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Project Summary

Tomato Cleaning and Water Recycle

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This summary discusses the findings of a study designed to develop a mud-removal/water recycle system for a tomato dump tank operation employing rotating soft rubber discs.

Over a three-year period (1974, 1975, and 1976), modifications were made to a mud-removal-water recycle system. A false bottom-ejector transport system was developed to prevent soil from settling in the dump tank. Also, a physical/chemical treatment system was developed to remove soil from water being recycled back into the dump tank. Colloidal particles were removed from the thickener overflow tank before being recycled back to the dump tank or discharged to the sewer. A vacuum belt dewatering unit was constructed and evaluated for dewatering mud from the thickener tank prior to final disposal.

Two different designs of rubber disc machines were evaluated and found to be equally effective in cleaning the surfaces of tomatoes. Minimal quantities of water were required in the cleaning of the tomatoes. Energy in the form of spinning soft rubber discs removed surface soil from the tomatoes. It was also observed that stems were removed from the tomatoes by the disc cleaners.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Mechanical harvesting of raw products has increased the amounts of soil being transported to food processing plants. The quantity of such soil for tomatoes is about two percent of the product weight. The soil is characterized in two forms: (1) as clods of dirt and (2) as smear soil on the surface of the product. The increase in soil on the product has caused food processors to use more water to clean the product.

When the velocity of water is insufficient to scour the bottom surface of the tank, soil solids accumulate in the bottom of dump tanks or initial flumes. After several hours, the soil accumulates to the extent that product flow is impaired and process downtime is required for the removal of the soil.

The food-processing industry has used high water-scouring velocities to prevent soil from settling, or allowed the soil to settle. In the latter case, processing was stopped periodically to remove the accumulated soil. The use of high water-scouring velocities results in the discharge of excessive amounts of water, which adds to the hydraulic portion of surcharges. The discharge of inert solids (soil) to a municipal waste treatment system may result in operational and maintenance problems. The intermittent shutdown by the processing plant reduces plant productivity and requires additional water for cleanup purposes.

This project was initiated to seek solutions to problems related to the processing of machine-harvested tomatoes. The specific objectives of the project were:

- To demonstrate on a commercial scale the substantial reduction in the volume of water required to clean tomatoes by using a flexible, spinning rubber disc machine.
- To develop a water recycle system for tomato dump tank water.
- To compare the cleanliness (based on bacteriological and physical criteria) of tomatoes processed in a conventional washing system with that of a low-water cleaning/washing system.
- To compare the plant effluent (with regard to volume, BOD, and suspended solids) of conventional versus low-water cleaning systems.
- To make economic comparisons between (a) conventional washing systems versus disc cleaner; (b) conventional washing system with dump tank recycle (no chemical flocculation) versus disc cleaner with dump tank recycle (no chemical flocculation); (c) disc cleaner with dump tank recycle (no chemical flocculation) versus disc cleaner without dump tank recycle; and (d) disc cleaner with dump tank recycle (with chemical flocculation) versus disc cleaner with dump tank recycle (no chemical flocculation).

Dump Tank Water Recycle

The initial approach used in the development of a water recycle system was to maintain a high water velocity in the dump tank and to withdraw, treat, and return the water. The withdrawn water was treated, then returned to the dump tank at various locations. It was postulated that the water would be of adequate volume and have sufficient head to maintain a scouring effect along the entire bottom of the dump tank.

The primary objective of the 1974 test program was to determine if it was feasible to maintain a closed-loop system of water usage around the tomato bin dump. The second objective was to evaluate the technique of utilizing high scouring velocities at the base of the bin dump to prevent accumulations of settleable solids within the bin dump itself. The third and final objective was to determine what benefits, if any, would accrue from a coagulation and flocculation system used in conjunction with the closed-loop water recycle system. The findings of the 1974 water recycle project indicated the following problems:

- Insufficient data coverage.
- Unsatisfactory mud removal procedure.
- Clogging of recycle system mechanical elements.
- Lack of soil solids concentration.
- Lack of liquid level control in the bin dump.
- No automatic control of coagulant dosage.

Major modifications were required in subsequent operations of the recycle system to assure its ability to meet the general project objectives. The four objectives set for the 1975 study were as follows:

- Modify and improve the water recycle system for the tomato dump tank.
- Compare wastewater quantity and quality under different operating modes.
- Compare the quality of final discharge waters from the system with and without the addition of coagulation/flocculation.
- Economically compare the sequences of operation of the initial bin dump with and without the water recycle system, and with the water recycle system operating in different modes.

Model Dump Tank Study

In January 1975, a model bin tank study was developed. The proposed grit collection system consisted of a false bottom near the point where tomatoes were dumped into water. Grit would pass through the false bottom and be transported by means of an ejector to a solids separation system. Two alternative methods were used to introduce recirculated water into the bin dump: (1) jet flow and (2) weir overflow. The jet flow system sustains high velocities for greater distances through the bin dump tank than does the weir overflow method. These methods were evaluated to determine if soil deposition could be concentrated near the point of introduction.

Soils selected for evaluation of deposition were Yolo Loam and Hanford Sandy Loam. Handford Sandy Loam is predominantly a sandy material, whereas Yolo Loam contains a significant amount of clay (Table 1). The major objective of the model study was to develop quantitative design criteria for scaling the solids collection and transport system for a full-scale bin dump operation.

Table 1. *Study Soil Compositions, Average Weight Percent*

Component	*Yolo Loam*	*Hanford Sandy Loam*
Sand	*22.5*	*74.5*
Silt	*50.0*	*16.0*
Clay	*27.5*	*9.5*

Test results showed no significant differences between the jet flow and weir overflow methods in the distribution patterns of soil deposits. However, the Hanford Sandy Loam did not develop the concentrated, settled condition experienced with Yolo Loam. With Hanford Sandy Loam, characteristic "ripples" or "humps" were observed on the downstream side of the deposited solids.

Also tests were conducted using both low- and high-scour channel velocities. Using low-scour velocities, only 30 percent of the loaded soil was effectively collected and transported from the bin dump to the solids separation system. However, excessive scour velocities in the channel resulted in a reduction in overall collection efficiency. Using high-scour velocities, patterns of soil deposition showed an accumulation of relatively fine soil particles immediately downstream of the hopper and false bottom. Observation of the flow pattern in the bin dump tank indicated that this accumulation of material was primarily due to the transport of soil particles by turbulence generated by the high-scour channel velocities.

Full-Scale Water Recycle System

The design for the full-scale recycle system included the false bottom, ejector solid transport, screen and solid discharge hopper, swirl concentrator, sludge thickener, and chemical flocculation systems. The four modes analyzed are discussed below.

Conventional Washing System

The conventional washing mode consisted of four washing steps: dump tank, inside washer flume, distribution flume, and final rinse. The wash water was countercurrent to the direction of the tomatoes (Figure 1). In this system, a significant savings in water consumption was realized. The conventional washing system adopted for this study used water recycling, and was not the same

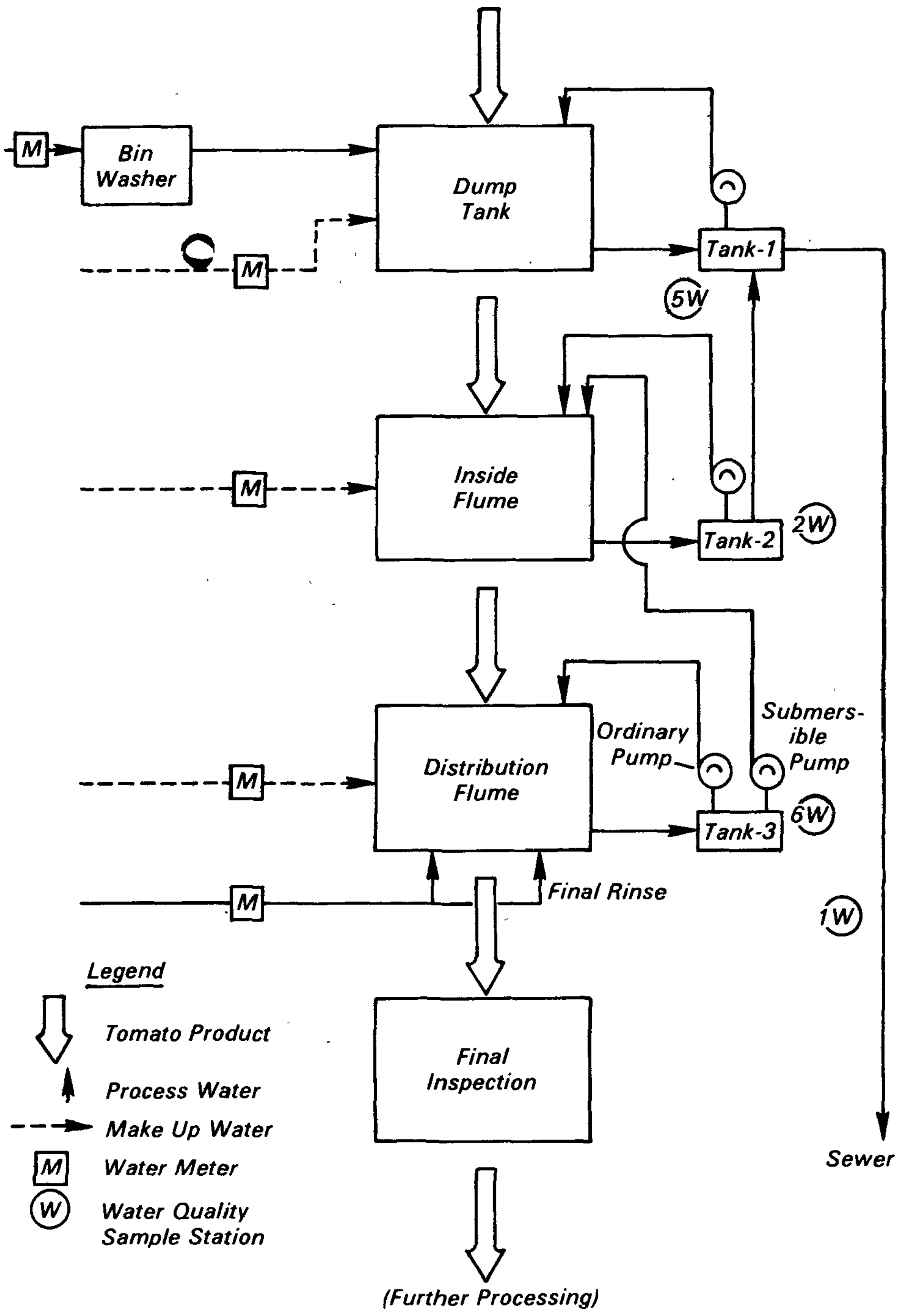

Figure 1. *Flow diagram of conventional cleaning system.*

as the "conventional" washing systems commonly employed in food processing.

Conventional Washing with Water Recycling System

Tomatoes coming into the plant were processed in the manner previously described. The only difference in this first mode of operation was the incorporation of a swirl concentrator into the water recycle system (Figure 2).

Disc Cleaner with Water Recycling System

In this mode of operation, tomatoes were transported directly from the dump tank to the rubber disc cleaner, and subsequently transported into a distribution flume, and then to a final inspection stage (Figure 3). The rubber disc provided an alternative method of cleaning. It replaced the flumes and sprays in the usual cleaning process.

Disc Cleaner with Water Recycle and Chemical Flocculation

For this mode of operation, the flow diagram is similar to the previous flow scheme. Here, however, an internal chemical coagulation and flocculation step was added prior to the sludge thickener process (Figure 4). The chemical coagulation-flocculation subsystem consisted of four components: (1) recirculation pump, (2) tube flocculator, (3) slip-stream turbidimeter, and (4) chemical feed mechanism.

Analysis of Water Consumption

In a typical tomato processing plant, water can be used for (1) filling, (2) operation, or (3) cleanup. The water used for filling purposes represents that portion of water used to fill up a dump tank, an inside washer, or a distribution flume. The water used for operational purposes represents that portion which is continuously utilized, such as bin washing, cleaning of the trash belt, and the final rinse of tomatoes. Cleanup water is that portion of water used for floor cleaning, tank and flume washing during a shutdown.

Table 2 presents the average amount of water consumption for various water usages. The data indicate that for the same usage purposes, there was no significant variation in the total daily usage at the various modes of operation. Approximately 7 percent was utilized for filling purposes, 55 percent for operational purposes, and 39 percent for cleanup purposes. The following observations and conclusions may be drawn from these data:

- The average daily tonnage of tomatoes processed increased substantially when water recycling measures were employed.
- A decrease of 26 percent in the average total daily water usage was realized when the disc cleaner with water recycling and chemical flocculation was applied. A decrease in water usage was also noted for filling and operational purposes.

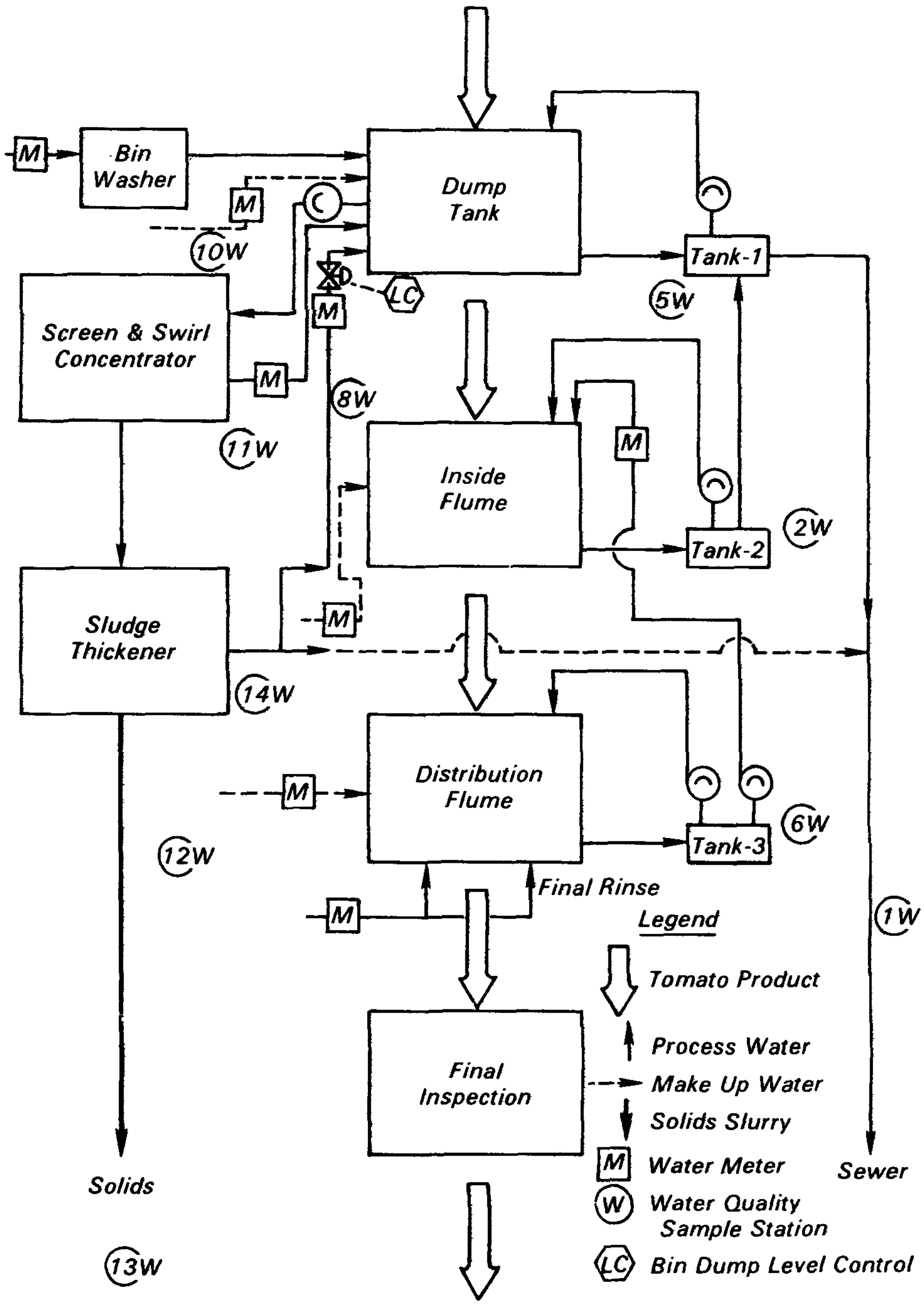

Figure 2. Flow diagram of conventional cleaning with water recycle system.

- A decrease in the average unit of water consumption (gallons of water used per ton of tomatoes) occurred when water was recycled.

Soil Solids Loading

Analyses of soil solids distributions at various modes of operation are presented in Table 3. In a conventional washing system, 31 percent of the soil is removed from the dump tank, and the remaining 69 percent is discharged into the sewer. Utilization of more sophisticated removal measures (i.e., disc cleaner, and chemical flocculation) significantly increases the unit weight of soil solids removed from the sludge thickener. At the same time, the percentage of soil solids discharged into the sewer decreases. The amount of soil solids carried to the processing plant is a function of soil type, moisture content of the soil when the tomatoes are harvested, and method of harvesting.

Vacuum Belt Dewatering Device

In September 1976, the vacuum belt dewatering unit was evaluated for cake solids production rate, dewatering efficiency, drying factor, sludge volume reduction, and solids recovery efficiencies. The unit was analyzed with and without the addition of a chemical coagulant. The following observations were made in comparing the two sets of data:

- A slight increase in the thickness of the feed sludge and cake with chemical coagulation at the clarification-thickening stage.
- Increases in the sludge loading rate and sludge cake production rate with chemical coagulation.
- A significant increase in the total solids concentration for the sludge feed and cake with chemical coagulation.

In comparing the performance of the vacuum belt dewatering unit with other sludge dewatering devices, two parameters are worth noting: cake solids production rate, and the cost of sludge dewatering. The cake solids production rate of the vacuum belt ranged from 10 to 117 lb/hr/ft^2, while a cake solids rate of 1 to 8 lb/hr/ft^2 was typical for other types of dewatering devices (i.e., vacuum filter or filter press). Also, it should be noted that the cake production rates for the vacuum filter and filter press used in this comparison were based on dewatering municipal sludges; cake production rates would be different for sludge from a tomato processing plant.

The second significant feature of the vacuum belt dewatering system was its low unit cost, estimated to be approximately $2 per ton. Unit costs of other dewatering devices ranged from $12 to $29 per ton of dry solids.

The data showed significantly larger sludge solids loading rates and cake production rates when chemical coagulation was employed. The average sludge solids loading rate with chemical coagulation was 76.2 lb/hr/ft^2 versus 38.9 lb/hr/ft^2 without chemical application. Similarly, the average cake production rate with chemical application was 75.2 lb/hr/ft^2 versus 38.3 lb/hr/ft^2 without the application of any

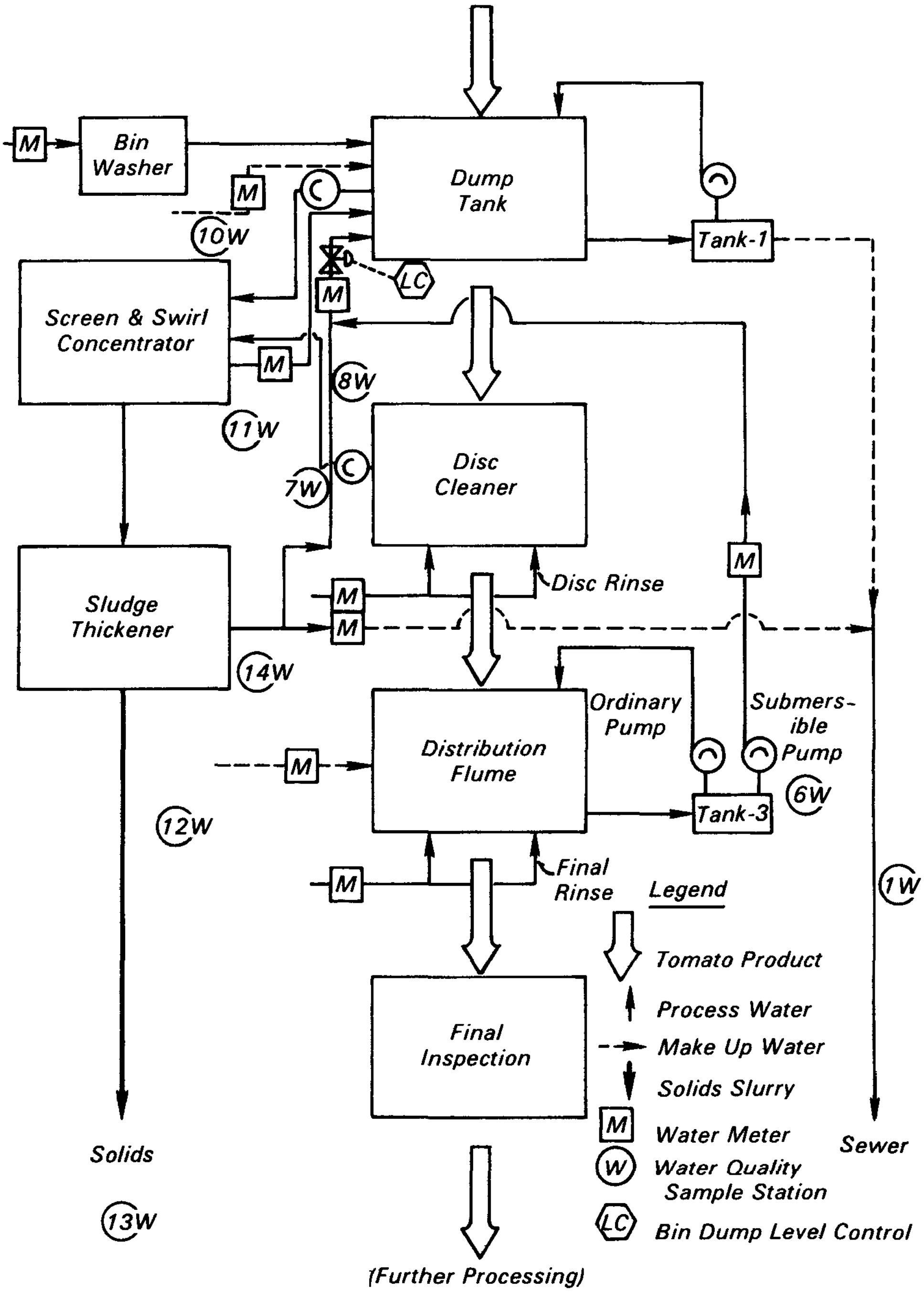

Figure 3. *Flow diagram of disc cleaner with water recycle system.*

chemicals. Results for the other parameters were approximately the same.

Tomato Cleaning with Magnuwasher

In September 1976, a Magnuwasher, significantly different from the flat bed disc unit, was evaluated. This machine contained parallel rows of soft rubber discs arranged in a circle. By means of a drive mechanism, a tumbling movement was imparted to the product, and the spinning of the discs provided the cleaning. The Magnuscrubber was analyzed in the same manner as the flat bed disc cleaner.

The data indicated that variations in the volume of water used by this device influenced the characteristics of the effluent. As more water was used, the concentration of measured parameters decreased. The results suggest that tomatoes after Magnuscrubber treatment were as clean as those found after the final rinse. A summary of the effluent from the Magnuscrubber is provided in Table 4. The BOD results suggest that variations in the volume of water had no effect on the amount of organic matter being discharged. The COD and TOC results were more variable with flow. The TOC increased as the volume of water increased, whereas COD was maximum at 7 gpm. Apparently, this device can clean tomatoes with minimal amounts of water.

Economic Analysis

Because of the wide variation in wastewater treatment costs, a summary comparison of alternative recycle systems is presented in Table 5 for three wastewater agencies. Industrial wastewater charges among San Jose, East Bay Municipal Utility District (EBMUD), and Sacramento, California, were evaluated for cost-effectiveness under the various cleaning methods. The total cost of processing tomatoes involved the following:

- Cost of water.
- Wastewater treatment costs.
- Energy cost.
- Equipment capital and depreciation costs.
- Solid waste disposal cost.
- Chemical cost.
- Labor and maintenance costs.
- Indirect costs.

A summary of the total costs for tomato cleaning for the alternative recycle systems considered is presented in Table 6, which summarizes all identifiable costs for the alternative systems where the costs were not equivalent for all systems considered. The costs range from a high of approximately $1.50 per ton for the modified conventional washing system with recycle to a low of $0.92 per ton for the disc cleaning system with water recycle and solids concentration. The advantages of utilizing water recycle systems in terms of overall cost savings are clearly demonstrated in this table. In this analysis, the overall cost, including capital costs of the required equipment, is reduced by as much as $0.59 per ton of tomatoes processed. Hence, there is a potential net annual savings of approximately $20,000 per year for a 36,000-

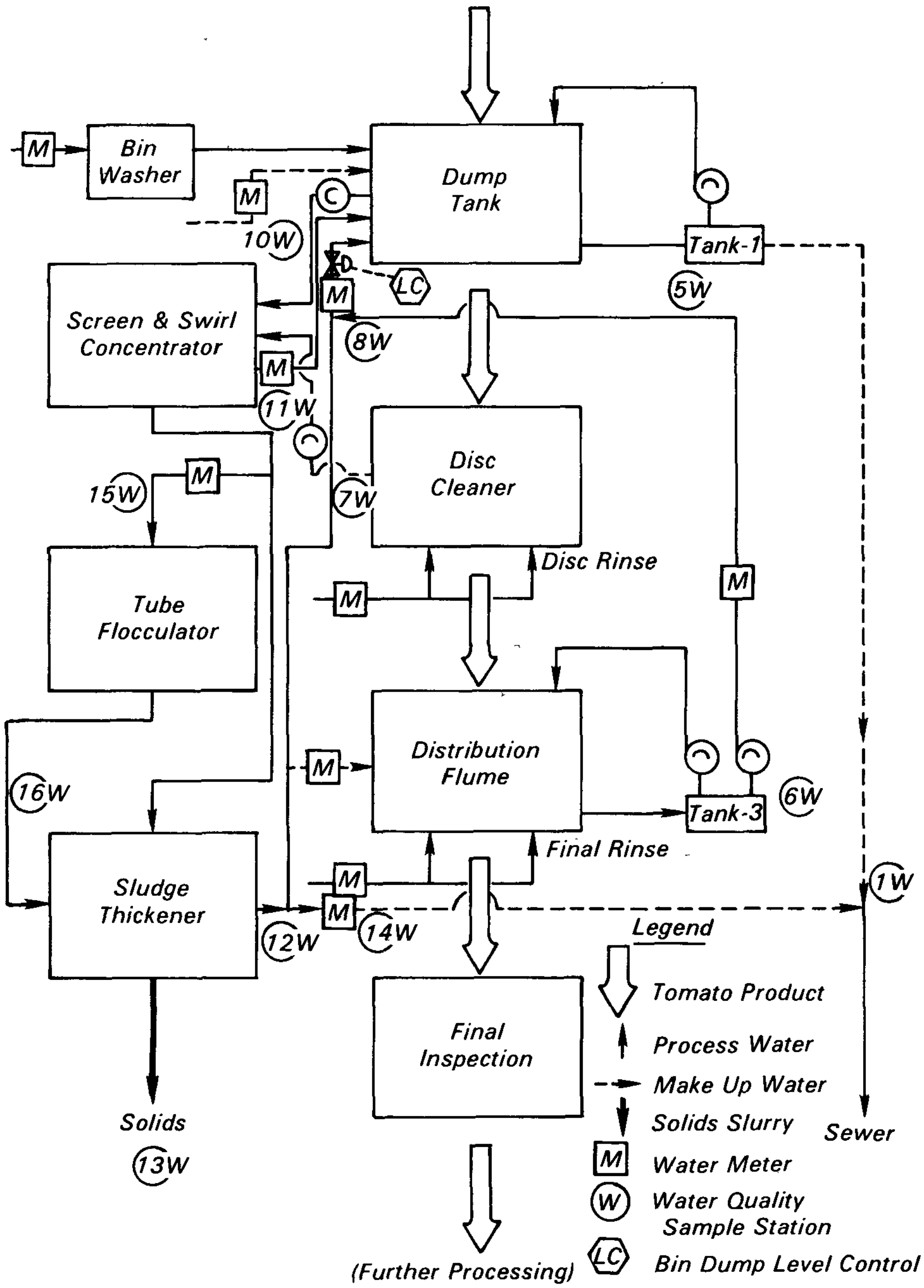

Figure 4. *Flow diagram of disc cleaner with water recycle system with flocculation.*

ton/year season. These savings represent a substantial return on the investment as these are direct savings in operating costs.

The use of chemical flocculation resulted in an additional cost for chemicals that was absent from the other alternative systems. However, lower costs for water and wastewater treatment resulted in lower overall costs for disc cleaning and water recycling with solids concentration.

The 25 percent increase in tomatoes processed with the water recycle systems has economic savings other than those associated with waste treatment costs. Compared to conventional methods of processing, the 25 percent increase can be translated into the processing of an additional 140,000 tons of tomatoes without additional costs. Another way of interpreting the potential savings from using the water recycle system is to compare processing time for a given tonnage of tomatoes. For example, 60 days of conventional processing is required to produce 720,000 tons. With recycling, the same tonnage can be processed in 45 days with a labor savings of $54,000 per season.

Conclusions

Performance parameter values were obtained by investigating four modes of operation: (1) conventional cleaning, (2) conventional cleaning with water recycle, (3) disc cleaner with water recycle, and (4) disc cleaner with recycle and chemical coagulation/flocculation. Using these parameters, it was demonstrated that the installation and operation of an in-plant water recycle system with off-line mud removal could save approximately 50 percent of the total annual wastewater-related costs. For a 30-ton/hr plant, annual savings could amount to approximately $47,000. Water usage utilizing a disc cleaner was significantly lower than conventional washing operations, supporting the concept of using mechanical energy as a major substitute for hydraulic energy. There was no need for an inside washer when using a disc cleaner. A potential water savings from the use of this device would result in the elimination of the inside water volume (33 gal/ton). Another benefit from the use of the disc cleaner is the potential for a higher quality of water in the distribution flume recirculating system.

As compared to the conventional system, the daily average tonnage of tomatoes processed increased substantially with disc cleaning and water recycle. The 26 percent increase in the tonnage of tomatoes processed was primarily due to the virtual elimination of solids which accumulate in the dump tank. During modes of operation with water recycle, no shutdowns of shift operations (for the purpose of removing soil from the dump tank) were encountered. The following findings were established in this study.

- The majority of daily water usage was for operational purposes (48 to 61 percent), followed by cleanup (31 to 44 percent), and filling (6 to 8 percent). Regardless of the mode of operation, no significant variation in the percentage of the total daily water used was observed.
- A 25 percent decrease in average total daily water usage was realized with disc cleaner and water recycling with chemical flocculation.

Table 2. *Summary of Average Water Consumption at Various Modes of Operation*

Mode of Operation	Average Tomato Processed (ton/day)	Average Water Consumption (gal/day) Filling Purpose	Operational Purpose	Cleanup Purpose*	Total	Average Unit Water Consumption Rate (gal/ton)
Conventional	481	10,700	81,300	41,500	133,500	278
Conventional (with swirl, without flocculation)	445	7,800	59,800	41,500	109,100	245
Disc Cleaner (with swirl, without flocculation)	594	7,000	44,300	41,500	92,800	156
Disc Cleaner (with swirl, with flocculation)	605	6,400	51,100	41,500	99,000	164

*Averaged value.

Table 3. *Average Total Soil Solids Loadings at Various Operational Modes*

Mode of Operation	Total Tomatoes Processed (ton/day)	Soil Solids Removal from Dump Tank		Soil Solids Lost to Sewer		Soil Solids Removal from Thickener		Total Soil Solids to Plant	Soil Per Unit of Tomato
		(lb/day)	(lb/ton)	(lb/day)	(lb/ton)	(lb/day)	(lb/ton)	(lb/day)	(lb/ton)
Conventional	481	2,757	5.7	6,029	12.5	—	—	8,786	18
Conventional (with swirl, without flocculation)	445	941	2.1	2,332	5.2	1,453	3.3	4,726	11
Disc Cleaner (with swirl, without flocculation)	594	684	1.2	1,609	2.7	3,353	5.7	5,646	10
Disc Cleaner (with swirl, with flocculation)	605	856	1.4	2,920	4.8	4.568	7.6	8,344	14

Table 4. *Characteristics of Effluent from Magnuscrubber*

Flow (GPM)	COD	BOD	TOC
	(lb/day)		
4	337	281	119
7	440	283	158
13	420	282	172

- The daily average tonnage of tomatoes processed increased substantially during modes of operation with water recycling.
- A 41 percent decrease in the average unit water consumption rate (gallons of water per ton of tomatoes processed) was realized when disc cleaner with water recycling and chemical flocculation were applied.
- When water conservation and reuse measures were implemented, the soil solids removed from the dump tank per ton of tomatoes processed decreased, soil solids lost to the sewer decreased, and the soil solids removed from the thickener tank per ton of tomatoes processed increased.
- Estimated incoming soil solids ranged from 10 to 20 lb/ton of raw tomatoes (13 lb/ton average). Estimates were based on the sum of soil solids collected from the dump tank, lost to the sewer, and removed from the sludge thickener.
- The amount of soil solids varies considerably and depends upon the type of soil in which the tomatoes were grown, the moisture content of the soil when the tomatoes were harvested, and the method of tomato harvesting.

Recommendations

Methods for the removal of soil from water, the recycling of water from dump tank operations, and the cleaning of tomatoes using a low volume of water have been demonstrated, and should be placed into commercial use. There is a need to find an effective method to eliminate vines, stems, grass, and other materials that accumulate at product transfer points, as well as to periodically clean the false bottom of spacings which become clogged with soil clods, rocks, metal trash, etc.

Table 5. *Summary Comparison of Wastewater Treatment Costs for Alternative Recycle Systems*

Agency	Modified Conventional Washing Plus Recycle ($/ton)	Modified Conventional Washing Plus Recycle and Solids Concentration ($/ton)	Disc Cleaning Plus Recycle and Concentration ($/ton)	Disc Cleaning Plus Recycle, Flocculation, and Concentration ($/ton)
San Jose	1.104	0.469	0.312	0.255
EBMUD	1.237	0.495	0.438	0.437
Sacramento	1.324	0.531	0.467	0.357
Average	1.222	0.498	0.406	0.350

Table 6. *Summary of Costs for Tomato Cleaning*

Overall Cost	Modified Conventional Washing with Recycle ($/ton)	Modified Conventional Washing with Recycle and Solids Concentration ($/ton)	Disc Cleaning with Water Recycle and Solids Concentration ($/ton)	Disc Cleaning with Water Recycle, Solids Concentration, and Flocculation ($/ton)
Water Use	0.074	0.066	0.042	0.044
Wastewater Treatment	1.222	0.498	0.406	0.350
Energy	0.016	0.038	0.034	0.035
Equipment Capital Cost	0.186	0.605	0.424	0.474
Solid Waste Disposal	0.005	0.009	0.012	0.013
Flocculant	—	—	—	0.017
TOTAL	1.503	1.216	0.918	0.933

Potential net annual savings = (1.503 - 0.933) (36,000 ton/year) = $20,520.

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***Kenneth A. Dostal** and **Harold W. Thompson** are the EPA Project Officers (see below).*
The complete report, entitled "Tomato Cleaning and Water Recycle," (Order No. PB 82-255 381; Cost: $12.00, subject to change) will be available only from:
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