This fact leads the management of the enterprise to look into the ways which can reduce the cost, and as a result a waste auditing was sought. Further it was found that 74 % of wastewater generated by the establishment was from the ice cream plant and hence the priority was given to it. It was also found that the volume of the wastewater generated in processing ice cream products as well as the resulting wastewater BOD and total suspended solid loads (TSS) per unit weight of the product exceed the benchmark for an ice cream factory (Economopoulos, 1993).

## Ice Cream Processing

Figure 2 shows the process flow chart in the manufacturing of the ice cream. Liquid ingredients such as glucose, vegetable oil, and butter oil are mixed with the dry raw materials such as sugar, skimmed milk powder, whey powder, wheat flour, cocoa powder, sweeteners, stabilizers, and emulsifiers. Color and flavors are added in the aging tank. Flavors, topping sauce, and caramel are kept in the chilled room at a temperature of about 5℃. Chocolate is prepared in the local chocolate preparation area and then pumped into the production hall area. All the mixing materials go into the pasteurizer at a temperature of 82℃ for 29 seconds. Homogenization takes place at 82℃ to reduce the size of the fat globules. The mixtures are cooled rapidly to a temperature of 4℃ to prevent bacterial growth. After cooling, the mixture is sent into the aging tanks at an aging time of at least 3 hours. Freezing of the mixture is then carried out where the average freezing temperature is -5℃ to -6℃. To recover the product from the freezer, reworking is being done. A rework room is provided for the

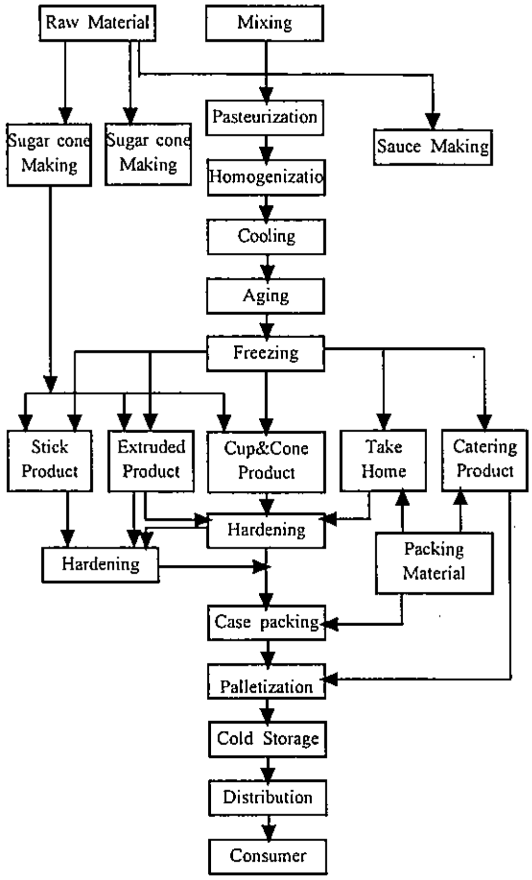


Figure 2. Flowchart of ice cream processing.

sole purpose of recycling the deformed ice cream products coming from the freezer. In the rework room, the rework is mixed and melted in the rework tank. Then it goes into the rework pasteurizer system and then to the homogenizer. The temperature is about 80℃. Then the mixture is cooled down to 4℃ and sent into the two aging tanks for reworking called the rework solid tank.

The frozen mixture is pumped into the various filling machines such as the Gram Ria 8, Omni 3000, and Extruline and others to mould the product. Sticky products are wrapped and packed in cases. Ice cream products are conveyed into the hardening room at a temperature of -40℃ to -45℃. From the case packing section, the products are sent for palletization (-10℃) and cold storage (-30℃). The product is now ready to be distributed for consumer consumption. Distribution temperature should be -18℃ or less.

### Existing Wastewater Treatment

There are two wastewater streams from the various production units of the plant. These two are: (i) ice cream wastewater which is treated at Plant No. 3 and No. 4 by alum coagulation and sedimentation; and (ii) the combined wastewater coming from all other production processes of the remaining plants except ice cream by lime coagulation treatment. The second wastewater stream is pumped to Plant No. 1 and No. 2 treatment units. The treated effluents from these two separate waste treatment plants are combined together in one effluent tank for common disposal to IEAT. Ice cream wastewater is pumped from the plant's collection sump to the two treatment plant units, Plant No. 3 and Plant No. 4.

The effluent ice cream wastewater from the collection sump flows through the 500 m length overhead pipes into the fat traps of Plant No. 3 and No. 4 of the Effluent Plant. It is sent to the equalization tank and then fed to the flocculation tank where alum and a polyelectrolyte are added for the better flocculation. The pH adjustment is done by the addition of hydrochloric acid. Settled sludge from the sedimentation tanks are subsequently dewatered by the two press filters while the treated effluent is placed in the collecting tank before finally discharging into the combined treated effluent stream from the plant to the central wastewater of IEAT. The sludge cake is disposed into a landfill.

## WASTE AUDITING OF ICE CREAM PLANT

The five principal areas of major importance in the ice cream plant include the mixing and homogenizing area, rework handling room, mix storage room, production hall area, and chocolate making room. Notably, considerable amount of water, about 20 %, is primarily used in the evaporative condenser and cooling tower for the refrigeration and air conditioning system of the ice cream plant. The total wastewater flow thoroughly accounted averaged 302 $m^3$/d. Table 3 enumerates and quantifies the wastewater that is discharged into the ice cream sump with reference to the incoming water consumed by the plant.

## FEASIBILITY ANALYSIS

### Reduction of Water Consumption

To cut back plant water consumption, several

Table 3. Incoming water for consumption and outgoing wastewater discharged to sump

| Use | Water In ($m^3$/d) | Wastewater Out ($m^3$/d) |
|---|---|---|
| CIP | 261.9 | 129.2 |
| Water in product | 26.7 | - |
| Machine washing water[(a)] | 117.4 | 117.4 |
| Floor washing water[(b)] | 46.8 | 46.8 |
| Container washing water | 120.0 | - |
| Utility consumption | 4.4 | 4.4 |
| Hand washing water | 13.4 | - |
| Toilet | 594 | 302 |

(a) Polo water drain is taken into account.
(b) Homogenized cooling water is included.

proposals are mentioned in the preceding section. A summary of the proposed waste reduction measures and corresponding savings in volume is shown in Table 4. It can be noted from the table that a decrease in manual washing water usage could be achieved by following the implementation of the measures drawn up. Water reduction for manual washing is about 67 %. An estimated 12 % reduction in total water consumption for the ice

Table 4. Proposed water consumption reduction

| Activity | Recommendation | Water Savings ($m^3/d$) |
|---|---|---|
| Manual washing | Elimination of open water hose system | 28 |
| Manual washing | Good housekeeping | 12 |
| Cooling water draining | Reuse for container washing | 4 |
| Water draining from Polo | Reuse for floor washing | 26 |
| | Production Hall Area | 70 |

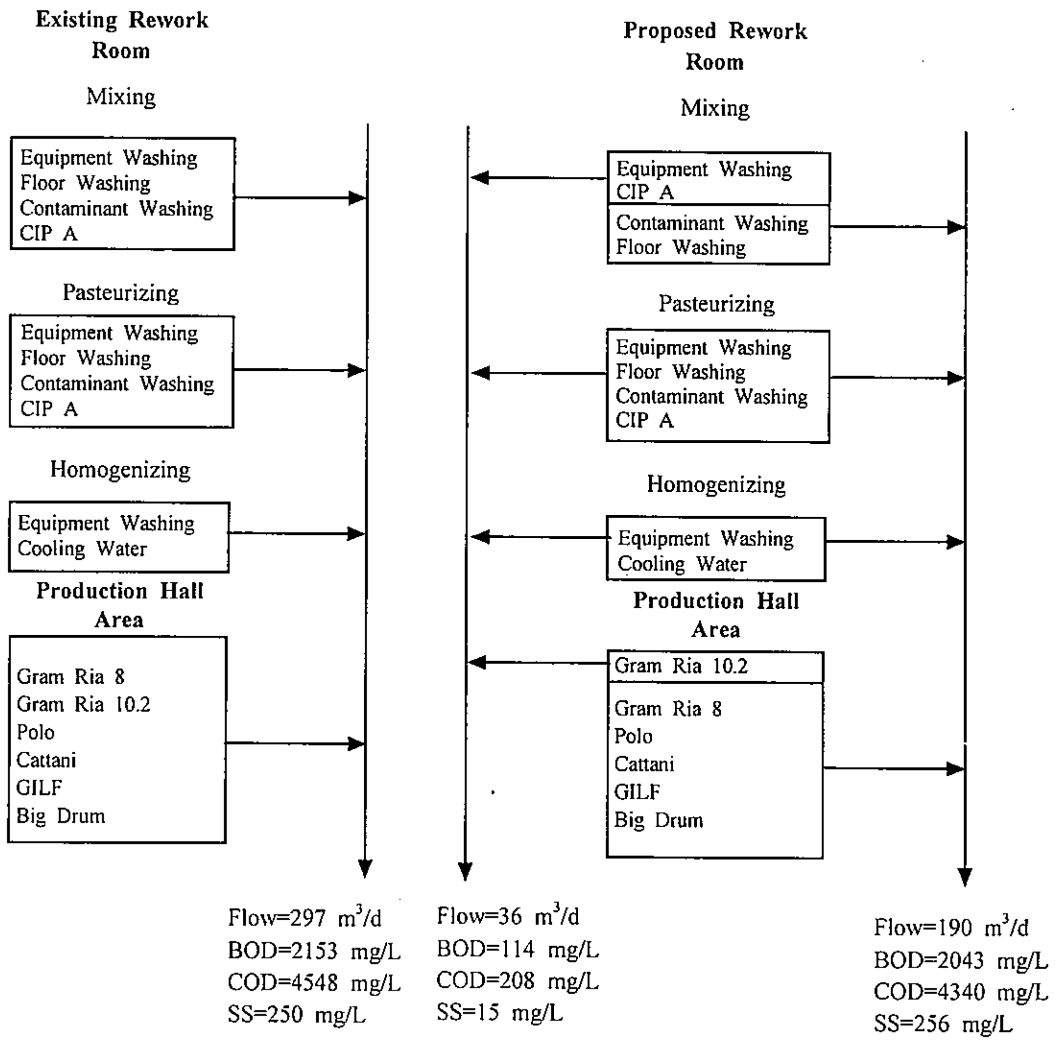


Figure 3. Effects of wastewater flow, BOD, COD and SS after waste segregation.

cream plant is envisaged upon adoption of good housekeeping practices and water reuse. This corresponds to the annual savings of 127,750 Baht. Total wastewater reduction is about 18 %.

## Waste Segregation

Figure 3 shows the effects on wastewater flow, BOD, COD, and SS concentrations after segregation of wastes. Figure 4 shows the ice cream effluent pollution loads at the sump and at the treatment plant. A proposed design for the ice cream wastewater treatment plant is summarized as shown in Figure 5. A micro-screen and dissolved air flotation (DAF) units are incorporated for the removal of suspended and floating fat solids in strong ice cream wastewater. For the weak wastes, a line going

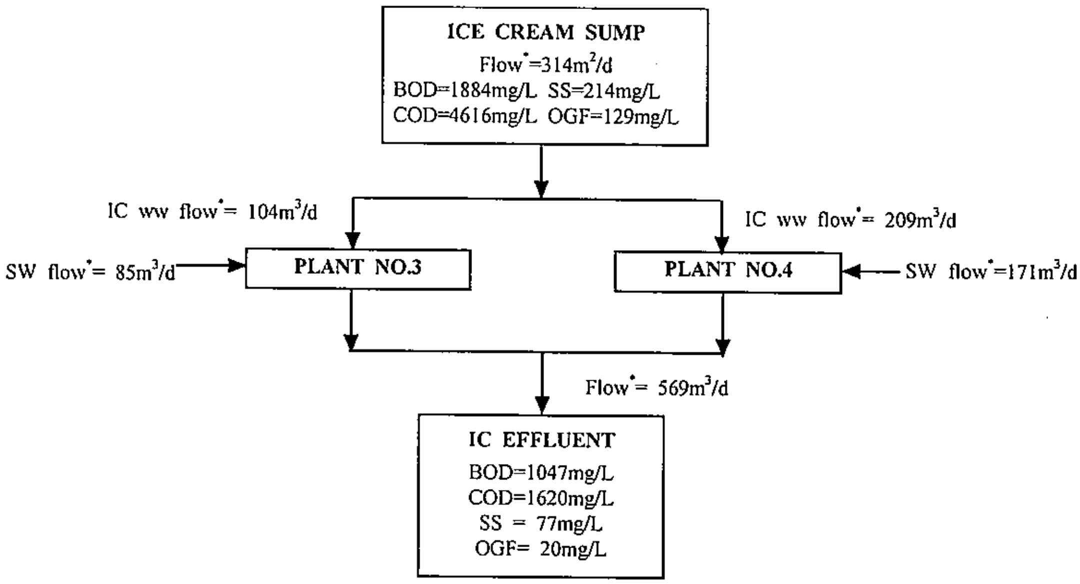


Figure 4. BOD, COD, SS and OGF loads (in kg/d) at the treatment plant.

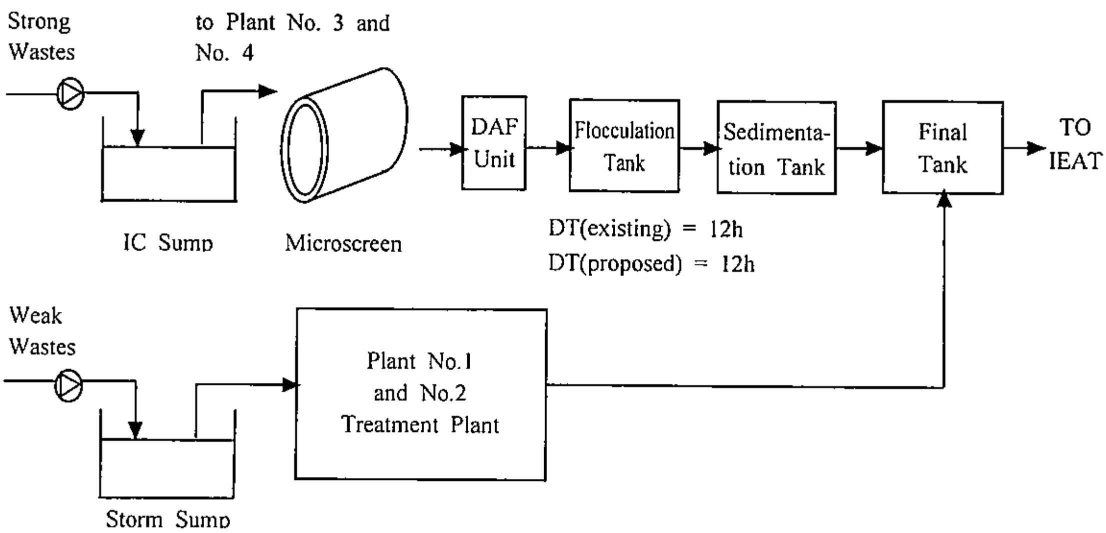


Figure 5. Proposed design of ice cream wastewater treatment plant.

to the storm sump can be set out. From there, storm waters together with the weak ice cream wastewater are pumped to treatment plants before they are discharged into the final effluent tank. To upgrade the existing sedimentation basin, plate and tube settlers can be employed. Plate and tube settlers are shallow settling devices consisting of stacked off-set trays or bundles used to enhance the settling characteristics of sedimentation basins. (Metcalf and Eddy, 1985).

## Ice Cream Effluent Quality

Composite samples collected daily by combining manually-taken samples in proportion to flow were forwarded to the laboratory for analysis and quality determination. Tables 5A and 5B presents the process wastewater flows and their corresponding strengths and pollution loads. It must be noted that wastewater arising from hand and body washing is not taken into account.

Samples from ice cream sump wastewater analyzed in the laboratory showed a detergent concentration of 1.05 mg/L which is well within the allowable limit set up by IEAT (Table 1). Therefore, the ice cream effluent is free from toxic materials and refractory inorganic elements. In this sense plant control over the use of alkaline cleaners (NaOH solution) as detergents is not necessary. Likewise, the effects of using chlorohexedene, the sanitizing compound

Table 5A. Process flows, strengths and pollution loads of wastewater

| Unit Operation | Area | Activity | Flow | | BOD | | COD | | SS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $m^3/d$ | pH | mg/l | kg/d | mg/l | kg/d | mg/l | kg/d |
| Mixing | Mixing and Homogenizing | Equipment Washing | 1.4 | 8.4 | 11,330 | 15.9 | 30,090 | 42.1 | 3,580 | 5.0 |
| | | Floor Washing | 1.0 | 6.5 | 6,940 | 6.9 | 13,200 | 13.2 | 10,060 | 10.1 |
| | | Container Washing | 1.8 | 6.9 | 10,390 | 18.7 | 15,190 | 27.3 | 1,110 | 2.0 |
| | | CIP | 5.0 | 11.2 | 1,350 | 6.7 | 2,360 | 11.8 | 116 | 0.6 |
| Mixing | Rework Handling | Equipment Washing | 5.4 | 6.5 | 911 | 4.9 | 2,720 | 14.7 | 330 | 1.8 |
| | | Floor Washing | 4.8 | 7.6 | 4,710 | 22.6 | 9,050 | 43.4 | 2,470 | 11.9 |
| | | Container Washing | 1.6 | 4.6 | 38,400 | 61.4 | 60,190 | 96.3 | 2,370 | 3.8 |
| | | CIP | 5.0 | 11.2 | 1,350 | 6.7 | 2,360 | 11.8 | 116 | 0.6 |
| Pasteurizing | Mixing and Homogenizing | Equipment Washing | 0.1 | 8.1 | 40 | 0.0 | 70 | 0.0 | 10 | 0.0 |
| | | CIP | 5.0 | 10.4 | 450 | 2.2 | 850 | 4.3 | 80 | 0.4 |
| Pasteurizing | Rework Handling Rm | Equipment Washing | 1.5 | 8.5 | 40 | 0.1 | 70 | 0.1 | 10 | 0.0 |
| | | CIP | 5.0 | 10.4 | 450 | 2.2 | 850 | 4.3 | 80 | 0.4 |
| Homogenizing | Mixing and Homogenizing | Equipment Washing | 0.1 | 8.2 | 70 | 0.0 | 150 | 0.0 | 10 | 0.0 |
| | | Cooling Water | 4.8 | 8.3 | 70 | 0.3 | 120 | 0.6 | 10 | 0.1 |
| Homogenizing | Rework Handling Rm | Equipment Washing | 0.8 | 8.4 | 30 | 0.0 | 80 | 0.1 | 10 | 0.0 |
| | | Cooling Water | 4.8 | 8.5 | 10 | 0.0 | 30 | 0.1 | 10 | 0.1 |
| Melting | Rework Handling Rm | Equipment Washing | 3.1 | 7.4 | 1,800 | 5.6 | 2,410 | 7.5 | 140 | 0.4 |
| Melting | Chocolate Preparation Rm | Container Washing | 0.5 | 6.5 | 600 | 0.3 | 2,650 | 1.3 | 790 | 0.4 |
| | | Floor Washing | 0.5 | 6.5 | 1,140 | 0.6 | 4,650 | 2.3 | 790 | 0.4 |
| Aging | Mix Storage Rm | Floor Washing | 5.0 | 10.0 | 8,700 | 43.5 | 16,370 | 81.9 | 580 | 2.9 |
| | | CIP | 63.0 | 7.6 | 3,900 | 245.7 | 9,500 | 598.5 | 90 | 5.9 |
| Freezing | Production Hall Area | CIP | 42.5 | 7.9 | 12,750 | 541.9 | 23,040 | 979.2 | 140 | 5.8 |
| | | Water Rinse | 3.7 | 6.7 | 6,200 | 22.9 | 14,490 | 53.6 | 80 | 0.3 |

Table 5B. Wastewater process flows, strengths and pollution loads n filling operations

| Machine | Activity | Flow | | BOD | | COD | | SS | |
|---|---|---|---|---|---|---|---|---|---|
| | | $m^3$/d | pH | mg/L | kg/d | mg/L | kg/d | mg/L | kg/d |
| Ria 8 | Machine Washing<br>Floor Washing | 14.4<br>4.1 | 6.9<br>6.9 | 3,560<br>3,560 | 51.3<br>14.6 | 6,090<br>6,090 | 87.7<br>25.0 | 2,830<br>2,830 | 40.8<br>11.6 |
| Ria 10.2 | Machine Washing<br>Floor Washing | 2.0<br>2.3 | 6.8<br>6.8 | 4,800<br>4,800 | 9.6<br>11.0 | 8,210<br>8,210 | 16.4<br>18.9 | 370<br>370 | 0.7<br>0.9 |
| Polo | Machine Washing<br>Floor Washing<br>Water Drain | 14.5<br>5.5<br>54.5 | 5.8<br>5.8<br>7.3 | 17,400<br>17,400<br>9,220 | 252.3<br>95.7<br>502.5 | 44,790<br>44,790<br>21,090 | 649.4<br>246.3<br>1,149.4 | 1,400<br>1,400<br>1,360 | 20.3<br>7.7<br>74.1 |
| Cattani | Machine Washing<br>Floor Washing | 7.0<br>4.5 | 5.7<br>5.7 | 6,300<br>6,300 | 44.1<br>28.3 | 10,950<br>10,950 | 76.7<br>49.3 | 1,180<br>1,180 | 8.3<br>5.3 |
| GILF | Machine Washing<br>Floor Washing | 3.7<br>3.7 | 5.7<br>5.7 | 6,300<br>6,300 | 23.3<br>23.3 | 10,950<br>10,950 | 40.5<br>40.5 | 1,180<br>1,180 | 4.4<br>4.4 |
| Big Drum | Machine Washing<br>Floor Washing | 7.0<br>4.5 | 5.7<br>5.7 | 6,300<br>6,300 | 44.1<br>28.3 | 10,950<br>10,950 | 76.7<br>49.3 | 1,180<br>1,180 | 8.3<br>5.3 |
| Calippo | Machine Washing and Floor Washing | 1.8 | 6.9 | 3,560.0 | 6.4 | 6,090.0 | 11.0 | 2,830.0 | 5.1 |
| Omni | Machine Washing and Floor Washing | 0.3 | 5.4 | 27,780.0 | 8.3 | 47,890.0 | 14.4 | 1,800.0 | 0.5 |
| Extruline | Machine Washing and Floor Washing | 0.4 | 8.2 | 1,210.0 | 0.5 | 3,010.0 | 1.2 | 100.0 | 0.1 |
| Cake Walk | Machine Washing | 0.7 | 6.2 | 600.0 | 0.4 | 1,490.0 | 1.0 | 130.0 | 0.1 |
| Total | | 297.3 | | | 2153.1 | | 4548.1 | | 250.8 |

utilized by the plant as a preventive measure against bacterial contamination are also not likely to give rise to any concern in terms of chlorine and toxic materials concentration in the resulting wastewater. The combined loads of 2,153 kg/d of BOD, 4,548 kg/d of COD and 251 kg/d SS of the process effluent discharged to the sump daily is obviously a major matter of concern to the management, as we consider the gravity of the environmental impacts these wastes would bring about if disposed un-treated.

# DISCUSSION AND CONCLUSION

## Ice Cream Plant

Ice cream plant has been operating to a significant degree of water wastage leading to a considerable amount of effluent generated. Pollution potential of the ice cream effluent is also high. Manual washing water consumption (18 % of total) for clean-up operations of machines and equipment, raw material mixing tanks and mix storage tanks, and floors can be scaled down significantly by simple in- plant modifications which in this case involve only procedural cleaning changes as follows; (i) Good housekeeping practices such as elimin-ation of the open water hose system, closing of water taps after using, repair of leaky valves and connections, dry cleaning of floors and avoiding non-food residues (wood sticks, pa-pers, etc.) from entering the wastewater stream. (ii) Reuse of water from Polo machine for floor washing in the production hall area as well as reuse of homogenizer cooling water for washing of buckets and pails and (iii) Waste segregation for easy and economical treatment of the resulting lesser volume of strong wastewater.

A proposal for a central washing system for buckets and containers which allow the segregation of strong from the less-contaminating wastes is recommended. For washing of used plastic packages, a spray system which also allows reuse of final rinse as initial rinse to the next batch may be employed. However, this is dependent on the amount of spoiled ice cream products processed for rework. If the amount is reduced, then this system can not be used. Waste segregation which refers to the collection of strong wastes for separate treatment is highly recommended. Isolation of highly-polluting process outputs such as effluents from CIP of aging tanks and freezer lines, Polo water drain, cleaning of mixing tank exteriors in the mixing area and rework handling room is proposed to reduce the wastewater volume and other parameters. Diameter of the present pipe used to convey wastewater from the factory to the treatment plant is 150 mm. Based on the proposed waste segregation measures, pipe diameter is 80 mm for strong wastes. Another pipeline for the weak wastes can also be installed for transport of wastewater to the storm sump. Design pipe diameter is 50 mm.

## Other Good Housekeeping Techniques

The followings are some improved clean-up practices for water conservation in cleaning procedures; (i) High pressure, low-volume cleaning wand - Ordinary hoses can be replaced with high-pressured cleaning wands which use far less water and are more efficient in removing dirt. (ii) Mechanical cleaning devices - Brushes or squeegee devices attached to hoses and equipped with shut-off valves can be used to loosen dirt from equipment and wash with detergent at the same time. (iii) Recycling of detergents and sanitizers in CIP systems by use of mechanical cleaning devices can be employed. Pumps gather spent cleaning solutions, screen them to avoid clogging nozzles and send the cleaning solution back to the cleaning wand. The practice not only saves water, but reduces expenditures for detergents and sanitizers. (iv) Non-food residues should be kept out of the wastewater stream.

## Waste Management Viewpoint

Several factors to affect the effectiveness of in-plant modifications and changes upon implementation of the waste reduction proposals can be identified as follows; (i) manufacturing practices, (ii) housekeeping and water conservation practices, (iii) equipment operation and maintenance, (iv) measurement of losses, (v) attitude of workers, (vi) education and training of personnel.

Apparently, all factors are largely dependent on the management stand on environmental issues like waste minimization and cleaner production. Understandably, concerted efforts between the management and the workers are of prime importance towards attaining waste minimization goals. It is usually necessary that initial efforts must come from the top management and all personnel in the plant will subsequently carry through succeeding work. Recognizing the worker's role as a key towards pollution abatement is often disregarded. The workers must fully understand the concept of waste minimization and realization of the importance of application of cleaner production in the plant. Implementation of waste reduction measures like good housekeeping practices requires training and good supervision of employees.

The treated final effluent for disposal to IEAT contains 1,840 mg BOD/L which is substantially higher than the IEAT requirement of 900 mg BOD/L. It is clear that the treatment plant has not been operating satisfactorily. The problems currently affecting the treatment plant can be curtailed by effective removal of floating fats and suspended solids. To increase the opportunity of flocculation, a need to increase the detention time is required. Avoiding the addition of relatively clean storm water to the treatment plant will serve this purpose. Installation of plate and tube settlers is also recommended to enhance settling characteristics of the existing sedimentation basins. Optimum coagulant dosage for alum is 545 mg/L and for SOP the proposed dose is 2.8 mg/L. Alum is proven to be the best coagulant on the basis of its actual performance in laboratory tests conducted. Low BOD removal after jar test analysis indicates that most of the BOD in the ice cream wastewater is in solution. Since primary treatment is insufficient, it is proposed that a biological treatment should be added to reduce soluble BOD. A proper attitude of preventing waste must also be developed.

The period of increased ice cream production began in the first week of Cycle 6 to the fourth week of Cycle 13. All calculations for the daily average ice cream water consumption, ice cream production, and total effluent discharge are based on this period. It is also important to note that water consumption and effluent generations are done regularly 7 days a week while ice cream production is 6 days a week. Although ice cream is produced for 6 days a week, that is, from Mondays till Saturdays, but cleaning is usually done on weekends for tunnels such as Omni, Extruline and Cake Walk. Normally, CIP is done when there is a product changeover or when shifting from one flavor to another. The most convenient time for doing CIP is at night time or early morning (Shift C) though at other times it is also done in the morning (Shift A) and afternoon shifts (Shift B) depending on the weekly production plan schedule. Large amounts of dechlorinated warm and cold water are consumed in washing and cleaning activities such as machine washing, floor and container washing and cleaning-in-place in five areas of the plant. The five most water-consuming and water-wasting areas of the plant include the mixing and homogenizing area, rework handling area, mix storage room, chocolate preparation room and the production hall area.

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