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Liquid Wastes From Canning and Freezing Fruits and Vegetables

U.S. ENVIRONMENTAL PROTECTION AGENCY

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LIQUID WASTES

FROM CANNING AND FREEZING

FRUITS AND VEGETABLES

by

National Canners Association
Western Research Laboratory
Berkeley, California 94710

for the

OFFICE OF RESEARCH & MONITORING

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ABSTRACT

The size of the U.S. fruit and vegetable canning and freezing industry and estimates of its output of waste water, biochemical oxygen demand (BOD), suspended solids (SS), and solid residuals are presented. Typical processing operations and the sites of generation of wastes are outlined. Estimates are made of the proportions of waste loads generated at each of several processing steps for 15 commodities. The proportions of waste effluents treated and the the costs of liquid waste management in this industry are estimated.

The generation of waste and factors influencing waste loads are discussed; quantities of waste and its treatment and/or disposal costs are estimated. References are listed for operations important in pollution control such as: harvest and delivery, in-plant water uses, blanching, and peeling. Solid residuals and their use and disposal are discussed.

Under liquid waste treatment, the separation of particulates, biological treatment, land disposal, and other methods are discussed. Treatment efficiency, important variables, costs, and references are given.

Additional research is recommended in: determining the sources of waste, water conservation and reconditioning, blanching, peeling, solid residuals utilization, liquid waste treatment and pollution evaluation.

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SECTION I

SUMMARY

About 170,000 persons work in about 1,800 plants in the canned and frozen fruits and vegetables industry in the United States. It is estimated that this industry annually:

utilizes 26 million tons of raw product,
discharges 83 billion gallons of waste water,
generates 800 million pounds of biochemical oxygen demand (BOD) and 392 million pounds of suspended solids (SS),
and produces 8 million tons of solid residuals.

On the average the food industry utilizes more public treatment and ground disposal (mostly irrigation) for the ultimate disposal of its waste than do other U.S. manufacturers. Non-urban plants are much more likely to have their own treatment systems than are urban plants. Disposal methods for liquid wastes vary widely among commodities.

Flow diagrams, typical of the industry's commodities, are presented for peaches, peas, corn, beets and tomato products. Proportions of the total liquid waste flow, BOD, and SS from each of five or six processing steps for 15 commodities are estimated. Pollutional loads tend to concentrate in relatively little water at some of the steps (for example, peeling, blanching); relatively clean water is discharged from some operations (for example, washing some products, final canning and freezing operations). The effluent pH varies from less than 4.0 to more than 12.0 depending upon the commodity being processed and the specific type of unit operation utilized during processing.

A trend toward increased mechanical harvesting of the industry's crops is continuing with increased problems in product damage, soil, and loss in yields. Movements toward more in-field processing and improved transportation methods are noted.

Water is used extensively for transporting commodities within the processing plant because it is a convenient transportation medium and helps maintain sanitary conditions. Water is necessary for cleaning raw commodities. However, solubles leached during transportation add to the organic load in the plant effluent. Water is extensively recirculated within equipment and reused at upstream operations in food processing, but additional water savings by reuse are possible and needed. Reconditioning of the water is sometimes necessary.

Blanching is essential in the preparation of many vegetables for canning and freezing. High pollutional loads are generated by conventional blanching methods using steam and, especially, hot water. Nutrients and minerals are leached or destroyed to some degree during blanching.

Peeling by some methods also produces strong pollutional loads. Mechanical peeling with dry-handling of the residuals is feasible for some commodities and minimizes water use and soluble pollutants. "Dry caustic" peeling, which reduces the pollution load in the liquid waste, is a proven process for potatoes and has been used successfully on several other commodities in pilot plant experiments.

The first and commonest step in treating liquid effluents from food processing plants is the separation of particulate matter. This step is generally accomplished by either screening or settling. Several types of stationary, vibrating, and rotary screens are used with a wide range of mesh sizes. Screening and/or settling equipment removes little of the BOD but if this equipment is adequately operated it will prevent further leaching of organics (BOD) into the transport water. The efficiency of settling can be improved by flocculents. Air flotation has promise for removing fine solids from some kinds of waste streams.

Solid residuals left from processing many fruits and vegetables have no ready use because they are: a) generated during a few months of the year, b) generated in small quantities by widely dispersed plants, c) not storable without expensive partial processing, and/or d) not as suitable as other raw products. However, the solid residuals from citrus, pineapples, and white potatoes are produced in large quantities over a long campaign season. Corn processing also generates large quantities of solids which may be stored. As a result, these residuals along with smaller quantities from many other commodities are used as stockfeed. A number of other by-products are made from food processing residuals in small amounts.

Biological processes are widely used to treat food processing waste effluents. These effluents often need added inorganic nutrients for efficient biological treatment. The sludge produced in biological treatment, largely cells of microorganisms, is usually separated by settling and disposed of by various methods.

A number of systems for biological treatment have been developed. Some waste conversion occurs by natural flora during long periods in holding ponds. Various methods of aerating the effluent and of recycling some or all of the sludge to the aerated or to an anaerobic section of the system improve the efficiency and shorten the time of treatment at increased costs. BOD and SS removals vary widely among and within the systems. Some biological systems are sensitive to shock loadings or pH changes, which, together with insufficient aeration, may reduce BOD removals and/or produce a sludge that is difficult to settle.

Within the food processing industry the most common method of liquid waste disposal on the land is spray irrigation. The availability of suitable land, the characteristics of the soil, the cover crop, the waste water, and climatic conditions all affect this method of disposal. Some irrigation systems operate with little or no run-off and remove practically all of the pollutional load; even with run-off fairly high removals can be achieved.

Such treatment methods as carbon adsorption, ultra-filtration, reverse osmosis, and liquid incineration have been little used for food processing wastes except experimentally.

Roughly half of the industry's plants discharge their liquid wastes to municipal treatment.

Liquid waste costs for a synthetic average plant in the industry are estimated at $18, 000 per year or $1. 30 per ton of raw product, including annual capital and operation and maintenance costs.

Extensive research is needed in many phases of the industry's waste problems: the sources, quantities, and characterization of waste loads during processing; water reconditioning, recirculation, and reuse in the plant; new, low-pollution methods of blanching and peeling; the operations of current treatment systems and explorations of new systems; improved monitoring methods; and cost estimates for all waste handling methods.

SECTION II

INTRODUCTION

SCOPE AND PROBLEM

The effective minimizing of the pollutional loads developed in fruit and vegetable processing is important to both the economic and social status of the enterprise. It is the objective of this report to consolidate and make available the substance and record of published information dealing with wastes generation during fruit and vegetable processing. Also, from this, to direct attention to potential areas for reducing the pollution loads through research, most of which will have economic advantages to the operation, and which will enable better meeting of the objectives in environmental protection programs.

The data in this report were taken largely from the published literature; more than 700 references are listed.

During the past 20 years there has been a constant consolidation of smaller fruit and vegetable operations into larger, more centralized process operations, resulting in greater usage of water and more discharge of wastes per operation. Thus, during the highly seasonal periods of operation in the industry it is not unusual for a process operation to utilize much more water and to generate more waste than the community in which the operation is located. The waste loads in this industry are generated within a relatively small harvest period during the year; treatment systems must be geared to prevent pollution at periods when rainfall and stream flow are at a minimum. Further, where the wastes are channeled into municipal systems, often these are already overtaxed in capacity and inadequate for the community requirements.

The solid wastes produced in processing many fruits and vegetables have relatively little economic value and are not marketable. Disposal may be by land fill or by spreading on land, and sometimes creates problems of pollution, hygiene or public annoyance. However, solid residual material from some products is specifically handled for stock feed.

The waste in the effluents from canning and freezing plants are biodegradable, but treatment costs are increasing, effluent discharge requirements are becoming more stringent, and urbanization increasingly limits the availability of land.

Thus there are many problems to be dealt with in handling the industry's waste.

TOTAL WASTE PRODUCTION

CURRENT - The fruit and vegetable canning and freezing industry includes operations in 1,838 plants employing 167,000 persons, resulting in increased value to the raw crop of some $2.2 billion. This industry utilizes an estimated 99 billion gallons of intake water, recirculates about 64% of it, and discharges about 96 billion gallons. The percentages of these values compared to those for all U.S. manufacturing and for all food and kindred products are, respectively:

number of plants, 0.6 and 5.6%
number of employees, 0.9 and 10.1%
value added, 0.8 and 8.3%
intake water, 0.6 and 12.2%
recirculated water, 0.3 and 12.4%
discharged water, 0.7 and 12.8%

All of the figures above are from preliminary reports of the 1967 Census of Manufacturers, U.S. Department of Commerce, issued in 1970.

An independent estimate of the quantity of water discharged in canning and freezing fruits and vegetables made for this study is somewhate lower than the census value: 83 billion gallons, including a very small quantity used in dehydration plants and a substantial quantity used in types of manufacturing excluded from the census figures. The independent estimates are in the Appendix in Table A1.

Table A1 also gives estimates of raw product tonnages, and of BOD, SS and solid residuals generated. "Other fruit" and "other vegetables" include all those not specifically listed. Estimated totals, for the United States in 1968, are:

26 million tons of raw product
83 billion gallons of wastewater discharged
800 million pounds of BOD generated
392 million pounds of SS generated
8 million tons of solid residuals.

Citrus, tomatoes, corn, and white potatoes (excluding dehydrated potatoes) account for 67% of the raw tonnage, 57% of the waste water, 52% of the BOD, 62% of the SS, and 72% of the solid residuals.

The raw tonnage estimates are believed to be the most precise. They are mostly from the U. S. Department of Agriculture Crop Reporting Service but some are National Canners Association estimates based on canned and frozen pack statistics. They are for 1968 except that tomato tonnage was reduced from 7 million to 5 million tons because 1968 was abnormally high for canning tomatoes. The other estimates are based on averages of widely varying figures per ton, mostly published in the 1960's; some of the sources are unpublished data of the National Canners Association; most of the figures on BOD per ton and SS per ton are from reference 582. The varying estimates for a given product are partly the result of real plant to plant differences. Data from many of the references were converted from values per case to values per ton using U. S. Department of Agriculture figures for average cases per ton (10). Missing data, in particular those for "other fruit" and "other vegetables", were estimated by comparison with data for the principal products. The numbers in the table are best estimates from currently available data.

Estimates were made for the current survey of total solids in the wastewater generated by the industry. They were based on sparser data than were available for the other items and are therefore not listed in detail. The estimated total was 2.4 billion pounds of total solids, a very high proportion coming from potato processing.

Powers et al (521) gave 87 billion gallons of water discharged from canned and frozen fruits and vegetables in 1964; and for 1963 the same quantity of wastewater and also 1,190 million pounds of BOD and 600 million pounds of SS generated from all canned and frozen foods. These figures are somewhate higher than the current study estimates and the additional products included in the earlier estimates do not seem to account for the differences in BOD and SS.

Other estimates derived from reference 521 indicate that in 1963 all food and kindred products manufacturing was about 1/10 and the canned and frozen fruits and vegetables industry was about 1/100 of all U. S. manufacturing as measured by value added. These two segments of the economy used about 5.4 and 0.5%, respectively, of the total water, but produced about 20% and 5%, respectively, of the total BOD. The comparisons reflect the relatively high strength wastewater discharged by food manufacturing.

FUTURE - Other discharges estimated for canning and freezing fruits and vegetables were (584):

1963 estimate: 71 billion gallons wastewater; 660 million pounds BOD
1972 projection: 93. 5 billion gallons wastewater; 845 million pounds BOD.

A 1967 publication (637) estimated for canned and frozen fruits and vegetables the following total waste loads, million pounds:

Year	1963	1968	1972	1977
BOD	660	785	845	905
SS	750	890	960	1035
TDS*	710	845	910	980

*Total dissolved solids

Projections of the U. S. per capita consumption of canned and frozen foods (10) and of the U. S. population indicate an increase by 1980 of about 30% in the production of these foods. Without changes in processing procedures the following totals would be estimated for 1980:

34 million tons of raw product
110 billion gallons of wastewater discharged
1000 million pounds of BOD and 500 million pounds of SS generated
10 million tons of solid residuals

However, water conservation practices and improved procedures are certain to reduce both effluent flows and pollutional loads per unit of product in the next few years.

GENERAL DISPOSAL PRACTICES

All of the figures on wastes referred to above pertain to generated wastes. Large proportions of these are reduced by treatment before final discharge.

The 1963 Census of Manufacturers is the source of data in Table 1, which shows the totals and percentages of wastewater flows from plants discharging 20 million gallons per year or more.

Table 1. Wastewater Flows and Disposal

	Total waste-water flow, billion gallons	Percent to: public treatment	ground	surface water	total*
All U.S. manufacturing	13,200	7	1	90	98
Food and kindred products	688	35	11	51	97
Canned and frozen fruits and vegetables	66	38	17	42	97

*The small quantities unaccounted for were transferred to other uses.

The food industries discharged much higher proportions of their liquid wastes to public sewers and to land disposal than did manufacturers as a whole. Discharges onto the land are principally by irrigation, mostly spray irrigation, but also by seepage from ponds and by pumping into non-productive wells. Ground disposal generally removes very high percentages of the pollutional load. The high degree of utilization of public treatment plants and ground discharge by food processors is partly explained by the need for reducing the relatively high strength of this industry's wastes.

Most industrial wastewater (including that from food processing) is used for cooling or for other relatively non-contaminating purposes. Added heat may be a problem, but not other types of pollution. Discharging this more-or-less clean water to surface water may be necessary to maintain stream flows and provide water for downstream populations and industries. Wastewater disposed of in streams and lakes is often treated before discharge.

A 1965 study (102) found the distribution of liquid waste disposal practices shown in Table 2 in 80 fruit and vegetable canneries, some of which were also freezers.

Table 2. Liquid Waste Disposal by Urban and Non-urban Plants

Discharge to:	Percent of Plants: urban	non-urban	total
City systems	100	9	47
Ponds	0	28	16
Spray irrigation	0	55	31
Surface water	0	9	5

Urban plants were defined as those located within cities; non-urban plants, those located in the country, in small towns, or on the outskirts of cities. The contrast in disposal methods by the two groups reflects the availability of treatment plants in cities and the high cost of city land.

Table 3, mostly 1969-1970 data from reference 471, shows the distribution of liquid waste disposal methods found in a study of all canned and frozen fruits and vegetables except pineapple. Some of these plants used more than one of the listed methods and a plant putting up more than one product was tallied under each commodity. "Holding" and "treatment" ponds were not strictly defined; generally the removal of pollution would be less in a holding than in a treatment pond. Some methods of treatment at the plant or of disposal were not included in the summary. For example, about half the citrus plants used additional methods, and the clarifiers which remove settleable material at most potato plants were omitted. Most reliance on city systems was by tomato, peach, pear, and miscellaneous fruit plants; on treatment ponds, by potato and apple plants; and on irrigation, by corn, apple, and pea plants. A survey in the western half of the United States reported in the same reference (471) found that plants farther away from open land were more likely to use city treatment and less likely to use their own treatment systems for their liquid effluents.

Table 3. The Use of Wastewater Treatment Systems

Product	Percent of plants using: city systems	holding ponds	treatment ponds	irrigation
citrus	12		10*	24
tomato	67	11	19	13
corn	40	12	28	44
potato	43	14	57	21
peach	83	3	11	11
apple	30	10	40	30
snapbean	58	6	24	27
pea	39	13	10	36
pear	92	4	8	8
other fruit	67	10	16	20
other vegetable	59	10	23	17

*Both types of ponds combined

SECTION III

HARVEST AND DELIVERY

MECHANICAL HARVESTING

Mechanical harvesting has been applied recently to many crops and further developments are to be expected. Certain crops such as: green peas; lima beans; bush, green, snap, and yellow wax beans; spinach; corn; tomatoes; lettuce; cranberries; cherries; potatoes; beets; carrots; rutabagas; and turnips are now mechanically harvested. Formerly, certain wastes such as vines and stalk were accumulated during harvest and disposed of in one manner or other, principally as animal feed. Much of this material is still retained in the field and utilized by the grower for feed or as a soil additive. However, other unusable parts of vegetables and fruits are not separated at the field or orchard (tomato, corn, cranberry, cucumber, cherry, grape, beet, potato, and carrot) but are transported to storage or factory. Separation of cull material by hand during mechanical harvesting is being done to some extent for tomatoes and potatoes. Table A2 (in the Appendix) is a compilation of references dealing with procedures and problems in the mechanical harvesting of fruits and vegetables.

Mechanical harvesting, while beneficial economically and in other respects, may be accompanied by certain undesirable effects:

1. Greater physical damage to the crop, such as: split skins on tomatoes; bruises on apples, pears, peaches and cherries; broken ends of snap beans; smashed kernels of corn; and damage to plant or tree.

2. Inclusion of soil with the harvested crop, particularly with vegetables, and greater numbers of microbes adhering to the product surface.

3. Loss in yield and delivery of products at non-optimal maturity from non-selective harvesting.

Physically damaged areas of products such as tomatoes frequently become focal points for lodging of soil, sand, and dust; and for growth of various types of organisms. Rotting may readily occur at the damaged areas. Such damage or infection can be held to be indicative of unsanitary practices, and can affect the quality grade of the harvested crop and degree of safety expected in thermal processes.

IN-FIELD PROCESSING

In-field processing or preparation of the crop for subsequent processing has been used in one form or another for a considerable period. Peas were at one time harvested on the vine and transported to the canning plant where vining (or shelling) took place. In the past twenty years, the vining has been done at stationary viners within a 10 mile radius of the fields, and more recently, almost entirely with mobile viners. Developments have also included devices to assist in the removal of "trash" (stems, sticks, leaves, soil) from various crops which have been mechanically harvested or mechanically loaded, such as citrus, apples, potatoes, tomatoes, cucumbers, and sugar cane.

Some mechanical harvesting devices also sort the products according to size. Experimental systems for sorting tomatoes by color have been developed. More elaborate experiments (580a) have included "field site" tomato processing, in which tomatoes are processed by an acid-hot break procedure into juice for transport in bulk tanks to the cannery.

The concept of pre-washing and pre-sorting snap beans has been used in receiving stations to facilitate central process plant operations.

There are several advantages to such in-field treatment, including prompt processing after harvest; elimination of much damage and loss of solids during transport of fresh fruit; and retention of wastes, culls, seed, peel, and soil near the points of production. Separated wastes can be retained for disposal in field soils.

Table A3 is a compilation of references on in-field processing of fruits and vegetables.

SOIL LOADS ON FRUITS AND VEGETABLES

There is relatively little information available on the amount of soil included with various crops during harvest. A limited survey of processors of mechanically harvested root crops indicates that soil may range from 5 to 22% of the total harvest load weight, depending on the type of root, type of soil, and soil moisture (670).

The handling of crops containing much soil may cause problems during processing, such as plugging of flumes, conveyors, and sewer lines due to settling of soil. The inclusion of soil in the harvested loads has other economic implications: the withdrawal of irreplacable top soil and wasteful transport of unusable material.

The loss of soil from the land in the annual production of canned potatoes, carrots, and beets has been estimated at 27,000 - 54,000 tons (670). York, et al. (701) reported the soil loads on mechanically harvested tomatoes from different type soils to range from 0.1 to 0.37% of the weight of tomatoes. Mercer (424) reported as high as 1.87%. Soil loads on potatoes and carrots have been reported to be 3 - 5% of load weights (387). On the basis of total production, this would result in the removal of a few hundred thousand tons of soil from the land each year.

It would appear that increased mechanization of harvest has increased the quantity of soil on many crops hence the need for more thorough water washing or alternate systems. The increased soil loads can result in the presence of organisms with greater thermal resistance (424). Increased soil loads on tomatoes due to use of mechanical harvest has increased bacterial spore loads 10 - 200 times (424).

HAULING FROM FIELD TO PLANT

Approximately 14 million tons of vegetables and 12 million tons of fruit are harvested annually requiring transport to a treatment or process facility. In some instances multiple transportation is involved. The procedures in handling crops for transport have changed materially in the last decade. A significant development has been the direct transfer from mechanical harvesters into dry bulk loading trucks (e.g. potatoes, beets, carrots, citrus, peas, corn, tomatoes, and beans), tote bins or boxes, eliminating the use of smaller containers such as sacks, baskets, hampers, or lug boxes. There has been some transport of crops such as cherries in water. Tomatoes and potatoes have been transported in water experimentally.

Transport of crops in water is believed to provide possible economic advantages as well as such benefits as partial wash or soak, cooling, and ease of transfer through fluming at destination. However, the successful utilization of water as a transport medium for harvested crops depends on several factors:

1. The adaptability of the commodity to such treatment; tomatoes transported in water, for example, are subject to splitting.

2. The limitation of container size to that at which undesirable pressures on the product, which could cause bruising during handling, do not occur.

3. The availability of water.

4. The control of microbial growth.

The new methods of transport have been applied for economy, improvement in quality, and adaptation to other phases of the operations. The integration of mechanical harvesting with bulk transport facilities has decreased the delay between field and processing plant, and has permitted improved management of the harvesting and processing operations.

Table A4 is a compilation of references on transport of fruit and vegetable crops in-field and from field to process plant.

SECTION IV

PROCESSING OPERATIONS AND WATER USE

UNIT OPERATIONS

Processing steps for five typical commodities are outlined in Figure 1: peaches to exemplify fruits; peas and corn, common vegetables; beets, peeled root crops; and tomato products, pulped commodities. The principal steps where water (or steam) is used and where solid and dissolved residuals are generated are indicated. Some steps common to all products are omitted. Detailed flow diagrams and processing descriptions for many products are in references 471 and 582.

Receiving is generally in 40 - 50 pound lug boxes, half-ton bins, or larger bulk loads. The containers are dumped into the first stage washer or flume or onto belts. The product is conveyed by flumes, pipes, belts, elevators, or other conveyors between processing steps. Fluming water, generally reused, and small flows of water to belts, graders, and other equipment for lubrication and sanitation are not noted in the flow diagrams.

After the outlined processing operations, canned foods are filled into cans, brine or sirup may be added, and the cans may pass through an exhaust box (a steam chamber). Some spillage occurs in filling and in brining or siruping, and a small amount of steam condensate comes from exhausting. The cans are then sealed, cooked with steam, and cooled. Large amounts of cooling water are used; it is relatively uncontaminated and may be recirculated, sometimes after passing through a cooling tower, or reused for product washing or fluming. Because it is clean, cooling water may be reused or discharged separately from the rest of the plant effluent, into storm sewers or directly to a stream.

Vegetables for freezing are water cooled after blanching, with the generation of soluble waste. The products may be frozen before or after packaging. Freezer condenser water is handled about the same as can cooling water. Overall, final freezing operations generate less pollutional load than do final canning operations.

All food processing products, containers, supplies, and equipment must be kept in a sanitary condition. Product handling equipment is washed, commonly with chlorinated water and often by continuous spraying during operations. In any case, each piece of equipment is cleaned periodically during plant shut-downs, with scrubbing and

Water	Operation	Peaches	Peas	Corn	Beets	Tomato products	Type of Waste Generated: Solid	Soluble	Soil
	Dry dump	X	X	X	(X)*		●		
→	Water dump				(X)	X	●	●	●
	Air cleaner		X	X			●		
	Trash eliminator	X					●		
	Husker			X			●		
	Sorting/trimming	X	X	X	X	X	●	●	
→	Washer	X	X	X	X	X	●	●	●
→	Grader/sizer	X	X		X		●	●	
	Cutter	X		X			●	●	
→	Peeler/rinse	X			X	(X)	●	●	
→	Blancher/rinse		X	(X)	(X)			●	
	Pulper/finisher	(X)				(X)	●		
	Slicer/dicer	(X)			(X)		●	●	
→	Evaporator	(X)				(X)	●	●**	

*Optional or alternative operations in ( ).

**Relatively clean water

Figure 1. The Use of Water and the Generation of Wastes in Typical Unit Operations

disassembly if necessary. Plant clean-up water contains solid and dissolved residuals and often detergents which raise the pH.

IN-PLANT CONVEYANCE - Various means have been adapted for conveying fruit or vegetable products at unloading docks into and through the process plant. These include fluming, elevating, vibrating, screw conveyor, air propulsion, negative air, hydraulic flow, and jet or air blast. Water, in one way or another, has been extensively used in conveying products within plants because it has been economical in such use and because it serves not only as conveyance but also for washing and cooling.

It has been traditional to consider water an economical means to transport fruits and vegetables within a plant and to assume there was some sanitary significance to such use, not only for the product, but also for the equipment. A significant disadvantage, however, may be leaching of solubles from the product, such as sugars and acids from cut fruit; and sugars and starch from cut corn, beets and carrots. Alternative systems to decrease such losses from water have been investigated, such as osmotically equivalent fluid systems (298, 426).

Table A5 is a listing of recent publications on in-plant conveyance of fruits and vegetables.

WASHING AND RINSING - Fruits and vegetables for fresh market may be and those for processing are washed and rinsed. These treatments are applied for a number of reasons:

1. Removal of soil, dust, pesticides, microbial contamination, insects, and their residuals.

2. Removal of adhering juices or exudate, products of respiration or of spoilage.

3. Removal of extraneous matter such as leaves, stems, dirt, stones, and silk.

4. Removal of occluded solubles or insolubles such as occur during cutting, coring, peeling, and blanching.

5. Cooling.

6. Extraction of solubles such as preservative salts or acids.

Table 4. The Use of Water in Washing Fruits and Vegetables

Product	Function	Water Used gal/ton*	Water Used gal/case**	Effluent load BOD lbs/ton*	Effluent load SS lbs/ton*	Ref.
Beans, green	wash		25.5			155
	(two years)		20.8			
Beans, green	tank & spray	52				425
	flume	108				
Beets	primary wash flume	100		0.8	20.0	673
Carrots	primary wash flume	90		0.5	2.0	673
Corn	spray	8-18(gal/min)				203
	cool	10-24(gal/min)				
Corn	husked corn washer	103		2.5	1.0	673
	washer & silker	212		15.0	4.0	
Cranberry	skimmer & washer	1440		36.5	15.0	379
Fruits	spray	385				423
Peaches	spray	360(gal/min)				487
Peaches	lye peel rinser	707(gal/min)				494
	flume	1028(gal/min)				
Peas	wash & flume	1200				357
Peas	clipper mill & wash	706		12.0	5.5	673
	wash	432		4.0	0.5	
Potatoes	spray	2500		20.0	30.0	258
Potatoes	spray & soak	640		10.7	21.0	516
	peel & wash	468		2.2	2.2	
Potatoes	spray	960		5.1	2.7	79
Potatoes (dehydr)	slicer-washer	1540		40.0	49.7	158
Potatoes	primary wash flume	70		0.5	2.0	673

Table 4. (continued)

Product	Function	Water Used gal/ton*	Water Used gal/case**	Effluent load BOD lbs/ton*	Effluent load SS lbs/ton*	Ref.
Tomatoes	wash	1320				421
Tomatoes	first wash		1-20	0.4***		203
	second wash		2- 4	0.8***		
Tomatoes	rinse after dump	1186				494
	lye peel removal	504				
Tomatoes	spray		712			599
	lye peel rinse		1374			
	lye peel rinse		790			

* Ton of raw product
** Case of finished product
*** Pounds per case

Table 4 summarizes reports on the quantities and characteristics of water used for washing and rinsing fruits and vegetables. The quantity of water used in wash and rinse operations may be as much as 50% of the total usage in process operations.

Examples of the effectiveness of washing to reduce contamination by extraneous matter are in Table 5.

Table 5. Removals by Washing

Product	Function	Item	Reduction %	Ref.
Potatoes (dehydr)	presoak & wash	surface contamination	0.5-12	387
Tomatoes	wash	soil	33-80	429
		organic debris	30-64	
		bacterial spores	6-79	
Tomatoes	wash	Drosophila eggs	10-70	253
Tomatoes	wash	bacterial spores	75-95	701
		lactic bacteria	75-96	
		mold	76-92	
Tomatoes	chlorinated wash	bacteria	90	486
Tomatoes	chlorinated wash	spores	92	469

Microbial loads, where excessive, have been shown to affect the thermal process required for sterilizing canned foods (463a). The presence of excessive mold in tomato is considered to be indicative of unsanitary conditions, and regulatory standards for mold content have been established. The presence of non-hazardous but objectionable extraneous matter (skin, leaves, stems) is a factor affecting the market grade and economic value of the product. Limits have been established for the quantities of residual pesticides in fruits and vegetables.

Thus on the one hand, water is essential to prepare fruits and vegetables for processing; yet on the other hand, it creates pollution loads in plant effluents. Procedures have been recommended for reuse of water in fruit and vegetable process systems based on reduction in bacterial loads and on beneficial effects in quality.

PEELING - The quantity of peel on fruits and vegetables affects the yield of the processed product. Geneticists have expended much effort in the development of varieties (particularly vegetables) with thin, smooth skin, absence of rootlets, and other desired conformation in order to reduce peeling losses.

Peel can be removed from fruit or vegetables by one method or a combination of several methods including: hydraulic pressure, immersion in hot water or lye solution, exposure to steam, mechanical knives, mechanical abrasion, hot air blast, exposure to flame, and infra red radiation. The more extensively used procedures for peeling root crops include: steam/abrasion, immersion in lye solution/hydraulic or abrasion, and abrasion. Frequently used procedures for peeling fruits include: mechanical knives, immersion in lye solution, and reamers and corers.

The separation of peel wastes is costly not only for the effort necessary to remove it, but also for the concomittant loss of edible material. Related costs include the economic wastes incurred in growing, transporting, and handling unusable material.

The equivalent cost for lagoon treatment of liquid wastes from peeling for which estimates could be derived is at least two million dollars annually, and would be much greater than this if commodities for which information is unavailable were included (670).

Dry caustic peeling of potatoes is reported to achieve removal of peel with less loss of product than by the more common liquid lye or abrasion procedures (255). The major portion of the peel and lye is withheld from the effluent waste stream. Similar results have been obtained in trial runs with apricots, peaches, pears, and beets (472a).

BLANCHING - Blanching of vegetables for canning, freezing or dehydration is done for one or more reasons: removal of air from tissues; removal of solubles which may affect clarity of brine or liquor; fixation of pigments; inactivation of enzymes; protection of flavor; leaching of undesirable flavors or components such as sugars; shrinking of tissue; and destruction of microorganisms.

Vegetables are blanched either in water or in steam at various temperatures and times. Water blanching is generally used for canned vegetables and steam blanching for frozen or dehydrated vegetables.

Vegetables are water blanched in order to remove air and to leach solubles for clarity of brine. These are factors in the USDA grades of canned vegetables. For freezing and dehydration, destruction of enzymes is important. Blanching in water removes more solubles, including minerals, sugars and vitamins, than does steam blanching.

The pollution loads from blanching are a significant portion of the total pollution load in the effluent stream during the processing of certain vegetables. The national amortized annual treatment facility cost for the pollution from selected vegetable blanchers is estimated at 2.4 million dollars and the annual maintenance and operation cost, about 3 million dollars (670). Research to reduce such costs should be beneficial.

IN-PLANT REUSE OF WATER

Table A6 shows a compilation of studies dealing with the reuse of water in the various phases of processing fruits and vegetables. These studies were undertaken primarily to establish the feasibility of multiple uses of water for conservation and economy and the acceptability of multiple uses.

The acceptability of procedures for reuse of water in processing operations requires such consideration as:

1. Water is an excellent solvent and vector, and is readily modified, chemically, physically, and microbiologically. Thus, one use may or may not render water suitable for upstream application, such as primary washing. Recovered downstream, the water may be suitable for further use only when given enough treatment to be considered potable.

2. The soil, organic, or heat loads in the used water may be such that considerable treatment is necessary to render it suitable for reuse.

Perhaps the most extensive work on feasibility in reuse of water has been done with peas and tomatoes, primarily in "counter-current" flow systems. Another example is the use of cooling water to wash products following blanching, and this water in turn used for initial washing of incoming raw product.

Consideration has been given to segregation of various wastewaters in the process plant for immediate reuse or reuse after suitable treatment for certain operations. The treatments required for reuse of the water may be relatively simple, such as chlorination, or may become quite involved, requiring sedimentation, flocculation, and filtration or other unit operations.

Multiple use of water is being applied in commercial processing of fruits and vegetables. This has unquestionably permitted conservation of water and greater efficiency in the treatment required for the total plant effluent.

There are many reports and suggestions on procedures for conservation of water in fruit and vegetable process operations (422, 428, 429, 431, 433, 458, 465). Few of these cite values for the magnitude of reduction in water usage. Eckenfelder et al. (213) calculated the possible reduction in waste flows by use of conservation procedures from 134 to 81 gal./min in the processing of tomatoes, and from 125 to 49 gal./min in the processing of corn. Cook et al. (155) showed reductions of 18 and 25%, respectively, in the quantity of water used in two different years in processing green snap beans. Mercer (425) cited procedures for recovery treatment of brines for olives.

The treatment of water to condition it for reuse in processing fruits and vegetables has been given considerable attention. Table A7 shows a compilation of reports on the treatment of water for reuse. Two aspects of such treatment are:

1. The economic factor, that is, the cost of fresh water vs the cost of treating and recirculating it for reuse, and the cost of disposal of wastewater following its use.

2. The acceptability of the treated water for its intended use.

The costs for treatment of water depend on the condition of the water and the treatment required to recondition it. If the water has acquired salt, sugars, starch, acids, or other organic or suspended materials, extensive treatment may be necessary. On the other hand, such treatment may be necessary anyway to reduce the total effluent degradation, or because such effluent cannot be discharged into municipal or waste streams.

Eckenfelder et al. (208) have cited the maximum effluent quality expressed as BOD, COD, soluble solids, and nitrogen attainable by various recovery treatments, and have related the parameters for cost determination of such water treatments.

Treatment methods which have been cited for the recovery of water to be reused are:

- carbon adsorption
- centrifugation
- chemical precipitation
- chlorination
- distillation
- electrodialysis
- eutectic freezing
- filtration
- flocculation
- flotation
- foam separation
- freezing
- ion exchange
- micro screening
- ozonation
- reverse osmosis
- screening
- sedimentation
- solvent extraction
- ultrafiltration

SECTION V

WASTE GENERATION AND CHARACTERISTICS

WASTE GENERATION BY UNIT OPERATIONS

Table A8 lists estimates of the wastewater quantities, BOD or COD, and SS from steps in processing fruits and vegetables as percentages of the total amounts generated (582). These data were estimated by experienced persons in the industry and are not carefully measured values.

Estimates of all three parameters for the same operation often varied widely. Some of the differences are explained by differences in style of pack, but many must come from ranges in product maturity, transportation method, and other factors. In many instances a concentration of pollutional load in relatively little wastewater is indicated; for example, apple peeling and pulping and cherry pitting. Examples of low pollutional load in relatively larger quantities of wastewater are in the final steps for canning. Freezing generally generated less waste load than did canning.

Data such as those in Tables A1 and A8 point out the principal sources of the industry's wastewater flows and pollutional loads and therefore where the greatest potential reductions can be achieved by further research and development.

Much of the total waste flows from many commodities, especially from citrus, come from relatively clean water used in cooling, condensing, and concentrating. The segregation of this water for reuse is practiced to some extent and should become almost universal. Other large waste flows are from washing tomatoes (roughly 8 billion gallons per year), peeling potatoes, peeling peaches, washing potatoes (all three roughly 2 to 3 billion gallons), cutting corn, cutting and pitting peaches, washing corn, and blanching corn (all four roughly 1 to 2 billion gallons).

Large quantities of BOD are generated in washing tomatoes, peeling potatoes (roughly, more than 50 million pounds per year from each), cutting corn (more than 40 million pounds), peeling peaches, blanching corn, and cutting and pitting peaches (roughly 20 to 30 million pounds from each of the three operations). Citrus by-products recovery also generates very large amounts of BOD and SS. Other large sources of SS are peeling potatoes (perhaps 70 million pounds per year), cutting corn (about 40 million pounds), and washing tomatoes (roughly 30 million pounds).

PEELING - Peeling of fruits and vegetables results in large quantities of wastes. Table A10 shows estimated quantities of peel in various fruit and vegetable products. The peeling must be done in such a manner that the peeled product is attractive and free of blemish or peel residue. The presence of peel in canned and frozen products is a factor in its market grade (10).

Table 6 shows a summary of estimated pollution loads in the effluent from peeling fruits and vegetables reported by various investigators. Studies other than these have been reported, but the data have not been covertible to quantitative values of pollution loads. Peel wastes comprise a high percentage of the total pollution loads in the effluent of fruit and vegetable plants.

BLANCHING - Table 7 shows examples of losses from vegetables during blanching expressed in BOD, COD, and SS.

Table 8 shows examples of the concentrations of suspended and of total solids in the effluents from water blanching of vegetables. It is the current practice to add this waste stream to the total plant effluent. The volume of effluent from blanchers is generally relatively small, and the concentrations of suspended and total solids high. There are, therefore, potential gains in the isolation and separate treatment of the effluent from blanchers. It is reasonable to consider the application of sophisticated procedures, including concentration by evaporation, chemical precipitation, centrifugation, and filtration, in the treatment of the effluent from blanchers to reduce total pollution loads.

NUTRIENT LOSSES

Figures 2 and 3 show reported changes in the nutrient content of vegetables from water and steam blanching; mostly the changes were losses but a few gains in nutrients occurred. Many of the points of these graphs are the highest and lowest reported losses from a series of data; the losses between the extremes are not graphed. Figure 4 shows losses in soluble solids and in ascorbic acid from several experimental blanching methods.

Very wide ranges in retention have been reported for most nutrients and blanching methods. Steam blanching retained slightly to definitely more ascorbic acid, riboflavin, ash, and phosphorus than did water blanching. The two methods were about the same in retaining niacin, carotene, calcium, protein, and solubles.

Table 6. Characteristics of Wastewater from Peeling Fruits and Vegetables *

	BOD			SS		
Product	lbs/ton	lbs/cs	% of plant waste stream	rate	lbs/cs	Ref.
Apricots	5-10					470
Beets (blancher/peeler)	194	4.0	84	220 lb/hr	1.0	673
Carrots (blancher/peeler)	97	1.4	65	163 lb/hr	.7	673
Peaches (rinse after peeling)			40			599
Peaches	60(COD)			10 lb/ton		472a
Peaches	8-12			5-9 lb/ton		470
Pears	12-18			10-15 lb/ton		470
Potatoes (peeler)	20			90 lb/ton		258
Potatoes	37-79			75-108 lb/ton		236
Potatoes (peeler, chips)	2.3			4 lb/ton		516
Potatoes (peeler/ dehydration	20			90 lb/ton		516
Potatoes	32					156
Potatoes (lye peel)	186	3.1	89		.5	673
Potatoes (dry caustic peel)	26		80			255
Potatoes (lye peel)	376					681
Potatoes (infra red peel)	260					681
Potatoes (steam peel)	260					681

Table 6. Characteristics of Wastewater from Peeling Fruits and Vegetables (continued)

Product	BOD lbs/ton	BOD lbs/cs	BOD % of plant waste stream	SS rate	SS lbs/cs	Ref.
Potatoes (infra red peel)	200					681
Peach/tomato (flume after peel)			1	383 ppm		665
Peach/tomato (rinse after peel)			19	1230 ppm		665
Peach/tomato (rinse after peel)		.29	20			599
Tomato (scald/trim)		.16				213
Tomato (lye peel)			39			123
Tomato (lye peel)		.30				599
Tomato (lye peel)		.12	35			599

* Pounds of BOD or suspended solids per ton of raw product, per case of finished product, or per hour of operation.

Table 7. Pollution Loads in Effluents from Water Blanching of Vegetables*

Vegetable	Effluent flow gal/hr	BOD lbs/ton	COD lbs/ton	SS lbs/ton	Ref.
Beets (& peeler)	13,100	194 (85)**	323 (83)	239 (55)	673
Carrots (& peeler)	8,420	97.6 (65)	196 (67)	338 (64)	673
Corn	270	610 (lbs/day)	860 (lbs/day)	144 (lbs/day)	213
Corn	2,272	24.6 (16)	30.1 (18)	6.0 (12)	673
Peas	1,280	3,500 ppm in effluent			386
Peas	1,280	3,500 ppm in effluent			492
Potatoes	2,520	52	58	37	79
Potatoes	2,310	22	32	25	79
Potatoes (& peeler)	9,210	186 (89)	279 (86)	181 (37)	673

* BOD, COD, and SS in pounds per ton of raw product except as noted.
** Percent of total effluent pollution load in ( ).

Table 8. Suspended and Total Solids in Blancher Effluents

Vegetable	Effluent flow gal/hr	SS ppm	SS lbs/hr	TS lbs/hr	Ref.
Beets (& peeler)	13,100 (51)*		122	2,510	673
Carrots (& peeler)	8,420 (49)		104	478	673
Corn	2,272 (14)		28.2	206.4	673
Peas		1,114			120
Peas		3,244			120
Peas	4,360 (20)		10.8	262	673
Potatoes					
hot blanch	1,800	3,300			79
wet blanch	5,400	195	37 (per ton)		79
Potatoes (& peeler)	9,210 (44)		70.1	3,330	673

* Percent of total effluent in ( ).

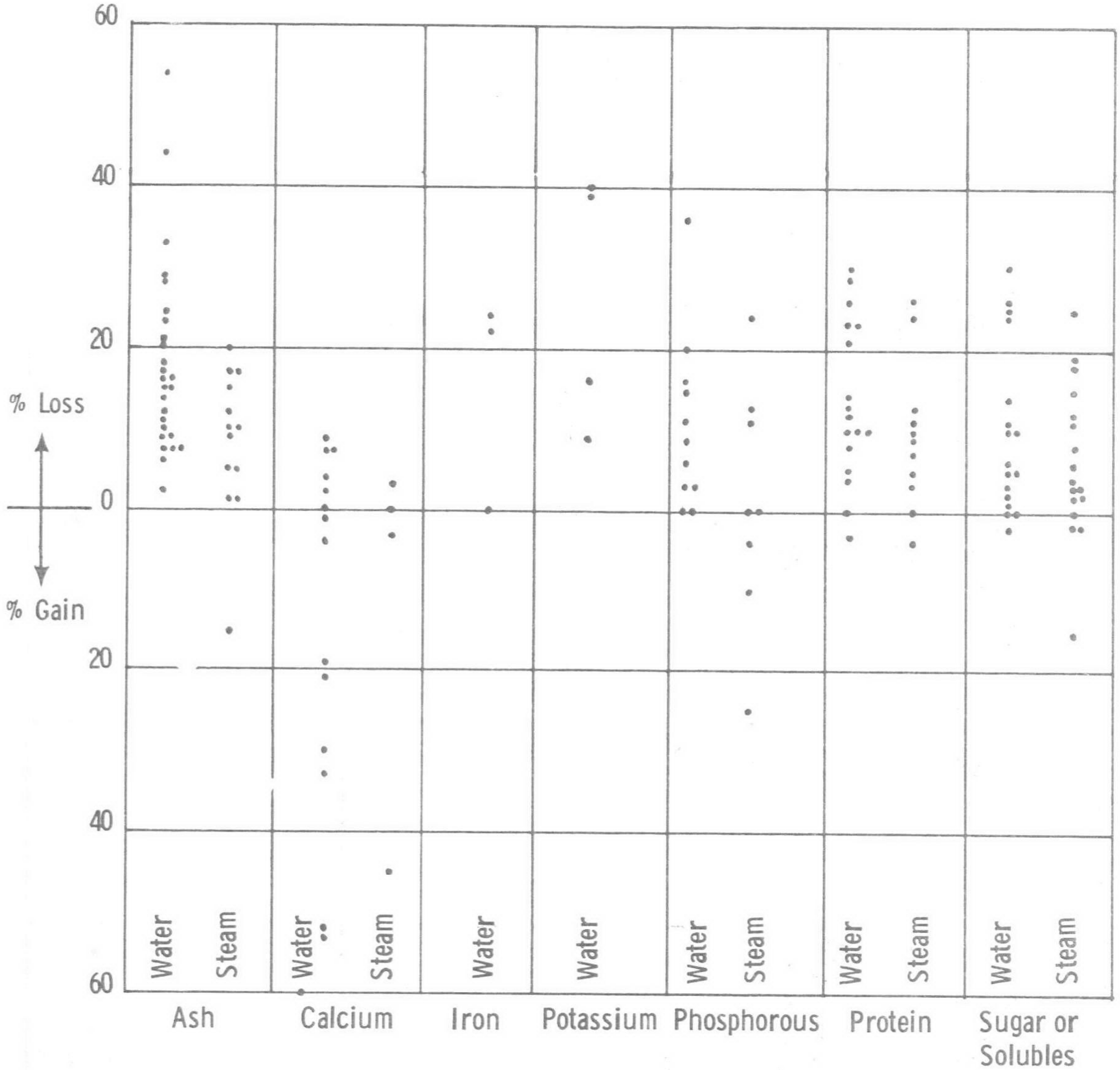

Figure 2. Changes in Product Minerals, Protein and Soluble Concentration from Water and Steam Blanching

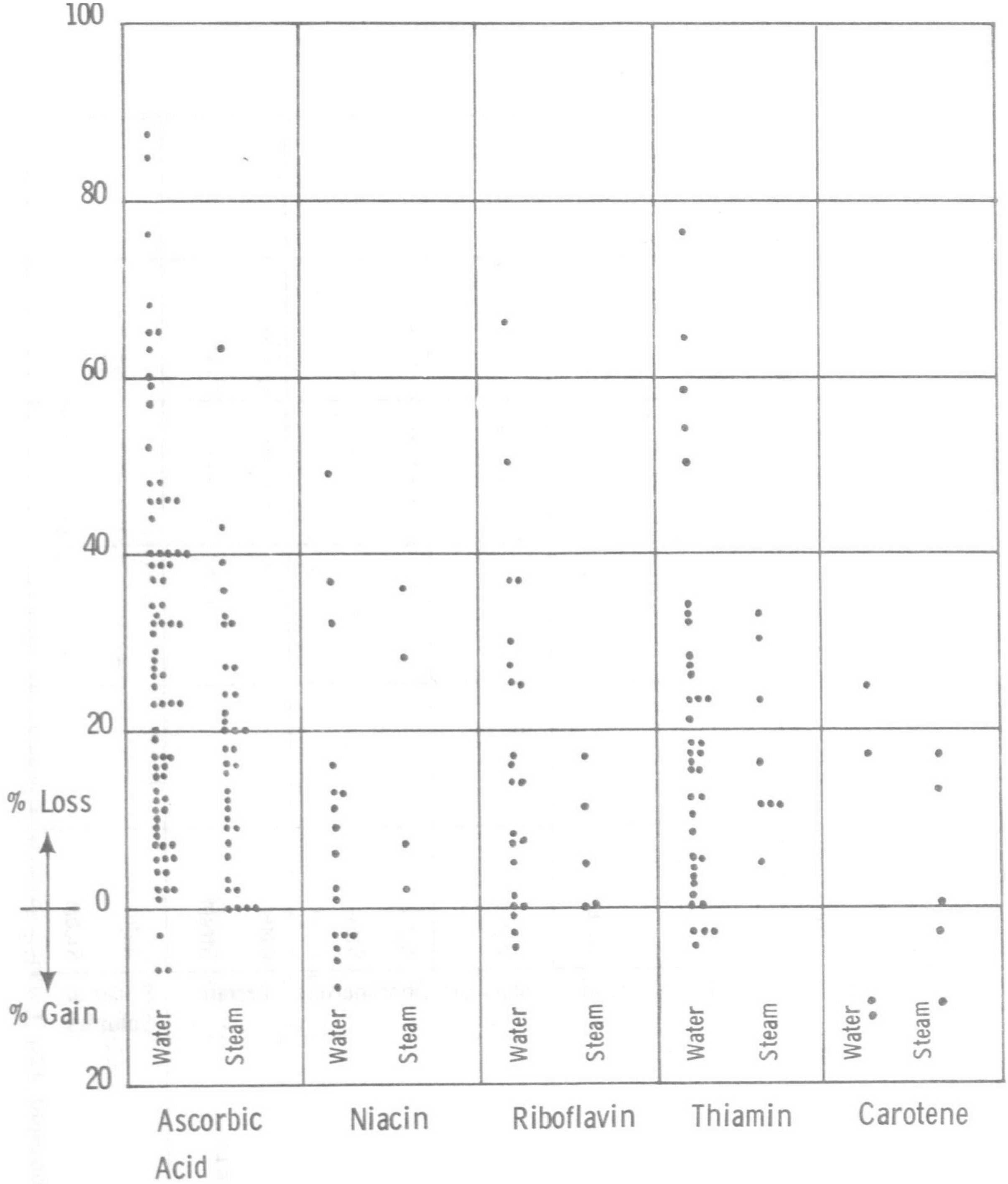

Figure 3. Losses in Vitamin Content of Fruits and Vegetables from Water and Steam Blanching

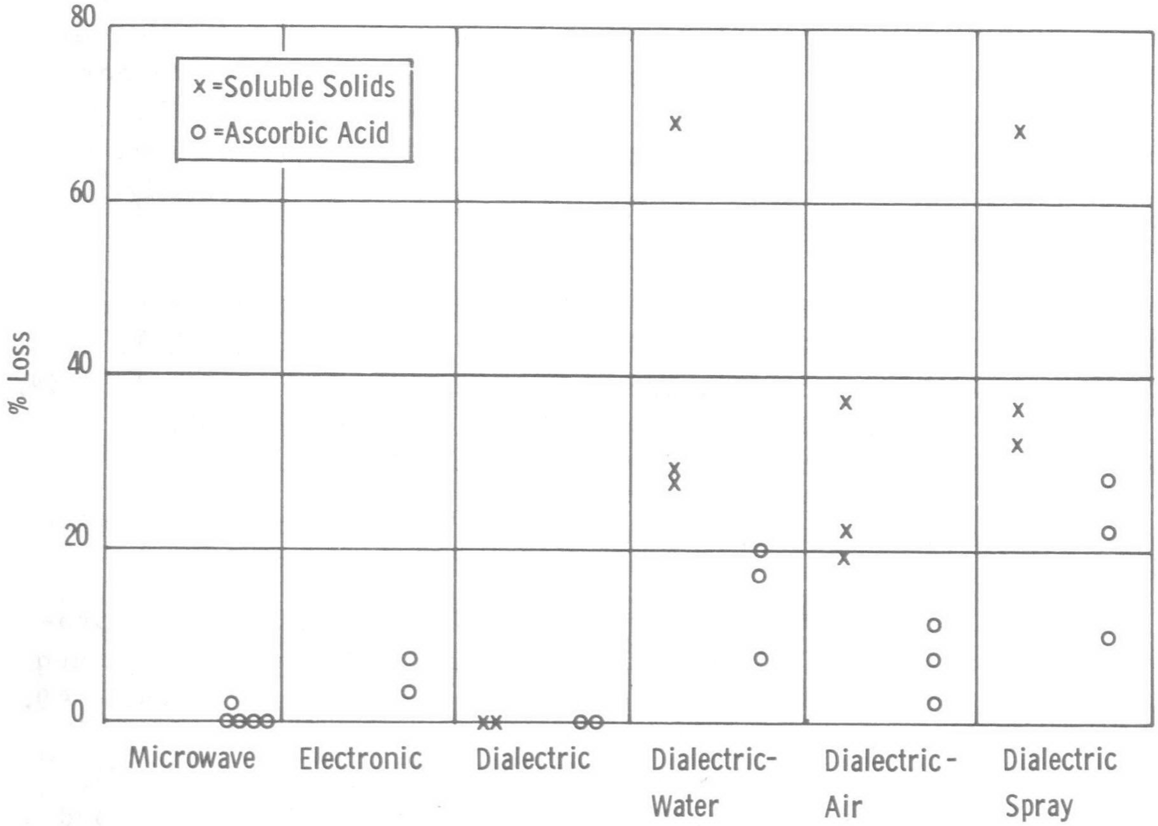

Figure 4. Losses in Soluble Solids and Ascorbic Acid from Experimental Methods of Blanching

Sparse data on experimental methods showed no or only slight ascorbic acid losses using microwave, electronic, and dialectic blanching; and no soluble solids losses by the last. The dialectric method combined with water, air, or spray brought about larger losses than dialectric alone. All three of these combined methods caused larger losses of soluble solids than did water or steam blanching. They retained ascorbic acid better than did water blanching; and were probably better for ascorbic acid than steam blanching, especially the dialectric-air process.

References for the three figures on blanching nutrient losses are:
Figure 2: 2, 275, 297, 299, 330, 348, 365, 367, 388, and 671.
Figure 3: 2, 183, 215, 225, 226, 263, 264, 281, 297, 298, 319, 354, 355, 365, 367, 419, 454, 455, 523, 622, and 657.
Figure 4: 76, 77, 275, 330, 439, 440, 452, 454, and 523.

THE pH OF PROCESSING EFFLUENTS

The pH of processed fruit and vegatable effluents varies among products, among plants, and from time to time within plants. Reported pH values of fruit and vegetable processing effluents are in Table A9. High pH accompanies lye peeling; fruit, tomato, and root crops peeled in other ways may yield an effluent with neutral or low pH. Drastic fluctuations in pH occur when lye peeling tanks are dumped periodically and smaller fluctuations may result from the caustic solutions used in plant clean-up.

SECTION VI

TREATMENT AND DISPOSAL OF SOLID AND LIQUID WASTE

SOLID WASTE

SOLIDS SEPARATION - The utilization, treatment and disposal of cannery and freezer effluent wastes involves, first, effective separation and segregation of the solids in the effluent. Separation of the discrete fractions may be important in economic treatment of the wastes.

The effective and efficient separation of discrete solids depends principally on the physical properties of the particles, including size, density, and concentration in the waste; and on the capability of the equipment for their separation. The decision to separate the smaller particles (colloidal or suspended) from the waste depends principally on: a) whether there is value in such wastes, b) whether such material may as readily and as economically be degraded by the usual disposal systems, such as land spray or lagoon treatments, c) the potential reuse of the water from the clarified wastes, and d) increased costs of liquid waste treatment if the particulates are not removed.

The cost-size relationships of different disposal systems have been reviewed by Parker (504); see also reference 123.

Screening - The separation of coarse discrete waste material from the total effluent is generally done with screens. The wastes in fruit and vegetable process effluent may contain some very large pieces of material several inches in size (whole fruit or vegetable) and other material ranging from smaller in size to colloidal. The separation of the larger material can be accomplished by steel bar screens separated 1/2 inch to 2 inches, and sloped at angles 30 to 60 degrees away from the direction of flow. The removal of the separated material may be done manually or mechanically.

The removal of smaller but discrete pieces of material is effectively done by mechanical screens of various types. The Tyler Standard Screen Sieve is frequently used for dimension reference of wire screens, which are commonly referred to by their number of meshes per inch. Perforated screens also are employed for limited uses.

The effectiveness of screening discrete fruit or vegetable material from the effluent is affected by a number of conditions, including:

1. Mechanical features: screen opening dimensions, screen porous area, screen motion, flow rate of effluent, and conditions of flow.

2. Properties of the effluent: concentration of discrete materials and of components such as fiber, and particle dimensions.

Manufacturers of screening equipment provide data and recommendations for various devices for screening discrete material. Generally the capability of the equipment is expressed in terms of the volume of the effluent per square foot of mesh dimension. Several types of screening systems are:

Stationary screens
Vibrating, gyrating, oscillating screens
Rotary screens
Endless belt screens

Screens used for separating fruit and vegetable wastes range from several meshes per inch to 150 mesh wire cloth. Vibrating screens are by far the most commonly used type and 20 meshes per inch the most common size in fruit and vegetable processing (471). About one tenth of the fruit and vegetable processors reported using no screens. Typical screening loads of wastes vary from 18 to 66 lbs/1000 gal. and the screened waste contains 70-96% moisture (213).

The degree of screening necessary may be prescribed by the nature of subsequent treatments of the waste. For example, vacuum filtration and centrifugal clarification require more complete pretreatment for particle separation. The efficiency of screening of fruit and vegetable process effluents depends upon the proportions of large and small particles present. A limiting factor in the efficiency of screening certain wastes such as pea and corn is that a high percentage of the dispersed solids is suspended or colloidal and not readily affected even by 150 mesh screens. There can occur also some mechanical reduction in particle size during screening of the wet pulpy solids (467). It has been suggested that, although some solids are separated from corn and pea effluent by use of fine screens, no significantly measurable reduction in BOD loads were noted (670).

In other studies, only slight reduction in BOD loads in the effluent resulted from screening cannery wastes (104, 105, 213).

Table 9 shows the performance reported for various screening systems applied to process effluents.

Table 9. The Performance of Screening Systems on Food Processing Effluents

Screen type	Screen mesh	Product	Input Load	Waste Removed	Ref.
Oscillating	100	Beet-carrot		2% SS	670
Oscillating	24	Beet-carrot		0% SS	670
Oscillating	60	Peas			670
Oscillating	24	Potato-carrot		60% SS	670
Oscillating	50	Potato-carrot		21% SS	670
Rotary	28	Red beet		56% SS	216a
Rotary	28	Tomato		79% SS	216a
Vibrating		Beet		7-17% SS	670
Vibrating	100	Beet-carrot		2% SS	670
Vibrating	10	Beet-carrot		44% SS	670
Vibrating	50	Peas	(8-12,000 gal./hr.)	400-600 lbs	33
Vibrating	40		(975 gal./ft.^{2}/hr.)	(135 lb/ft.^{2}/hr.)	287
Vibrating	10	Potato-carrot		60% SS	670
Vibrating	10	Potato-carrot		0% SS	670
Vibrating	30	Peach		13% TS, 35% settl. sol.	420
Vibrating	30	Pumpkin		20% TS, 47% settl. sol.	420
Vibrating	48	Fruit-tomato	(500 gal./min)	32% SS	467

Screening is an effective, economical procedure for removal of discrete material of particle sizes which may interfere with the treatment of liquid effluents in spray, lagoon, or municipal systems. The suitability of fine mesh screening for removal of material of lesser size depends on the capability of the screens, the concentration of such solids in the effluent waste, and the costs of such removal. There is a lack of reliable information on the efficiency of the simpler screening systems for the removal of smaller dispersed material and on the physical characteristics of such material. The concentrations of suspended solids in screened total process effluents are of relatively low order. Suspended solids in process effluents are reported in Table 10.

Table 10. Suspended Solids in Screened Effluents from Food Processing

Product	% SS in Screened Total Effluent	SS lbs per 1000 Cases	Ref.
Apples	0.005		221
Beets	0.10		531a
Beets		1100	673
Carrots	0.11		531a
Carrots		708	673
Corn	0.16		531a
Corn		220	673
Peas	0.04		531a
Peas	0.003		221
Peas		800	637
Peach rinse	0.04-0.15		430
Peach	0.01-0.001		221
Pear	0.03		221
Potatoes	0.10		531a
Potatoes		530	673
Tomato	0.3-8.0		213
Tomato	0.04-0.10		430

One study indicated that single deck, circular, vibrating screens had twice the hydraulic capacity of table top screens with comparable mesh size and area; and that the hydraulic capacity was 50% greater in two deck than in single deck, circular, vibrating screens (467).

Sedimentation, settling and chemical precipitation - Sedimentation is employed to remove suspended or settleable solids from fruit and vegetable process waste effluent. Sedimentation or settling of solids occurs in collecting ponds or lagoons. Separation of the solids from the effluent can be done in settling basins or tanks prior to the discharge of the wastes for further treatment. The basins or tanks are often equipped with overflow wiers and baffles for continuous operation and with means for addition of chemical agents to facilitate flocculation of the particulate matter. Factors involved in the effectiveness of the systems are physical properties of the particle, viscosity, and turbulence. Parameters for conditions for removal of the suspended solids can be established from laboratory tests.

The flocculation and settling of suspended material may be accelerated by use of coagulants such as alum (aluminum sulfate), and ferric and ferrous sulfate (669), which react with hydroxyl ions to form hydrous oxides. The latter are relatively insoluble at normal pH values and tend to floc, coalesce, and settle.

There is much greater potential in the application of procedures for the removal of coagulable and settleable solids from the effluent flow at various stages in the process line where the concentrations are greatest. The concentrations of settleable solids in tomato wastes and tomato-peach wastes were greatest at the skin peeling and removal areas (459). Similar concentrations were found in the processing of peas, corn, beets, carrots and potatoes (673). Preliminary trials have indicated such solids can be effectively removed by sedimentation and other procedures. There is need, however, for economic evaluation of such applications.

The efficiency of removal of suspended matter from certain vegetable wastes by chemical coagulation and by primary settling is in the range of 60-80%. Table 11 shows the reduction in SS and in BOD by such treatment. However, since there is a very high level of total dissolved solids in such wastes, the net reduction in BOD in the effluent is frequently insufficient to permit its reuse for some purposes even after such clarification (669). Table 12 shows the concentrations of SS in typical cannery wastes, after screening.

Table 11. Efficiency of Chemical Coagulation of Screened Effluents*

Product	Coagulants ppm		BOD ppm		SS ppm		Removal %	
	Alum	Lime	Infl.	Effl.	Infl.	Effl.	BOD	SS
Peas	44	266	68	39	95	18	42	81
Beets and corn	65	357	222	196	259	47	28	82
Lima beans	39	136	142	121	146	26	15	82
Lima beans and spinach	22	218	130	89	212	52	32	75

* Reference 669. (Figures rounded)

Table 12. Suspended Solids in Screened Fruit and Vegetable Effluents

Product	SS		Ref.
	%	lb/Case	
Apples	.03-.06	0.10-0.20	637
Apricots	.02-.04	0.14-0.25	"
Asparagus	.003-.018	0.02-0.12	"
Beans, baked	.02	0.07	"
Beans, green/wax	.006-.015	0.02-0.04	"
Beans, kidney	.014	0.02	"
Beans, lima	.042	0.02-1.02	"
Beets	.074-.22	0.05-1.0	"
Carrots	.18	0.04	"
Cherries	.02-.06	0.05-0.14	"
Corn, cream style	.03-.067	0.07-0.17	"
Corn, whole kernel	.03-.40	0.20-0.95	"
Cranberries	.01-.25	0.02-0.05	"
Peas	.027-.04	0.06-0.20	"
Peaches	.045-.75	0.024-0.034	"
Potatoes, sweet	.04-.25	0.31-1.95	"
Potatoes, white	.09-.118		"
Pumpkin	.078-.196	0.38	"
Sauerkraut	.063		503
Spinach	.009-.058		"
Tomatoes	.019-.20		"

Ten to 30% BOD removal and 50 to 80% SS removal by sedimentation of cannery waste effluents have been estimated (637). In potato plants sedimentation removes 41 to 70% of the BOD and 73 to 93% of the SS (186, 257, 351).

A study has been reported (123) on a city treatment plant which received waste flows from 19 canneries with an aggregate of 583,000 tons of raw products per year, about half tomato. Primary treatment removed about 44% of the BOD and 74% of the SS during non-canning months, when the flow was 55 to 60 million gallons per day; and about 18% of the BOD and 62% of the SS during canning months, when the flow was 75 to 80 MGD.

Eldridge (217) reported BOD removals of 33 to 75% in effluents from beet, tomato, pea, corn and kraut processing using lime, alum, iron sulfates and chloride, and zinc chloride in combinations at 700 to 2520 mg per liter. A BOD removal of 50% in tomato effluent with 40-50 mg/l of lime has been reported (592). BOD removals of 39 to 75% have been reported (637) from tomato, beet, corn, carrot, pea, and wax bean wastes flows using lime alone and in combination with alum or iron sulfate; with lime alone, 86 and 90% SS removals were reported for tomato and beet effluents, respectively.

Poor removals of BOD and COD were observed in the laboratory using peach and tomato waste water treated with lime (123). BOD was oxidized from the waste at the rates of 1.8 parts per part of potassium permangmate per hour, and 1 to 6 parts per part of chlorine (from NaOCl) per hour; these treatments were considered simple but expensive.

Vacuum filtration - Vacuum filtration requires relatively heavy investments for the removal of solids and has had limited usage in the treatment of fruit and vegetable wastes. However, this method has been used in solids thickening and removal of starch in the processing of potatoes. There is little information available on its application to fruit and vegetable wastes, and parameters and potentials for vacuum filtration in reclaiming water for reuse are not known.

Centrifugation - Centrifugation is used extensively to separate highly dispersed and suspended materials which have economic value. There are virtually no published data on its application for removal of SS from screened fruit and vegetable effluents. Pilot studies indicate that separation by centrifugation of such dispersed solids as corn, carrot, and beet (peeler effluent) is mechanically feasible (670).

The concentration of suspended solids in the total effluent from the industry's plants is relatively low. But concentrations are sufficiently great at certain stages in the process to warrant application of special procedures for removal, and to reclaim water. Probably the SS will have only low value, except where specific components may be isolated (starches, waxes, etc.). There is little information on the economic appraisal in removal of SS from fruit and vegetable wastes, either for obtaining the solids, for reclaiming water for reuse, or for reducing BOD loads in the total effluent. The SS may be a problem in the formation of scum layers in lagoons and sewage treatment plants (230, 378). Eckenfelder (205) described the use of centrifugation for separating sludge at various stages in the treatment of paper, municipal, and other wastes.

Flotation - SS may be removed from effluents by air flotation. The procedure starts by subjecting effluent waste to air pressure in pressure vessels. When the effluent, supersaturated with air, is released to atmospheric pressure, the excess dissolved air is released as small bubbles to which suspended material becomes attached and separates as foam or float. The use of lime and alum to floc the suspended organic material aids in its separation.

Nelson (478) reported 50-80% SS removal from peach and tomato waste water at flows to 7000 gallons/square foot/day by flotation. Pilot plant flotation treatment of peach and pumpkin effluents with air rates of 0.46 to 0.60 cubic feet/minute has been described (458). Influent BOD's were about 2000-2400 ppm for peach and 2200-2600 ppm for pumpkin wastes; ingoing pH, around 10 for peach and 6.7 for pumpkin. Percent removals with peach and pumpkin wastes, respectively, were: BOD, 17 and 7; SS, 84 and 62; total solids (TS), 16 and 2; and settleable solids, 94 and 99. Sulfuric acid neutralization improved BOD and settleable solids removal from peach waste. Lime addition depressed SS removal from peach waste to 73%, resulted in no decrease in peach waste settleable solids, brought about increases in SS and settleable solids in pumpkin waste, but improved BOD removal to 30% in pumpkin waste. Dissolved solids removals were mostly poor, but reached 26% in the lime treated pumpkin waste.

Pilot plant flotation studies were reported (467) on a two-stage pumping system with air injection between the two pumps and a short pressurized hold before release to the flotation tank. Ratios of raw waste flow to recycle were varied from 1:1 to 3:1; and solids loading from 0.3 to 2.2 lbs/hour/square foot for peaches and 9.7 to 19.5 lbs/hour/square foot for tomatoes. With peach lye peel rinsewater the best SS removal was about 93% at a flow rate of 1.0 gallon/minute/square foot; the poorest about 65% at 2.6 and 2.9 gpm/square foot. SS removals from tomato process water (which contained field soil) were 84% at 1.0 gpm/square foot and 61% at 2.9 gpm/square foot.

The separation of SS (and minimizing formation of sludge) from fruit and vegetable effluents has been found feasible through use of vacuum flotation procedures. When aerated liquid is subjected to vacuum, minute bubbles are released and become attached to particles which migrate to the surface where they can be removed. Treatments of 0.025-0.05 cu.ft. air/gallon effluent/30 sec were effective. Removal of suspended solids from effluents of tomato, pear, asparagus, string bean, and spinach ranged from 77-98% (230, 378).

SOLIDS DISPOSAL - Many recent changes in processing procedures affect the utilization of waste:

1. The scale of operations has increased in virtually all fruit and vegetable processing. Operations have been consolidated in fewer plants and within fewer management organizations. The quantities of product handled per hour are greater than before.

2. There has been sophistication in methods of separating wastes at the time of harvest (mobile mechanical harvest) and in process lines (improved separation devices).

3. Transport facilities (roads and trucks) have improved considerably in the past decade so that there can be and is more transshipment of unprocessed crop to plants for processing, and there exists better opportunity for withdrawal and consolidation of wastes for treatment.

4. There have been developments in preparing crops for ensiling preservation and utilization of plant leaf for proteins.

5. Animal and poultry feeding procedures have been sharply refined with better understanding of the nutritional requirements of these species. The growing of animals and fowl has been upgraded in scale. Feed cost/weight gain ratios are critical in successful feeding management practices. The acceptance of any livestock feed is affected by availability, cost, and performance.

6. There has been a continued increase in the utilization of canned and frozen food, accompanied by a decrease in utilization of

"fresh" product, in homes, restaurants, and institutions. This has increased the quantity of fruit and vegetable waste to be disposed of at processing plants and decreased the quantity disposed of, relatively, in community systems.

7. There is greater emphasis both legal and political on the need to reduce pollution by all industrial organizations, including food processors. Residents of communities near food processing operations exert continued pressure to correct undesirable conditions, emphasizing the problems in waste disposal.

Although the solid wastes from most commodities have little use and are disposed of mostly by filling or spreading on land, the residuals from some are used extensively for animal feed. Examples are citrus, corn, pineapple, and potato. These commodities are produced in large tonnages for processing and are located in areas where cattle or other stock are available for feeding. Citrus, pineapple, and potato are processed during most of the year and the silage from corn can be stored. Largely as a result of this use of these commodity residuals, about three-fourths of all residuals from fruit and vegetables processing are disposed of as by-products (471).

Smaller quantities of residuals from many commodities are used for vinegar (33,000 tons), charcoal (30,000 tons), alcohol (18,000 tons), and other by-products (57,000 tons). The figures in parentheses are estimated total annual tons of residuals used for each purpose (471).

Burch et al. (114a) have analyzed problems in handling food wastes: relative costs in disposal and utilization; marketing problems for derived materials; and research and development problems involved. They cite possible disposal procedures for food wastes including: municipal systems, dump disposal, lagooning, spray and furrow irrigation, and incineration. They stress the necessity of first knowing current costs of waste disposal for comparison with alternative methods.

Marketing problems in the utilization of wastes are most difficult to solve. Most cannery and freezer wastes have high moisture contents. Removal of the moisture may also remove carbohydrate solids, which are of low value commercially. Removal of extractives of some value may result in fibrous residuals of low value.

Establishing the market position for many processed wastes requires establishing a competitive price principally on the basis of replacement. Factors affecting market acceptance for derived products are:

1. The adequacy of the supply, which may be serious in light of the seasonal operation of many food processing plants.

2. The perishable nature of the wastes, which require conversion.

3. The necessity of users to alter their formulations in order to utilize the processed wastes or derivatives.

4. The costs of additional handling and transport.

5. The low value of the wastes compared to other sources of nutrients, oils, etc.

Ben Gera and Kramer (87a) have presented an excellent review on the utilization of food industry wastes. It is evident that for some wastes in-depth appraisal has been made of the feasibility of their utilization. Some studies also include appraisal of the economic feasibility of utilization of the wastes.

LIQUID WASTE

BIOLOGICAL TREATMENT - Many types of microorganisms remove organic materials from liquid wastes. Those most commonly used in treatment systems are heterotrophs, which utilize organic carbon for their energy and growth. Some are aerobic and require molecular oxygen for converting wastes to carbon dioxide and water. Others are anaerobic and grow without molecular oxygen. Anaerobic microorganisms grow more slowly than aerobes and produce less sludge per unit of waste treated than do aerobic microorganisms. Anaerobes also release acids and methane, and their action on sulfur-containing wastes may create odor problems. Some microorganisms are facultative; that is, they can grow in either an aerobic or anaerobic environment.

Added nutrients, most often nitrogen and sometimes phosphorous, may be required for efficient biological treatment of food processing wastes.

The multiplying microorganisms produce a sludge, measured as volatile suspended solids (VSS), by conversion of the soluble organic waste materials to bacterial cells. The rate of sludge generation is constant for a given waste under steady state conditions. In aerobic systems, oxygen is needed for both conversion of organic matter to cellular material and for cell maintenance. The settling characteristics of the sludge are important in affecting the ease of its removal from the system. Sludge settling rates depend on the types of microorganisms present and their growth conditions. Therefore, operating variables such as waste physical and chemical characteristics, waste loading rates, holding times, degrees of aeration, and proportions of sludge recirculated in the system will affect sludge settleability.

Eckenfelder (205) discussed and quantified the factors influencing biological waste treatment. Esvelt and Hart (223) studied their application to fruit processing wastes, and SCS Engineers (582) reported descriptions, advantages, and disadvantages of several biological (and other) treatment systems.

Anaerobic ponds - In anaerobic ponds biological degradation of organic material occurs in the absence of dissolved oxygen. The ponds are typically deep and heavily loaded with waste, reducing the land requirement per unit volume of effluent, and are used especially for stabilizing solids, including sludge from other types of treatment systems. In facultative ponds the anaerobic condition exists in strata of otherwise aerobic ponds. Under anaerobiosis, organic materials are converted to methane, hydrogen sulfide, ammonia, organic acids, and others, as well as to carbon dioxide and water. Conversions of 80 to 90% of the organic load may be achieved, at a slower rate and producing less sludge than in aerobic systems, but undesirable odors may be generated. Higher temperatures increase the efficiency of anaerobic systems except between 37 and 45, and above about 58 degrees C. (187a).

Some performance data on anaerobic ponds are in Table 13.

Table 13. Anaerobic Pond Performance on Screened Food Wastes

Product	BOD ppm	BOD lbs/1000cu ft/ /day	Detention days	BOD, % removed	Ref.
Cannery		9.6-430	1/6-37 (pilot)	40-95	6
Citrus	4600	214	1.3*	87	411
Corn		70-104	6-11.3	25-69	135
"		70-104	6-11.3**	53	135
Fruit, sewage	360-1200	110-430	1/6-1/4 (lab)	50-70	484
Pea		81.5-159	2.8-3.9	22-29	135
"		81.5-159	2.8-3.9**	47-49	135
Pea blanch	30000		10	90+	492
Tomato	550	7.5	7.4	80	288, 289
"		5.1	9.25	82	288, 289
"		.86	37	98	288, 289
"		2.5-9.9	7.5-10	70 +	96, 600
Tomato, lima		1975	2.53	40	126

* Contact anaerobic process
** With added sodium nitrate

Lagoons and stabilization basins - Lagoons, ponds, or basins are extensively used for treating food processing wastes where land is available. Holding or storage ponds are large enough to accommodate a whole season's effluent for discharge when a receiving stream is at maximum flow or to land, or for dispersal by evaporation. Some waste conversion occurs during the holding period by settling of solids and by biological processes. Oxygen may be supplied for aerobic bacteria by algae in "aerobic" or in "facultative" ponds; the latter are partly aerobic and partly anaerobic in action. Odors and seepage to ground water may be problems; large land areas and insect controls are necessary; and the reduction of pollutional load may be low.

Increasing urbanization, which increases land costs and odor annoyances, and increasingly strict discharge requirements on pollutional loads have led to developing more efficient lagoon operations, by nutrient additions and especially by aeration. Suggested design factors for various types of stabilization ponds are in Tables 14 and 15. The suitability of a lagoon or other biological waste treatment system is thus determined not only by cost, but also by such social factors as urbanization and pollution regulations.

Table 14. Typical Design Factors for Stabilization Lagoons*

	Aerobic	Facul-tative	Anaerobic	Aerated
Depth, ft.	0.6-3.0	3-6	8-15	6-15
Detention, days	2-20	7-30	5-25	2-10
BOD loading, lb/acre/day	50-200	20-50	300-1000	
Percent BOD removal	80-95	75-85	50-70	55-90
Algae concentration mg/liter	100	10-50	nil	nil

* Reference 532.

Table 15. Stabilization Lagoon Land Area Requirements*

	Facultative Ponds (A)	(B)	Aerobic-algae	Aerated lagoon	Anaerobic pond	Aerobic
Area	84 acres	73 acres	19 acres	2.6 acres	2.82 acres	42 acres
Depth	6 feet	6 feet	1 foot	10 feet	6 feet	6 feet
Retention time	82 days	72 days	6 days	4.0 days	4.60 days	41 days
Loading lbs BOD/acre/day	50	57	200			

* Reference 532.

Canham (135) reported that a pure culture innoculation failed to improve the performance of lagoons and that enzymes and odor maskers in the lagoon were not proven to help.

Porges (517) stated in 1963 that of 827 waste water lagoons in use in the United States, 238 were for canning wastes.

Data on the performance of lagoons are summarized in Table 16.

Table 16. Stabilization Lagoon Performance in Treating Food Processing Wastes

Product	BOD, ppm in	BOD, ppm out	BOD lbs/acre/day	Detention days	BOD % removed	Ref.
Apricot, peach			90	106	96*	502
" "			800	47	79*	502
" "			500	78	93*	502
" "			600	70	88*	502
Cannery			4770	2.5	40	124
"			786	72	90	124
Citrus			200	120	83*	324
Corn	2760			42	84	566
"	2760			40	95*	566
"	2936			9.6	59	213
"	774-3700	11-56	(6 ponds in series)			181
Pea	1430			49	91	566
"			70	84	96	180
"	337-1050	17 58	(6 ponds in series)			181
Potato	1000			116	91	495
Tomato			628	17	74-81*	502
"			396	26	80-81*	502
"	1800			42	93	566
Tomato, citrus			662	22	74-75*	502
" "			135	17	85 88*	502

* With added nutrient

Aerated lagoons - Several systems have been developed for mechanical transfer of oxygen to aerated lagoons, including surface mechanical aerators and pumped air injectors or diffusers. The achieved concentration of oxygen affects the efficiency of BOD conversion, and the oxygen transferred to the lagoon per horsepower-hour is an important factor in cost.

Aerated lagoons resist upsets from organic load and pH shocks and can achieve good BOD reductions without odors. In this treatment system the biological solids (SS) remain in the treated effluent.

Performance data on aerated lagoons are in Table 17.

Activated sludge - An activated sludge system is one in which the solids from an aerated treatment system are settled and returned to the first treatment basin. Several modifications of this basic scheme are in use. Poor settling sludge is often associated with activated sludge treatment of food processing waste. This problem may be the result of: a) filmentous organisms which tend to outgrow other forms at concentrations of dissolved oxygen below 0.5 ppm, or b) diffuse bacterial flocs which may form at high growth rates (205). The process can achieve 90% or higher reductions in BOD and in SS under good operating conditions.

Jewell and Eckenfelder (322) reported experiments with pure oxygen for aeration in a pilot scale activated sludge unit, using brewery waste. The pure oxygen improved sludge settling characteristics at high mass loadings with 90% COD removal.

Performance data are in Table 18.

Trickling filters - A trickling filter is a porous bed with a bacterial slime growth. As liquid wastes are passed down through the bed, they are biologically oxidized by organisms in the slime film. The filter may be deep or shallow and the packing medium stone, wood, or plastic. Many modifications in the system are possible, including changes in dimensions, medium porosity, waste flow and its organic load, recycling, adjustments in nutrients, pH, or temperature, and aeration. In an ideal system the various factors are in balance for maximum degradation of the BOD input. Some of the factors can be monitored and controlled. Data on the performance of trickling filters are in Table 19.

Table 17. Aerated Lagoon Performance in Treating Food Processing Wastes

Product	Influent BOD ppm	Detention days	BOD, % removed	Ref.
Beet	4236	1.1	98	273
"	3830	.75	96	273
Cannery	360	4.5(17.2 C)	94	522
"	920	4.5(6.3 C)	43	522
"	980	13 (8.5 C)	95	522
"	1650 (COD)	2-5	50-80	489
Carrot	1910	.37	86	273
Pea	535-1212	12	76-97	581
"	970	.39	94	273
"	578	.23	93	273
"	820	5.6	78	187
"	3000-4400*	5.5	76	184
Pea, carrot	1260	.25	81	273
Peach	1650	.16	54	420
"	1100	.6	60-70	545
Potato	1000	82	97	487
Pumpkin	1380	.35	60	420
"		6	77	198
"		6	85	198
"		6	88	198
"	2500	1.2	50-60	545
Tomato		5	68	213
"	1500		98	286
Tomato, corn	580	5 (lab.)	71	489
" "	550	4 (lab.)	61-70	489
" "	890	3 (lab.)	60	489
" "	840	2 (lab.)	59	489
" "	605	1 (lab.)	43	489

* Pounds/acre/day

Table 18. Activated Sludge Performance in Treating Food Processing Wastes

Product	Influent BOD ppm	Influent BOD lbs/lb solids	Influent BOD lbs/1000cu ft /day	Detention hours	BOD, % removed	Ref.
Apple	1200-1400			90-330 *	91-99+	222, 223
Bean, snap	140		2.4	101	35	96
Beet	4000	2.0		9.3*	96	117
"	3700			6.6**(pilot)	82	309
"	4800			20**(pilot)	97	309
"	5300			40**(pilot)	98	309
Cannery, sewage		50-70		6(+ 6 sludge rearation)***	90-95	484
"		200±			70-	484
"	300-1600	.47	200	4.6 & 8	90	501
"		.14	148		87	123
Citrus	1200	.04-.38		*(pH adjusted)	98-99.7	325
Food, sewage	100 ±	.1±			97	254
Pea, carrot	1100			6.6**(pilot)	89	309
" "	1500	2.5		3.1**	95	117
Peach	3200		24	95	82	96
"	860-1800			70-120±*	80-98	212, 223
Peach, tomato		.12-.65		(lab.)	93-98	123
" "	740			.65 + 1.3***	58	209
Pear	1600-2000			80-170±*	99	222, 223
Pimento	810		50	25	61	96
Potato	2100		20	129	74	96
"			138	20(pilot)	92	160
"			210	10(pilot)	86	160
"			480	1 + 10(pilot)***	59	160

Table 18. Activated Sludge Performance in Treating Food Processing Wastes (continued)

Product	Influent BOD ppm	Influent BOD lbs/lb solids	Influent BOD lbs/1000cu ft /day	Detention hours	BOD, % removed	Ref.
Potato			500	1 + 6(pilot)***	49	160
"	1000-2000	.3-.4 ±	190-360	6(pilot)	98 –	79
"	1000-2000	.3-.4 ±	190-360	.5 + 2(pilot)***	50 –	79
"	1000-2000	.3-.4 ±	190-360	1-1.5 + 6-8 (pilot)***	80 –	79
"			230-410	8 (lab.)	85-99 +	601
"			65-280	12	98	601
Tomato	410			.8 + 1.6***	85	209
"	540			.35 + 1.6***	84	209
Tomato, apple	490			1.0 + 2.0***	90	209
Vegetables		2-14 (COD)		4.9* (high rate unit)	33-99	607
"				36*(extend. aer.)	56-99	607

* With added nutrients

** Aerate and clarify in the same unit

*** Contact stabilization

Table 19. Trickling Filter Performance in Treating Food Processing Wastes

Product	Influent BOD ppm	Influent BOD lbs/1000cu ft/day	Flow	Recycle (Raw:recycle)		BOD, % Removed	Ref.
Apricot	320				* pilot	34	549
Beet	150				* pilot	87	549
Cannery		1200	1-7 gpm	7-14 gpm	* pilot	80	549
"		500	1-7 gpm	7-14 gpm	* pilot	50	549
"	1600	100			*	80	148
Cannery, sewage		40				77-85	484
"		60				63-78	484
"		80				50-68	484
"		100				35-57	484
"		140				35	484
Corn	500-2000	to 150		(1:10)	**	94-	278
"	500-2000	to 110		(1:5)	* **	94-	278
Fruit	2300 (COD)		50 gpm	150 gpm	* ** 12ft diam	46	432
"	2300 (COD)		100 gpm	100 gpm	* ** 12ft diam	50	432
"	3400 (COD)		150 gpm	150 gpm	* ** 12ft diam	33	432
"		640	.66 gal/sq ft/min	(1:1)		53	467
"		950	.88 gal/sq ft/min	(1:1)		20	467
"		1200	.88 gal/sq ft/min	(1:1)	**	39	467
"		1600	1.5 gal/sq ft/min	(7:4)	**	26	467
Pea	1100		15-20 mgd			14	366
"	1100			(1:4-5)		78	366
"	640				* pilot	25	549
"		180-420				25-37	593

Table 19. Trickling Filter Performance in Treating Food Processing Wastes (continued)

Product	Influent BOD ppm	Influent BOD lbs/1000cu ft/day	Flow	Recycle (Raw:recycle)		BOD, % Removed	Ref.
Pea		220				50	702
Pea, carrot	800				* pilot	41	549
Pea, sewage		250				45	593
" "		52				90	702
Peach	720				* pilot	33	549
"	2700-4000	960		(1:14)	* pilot	29	432
"	2700-4000	2300		(3:14)	* pilot	44	432
"	2700-4000	2500		(5:14)	* pilot	24	432
"	2700-4000	2900		(7:7)	* pilot	23	432
"	2700-4000	2400		(7:7)	* pilot **	85	432
Potato		400	2-5 gpm	14 gpm	pilot **	75	161
"		600	2-5 gpm	15 gpm	pilot **	49	161
"		800	2-5 gpm	14 gpm	pilot **	35	161
"		70	160 gal/sq ft/day		pilot	90+	122
"	(500 lbs/acre-foot/day)		.36 mgad			94	601
"	(1000 " ")		.72 mgad			92	601
"	(2000 " ")		1.4 mgad			77	601
"	(3000 " ")		2.2 mgad			55	601
Specialities		600	830 gal/sq ft/day		*	53	142
Vegetables		145	.38 mgd		2 stage filters	69	149

* Plastic medium
** With added nutrients

City treatment - Preliminary figures from reference 471 showed the following percentages of canners and freezers of the tabulated products disposing of effluents to city systems in the continental U.S. :

Product:	citrus	tomato	corn	potato	peach	apple	snap bean	pea	pear
%	1*	67	40	43	83	30	58	39	92

other fruit	other vegetable
67	59

* Reference 232

The degree of purification at public treatment plants varies widely; estimates of their average removals are (637): 75% of the BOD, 85% of the SS, and 14% of the total dissolved solids (TDS).

Other biological treatment - Yeast fermentation has been used for the production of alcohol and yeast and for treating food wastes simultaneously. Torula yeast has been grown on waste from citrus (24), potato (539), and other wastes (636a) but the process has not been widely adopted. Stricter waste effluent standards may make the method more attractive.

Strains of the fungus genus Imperfecti have been propogated on corn and soy bean wastes in pilot studies (151). Reductions in the COD of corn waste from 2,500 to 100-400 mg/liter in 20 days and fungus mycelium yields of 1000 mg/liter have been reported. The preliminary tests are promising and conditions for good growth of the fungus have been fairly well established.

McCarty (401) has discussed results with a pilot scale anaerobic filter, a medium something like a trickling filter but kept submerged and anaerobic by the effluent flowing upward through it. BOD removals of about 60% (at 4.5 days detention) to about 98% (at 36-72 days detention) have been observed experimentally with strong wastes (750 ppm COD and higher). Relatively little sludge was produced and the filter responded well to intermittant operation. However, clogging with waste solids may be a problem and pH must be controlled.

LAND DISPOSAL - The successful disposal of fruit and vegetable wastes onto land depends on a number of factors. Engineering aspects include infiltrative and percolative capacities of the soil, clogging, quality changes in the soil, and the engineering of soil systems (405). Other factors are the translocation of the underground water to springs and streams or through faults to water supplies, evaporation, and transpiration through cover crop plant growth.

The effects of disposal of wastes into the soil mantle are as complex as are the wastes. While many operations appear to be successful, the long term effects are less clearly understood. Several considerations are important for successful disposal of food wastes into the soil; they are:

1. Land area: sufficient land area must be available to handle the waste during peak operations without overloading. Some provisions should be made for land to accommodate expansion of operations.

2. Soil: the character of the soil is important to acceptability of land for irrigation.

3. Slope: some slope is desirable to minimize ponding of water which is followed by destruction of plants, bacterial decomposition, and odor development. Too great a slope may result in excessive runoff.

4. Rest interval: the necessary rest interval depends on several factors, including BOD load during spraying, porosity of the soil, and the distribution of the effluent.

5. Cover crop: this is essential for the spray irrigation method of soil waste disposal in order to increase absorption and transpiration, and to prevent soil settling and erosion. A dense cover crop protects the soil from physical change, increases transfer of water to soil through the root system, and from the soil to atmosphere by evapo-transpiration.

6. Waste: wastes vary considerably in characteristics such as pH, BOD, ratios of nutrients, SS, soluble solids, and salt concentrations which all affect the soil mantle. These, ultimately, affect degradation of the wastes.

Spray irrigation - Spray irrigation consists of spraying screened liquid wastes from vegetable or fruit process operations onto land where it undergoes percolation into the soil and biodegradation. Spray irrigation of sewage wastes was practised as early as 1860-1870 (579) and of cannery waste beginning at least in 1947 (574).

A large variety of cover crops have been successfully used for spray irrigation fields. There is, however, a great difference in the capability of various crops to absorb and transpire water. Cover crops used include planted vegetable crops, grasses, stands of native bush, trees, and orchards. In many instances efforts are made to maintain stands of certain grasses while in others the practice has been to let natural survival determine the stand. A dense growth will transpire 10-20 inches of water per season (110).

Percolation studies of cannery wastes in lysimeters have been made (305, 546). Waste waters from process plants have been found to contain greater concentrations of sodium and chloride and were more acidic than fresh waters. Permanent pasture was affected adversely by spraying of blancher water (588). Hydraulic loading was a prime factor in disposal of plant effluent (199). Spraying on wooded waste-land over a period of three years resulted in gradual replacement of the natural stand with other plants (583).

The parameters of water and waste disposal on land vary depending on the nature of the soil and land. Applications ranging from 0.4 to 1.0 in./hr with suitable interval rests of six days have been cited (129, 437, 442). Lane (359) found feasible a precipitation of 87,000 gal./acre/day (absorbency of 3 inches/day), with rest intervals of 4-10 days. BOD applications have been reported up to 649 lbs/acre/day and SS, 285/lbs/acre/day (99, 100).

Spray irrigation on slopes draining to lagoons appears to be very successful and adaptable to soils which limit lateral movement of underground water (618); 99% reduction in BOD, total color removal, and 90% reduction in N and P may be expected.

Comminuted pea waste has been applied to soil by spraying an estimated 1000-1300 tons/acre at rates of 1 inch per acre/day, equivalent to an average of 0.15 inch/day for the season (128).

Monson (442) reported that 250 canneries used spray irrigation systems in 1957. According to Ebbert (201), 50 out of 118 canneries in one midwestern state used spray irrigation in 1958; Zall Research Associates (547) found 4 out of 14 surveyed canners and freezers and 1 out of 23 surveyed dairies using spray irrigation in 1967; in addition, three of the former and 10 of the latter were situated where they could have installed the system.

Preliminary figures from reference 471 showed the following percentages of canners and freezers of the listed products disposing of effluents by irrigation in the continental U.S.:

Product:	citrus	tomato	corn	potato	peach	apple	snap bean	pea	pear
%	34*	13	44	21	11	30	27	36	8

other fruit	other vegetable
20	17

* Reference 232

Bendixen et al. (89) estimated there were 2,400 systems for disposing of effluents to the land in 1965 and that 900 of these were used by food processors.

Performance data on spray irrigation are in Table 20.

Other irrigation systems - The ditch and furrow system consists of developing shallow ditches in the land through which effluent is directed. At intervals of use the land is permitted to dry, is disced, and refurrowed. It has been estimated in one operation that 46 inches of effluent were spread over 66 acres in 4 months operation, refurrowing after 18 inches. About 50% of the effluent was believed to evaporate and the balance to percolate. All accumulated SS were disced into the soil. The estimated soil loading was 0.124 lb of COD per square foot per day, based on 66 acres in use, 100 days operation, and 35,600 lb daily COD load (13).

Table 20. Spray Irrigation Performance in Disposing of Food Processing Wastes

Product	Applied BOD		Flow		Crop	Ref.
	ppm	lbs/acre/day	1000 gal/ acre/day	inches/ day		
Aspar., bean		22		3.5		637
Cannery			9	1/3	alfalfa, cut, 180-day yr.	87
"	210	210	60-120	6.4	wooded, 8-month yr.	399, 667
"		210-1800				361
Cherry		810		3.6		637
Corn		860		3.4		637
"			20		pasture, wood	572
Dairy		140-680	2.1-5.4		mostly grasses	361
Lima		65		.38		637
Pea			150	4.0		199
"		1200	5.9	.16	grass, cut, inc. solid waste	132
Pea, corn				.5	grass, cut	197
Potato	(5-6 mil lbs organic solids)			.35	grass, alfalfa, cut	268
Poultry	640			1-	sandy over clay, drain pipes	248
Specialities	620			1/4-1/2	grass, cut, all yr.	249
Tomato		410		3.0		637
"		160		.7		637
"	(920,000 lbs COD/season)		24		grass, 2-month yr.	89, 248
Tomato, fruit	1100	42	4.6		grass, honeysuckle	384
Vegetables		40		.38		637
"			7-8	4-6	grass, pasture	199, 442

The ridge and furrow system was originally conceived as a system in which the waste overflowed furrows atop ridges on sloped land. Unabsorbed waste was collected in a furrow and directed for further disposal. Ridge and furrow irrigation now consists of confining the wastes to furrows several inches below the ridges. Vegetation may be grown on top of the ridges (99, 100, 578).

A number of installations were made in the 1940-1960 period with some success. Generally, this system has been replaced by the spray system.

OTHER TREATMENT SYSTEMS - Waste waters frequently contain, besides organic load, considerable amounts of polar material. Even when processed so as to reduce the organic load, the salinity may be too great to permit reuse. Ion exchange treatment may be used to desalinate the waste water and to improve it for reuse. The ion exchange process has been applied to pineapple press juice and to olive and pickle brines for reducing salt ion concentration (11, 39, 290, 641).

The solids in fruit and vegetable process effluents may be separated by one or more treatments during the various steps of processing or from the final waste effluent. Methods for in-process separation of discrete and suspended solids have been cited previously. Separation of the sedimentary or settleable solids called sludge, or activated sludge, resulting from secondary or tertiary treatment of the wastes may be achieved by similar treatments, including sedimentation, chemical coagulation and precipitation, chemical oxidation, incineration, and land disposal (116, 208). The selection of a treatment for the wastes from various operations necessarily will be influenced by the type of wastes, their degree of degradation, and economics.

Incineration is applied to the disposal of various industrial solid wastes. Solid wastes may undergo size reductions from which by-products may be extracted, and which may be disposed of by biological degradation or incineration. Solid wet wastes of various types can be incinerated by designed systems; in some cases the combustion is sustained by the wastes when the organic compounds have adequate heating values. Liquid wastes can be concentrated prior to incineration treatment. Thermal treatments generally operate at temperatures up to 2000°F; applications of temperatures to 4500°F for chemical processes indicate potentials in engineered systems.

Carbon adsorption is a process by which wastes are chemically clarified by granular carbon. The waste is pretreated with polymer and brought into contact with carbon, which is regenerated and recycled. Olive brines were successfully conditioned for reuse as storage brines, producing olives of good quality (425, 428, 472). Estimated costs of $36.40 per 1000 gallons of brine might be reduced to about one-third by a centralized operation.

Reverse osmosis is a process by which water is forced by pressure through a molecular selective membrane. The process is also described as molecular filtration. Separation of salts, acids, and other components is feasible. Variables in the process involve pressures, types of membranes, and their dimensions. Reverse osmosis has many potentials for separation of components of food process waste (sugar, acids, salts) and for reconditioning water for reuse in food processing operations (425).

The rapid oxidation of organic substances can be achieved at a suitable catalytic electrode. A proposed system (387a) has porous electrodes with air and the liquid waste in alternate channels.

Except for some of the solids separation procedures mentioned incidentally, none of the "other treatment" systems summarized here has had significant commercial use for treating wastes. Their application to wastes in the future depends on further development and on comparison of their costs to those of other treatment methods.

SECTION VII

COSTS OF LIQUID WASTE TREATMENT AND DISPOSAL

INDUSTRY WASTE COSTS

Preliminary data from reference 471, supplemented by references 102, 105, 460, 522, 644, and 645, are the bases of the estimated expenditures in Table 21 for an assumed average fruit and vegetable processing plant.

Table 21. Estimated Liquid Waste Costs

	Item costs, $		Proportion	Per plant cost, $		
Item	capital	O & M	of plants	capital	cap./yr	O & M
In-plant	42,000	2,000	all	42,000	4,200	2,000
Primary treatment	7,000	5,000	1/4	500	50	350
Secondary treatment	20,000	12,000	1/6	3,600	360	2,200
Irrigation	17,000	4,500	1/5	3,600	360	900
City treatment	--	15,000	1/2	--	--	7,500
Total					$5,000	$13,000

The characteristics of an "average" plant were estimated from data on apple, peach, pear, snap bean, corn, pea, and tomato processing. The following plant size and waste averages were assumed: 15,000 tons of raw product in a 100-day season; 3,000 gal./ton, or about 450,000 gpd, or 45 million gal./year; 30 lbs BOD/ton of product, approximating 1000 ppm BOD; 10 lbs SS/ton of product, approximating 400 ppm. Component costs from the cited references were estimated for a plant with these "average" characteristics; they were converted to 1970 dollars using reference 645 data. Some estimates were averages of figures that varied over a wide range. Capital costs per year were estimated as one-tenth of capital costs.

"In-plant" costs included expenses for waste flumes, piping, pumps, tanks, sumps, gutters, and screens. Primary and secondary treatment systems were not well or consistently defined in the references.

Using unit costs per year as estimated above and the assumed BOD removals given in Table 22, overall costs for different treatment efficiencies were estimated for an "average" plant; the in-plant costs were added to each of the other systems' costs; see Table 22.

Table 22. BOD Removals and Costs (1)

Treatment	BOD, % removed	Cost per year
In-plant	5	$ 6,000
Primary	50	12,000 *
Secondary	80	20,000 *
Irrigation	100	12,000 *
City treatment	75	21,000 *

* Including in-plant costs

SS would be removed in higher percentages than BOD by the simpler systems, which include settling. Irrigation costs could be much higher than shown in Table 22, depending on the availability of suitable land.

Estimates derived from figures in reference 123 for a 0.5 mgd plant were approximately (converted to 1970 costs and rounded) as in Table 23.

Table 23. BOD Removals and Costs (2)

Item	BOD, % removed	Cost per year	
		capital	O & M
In-plant	0-10	$1,200	5,000
Sedimentation	10	4,200 *	7,500 *
Aerobic pond	50	4,700 *	9,000 *
Aerated lagoon	80	8,700 *	11,000 *
Irrigation	100	4,000 *	12,000 *

* Including in-plant costs

In-plant costs included those for screening and for handling solid wastes; these in-plant costs were estimated to be required in all plants and have been added to the costs of the other systems.

SPECIFIC SYSTEMS COSTS

Estimated costs of specific waste treatment systems are presented in the following discussion.

SCREENING - Boyle and Polkowski (104) estimated the following screening costs per case:

Product	capital	O & M	total
peas and corn	$.0014	$.0012	$.0026
beets and carrots	.0022	.0092	.0114

Screening costs for a plant canning about 15,000 cases of peaches and 57,000 cases of tomatoes per day and discharging about 300,000 gal./hr were detailed as (123):

capital $47,000, at 10 year life and 6%, per year	$ 6,375
maintenance and repair	2,170
attendant	3,800
cleaning	700
power	1,250
annual total	$14,295

Hauling the 10,140 yards of resulting solid waste cost an additional $12,168. The cost per equivalent case of peach and tomato products combined was $.0029 ($.0054 including hauling).

The same reference estimated the costs for a 300 days per year operation with a 40-mesh vibrating screen, conveyors, and hoppers to vary from (figures rounded) $9,500 plus $3,750 for a plant with 0.5 million gallons/day flow to $65,500 plus $32,900 for an 8 MGD plant (capital costs and operation and maintenance costs per year, respectively).

SEDIMENTATION - Estimated costs of sedimentation of cannery effluents in 1965 for 1 and 3 hours detention, corresponding to about 9 and 14% BOD removal, are in Table 24 (123).

Table 24. Costs of Sedimentation of Cannery Effluents *

Waste flow MGD	Acres required	Capital cost $1000	Annual O & M $1000
.5	.06-.12	18-33	1.9
1.0	.10-.16	26-61	3.4
2.0	.14-.24	44-110	6.3
4.0	.18-.36	82-210	12.0
8.0	.28-.58	150-390	21.0

* Figures rounded

LAGOONS - Lagooning costs for removing 80-90% of the BOD from screened effluents were estimated to be $.0014 per case for pea and corn canning and $.0022 per case for beet and carrot canning (105). The costs for various types of ponds for cannery effluents have been estimated assuming a 300 day operating year (123). Figures estimated for a plant discharging 8 million gallons per day are in Table 25.

Table 25. Costs of Lagoon Treatment *

Lagoon type	Depth feet	Acres	BOD, % Removed	Capital $1000	Annual O & M $1000
aerobic	3	37-330	68-96	14-980	45
facultative	6	12-110	60-90	120-720	59
anaerobic	12	10-71	50-80	170-1100	56
evaporation, percolation	6	--	all	2000	29

* Figures rounded

AERATED LAGOONS - Aeration equipment to remove 90-95% of the BOD from the effluent was estimated to cost \$.0227 per case of peas and corn or \$.092 per case of beets and carrots; costs of the lagoon, piping, etc. would be additional (105). Approximate costs were given by Esvelt (222) for removing about 80% of the BOD from flows of about 0.6 to 1.4 million gallons per day from peach, pear and apple processing. Capital was estimated at \$205,000 and calculated at 7% interest and 20 years life.

Item	capital	power	nutrients	operation	maintenance	other
Annual cost, \$	19,400	7,000	10,500	6,000	1,500	4,500

Total costs came to \$.041 per pound of BOD removed.

Aerated lagoon costs for a range of waste flows and BOD removals were estimated assuming a 300 day operating year (123). For 8 million gallons per day, capital costs were \$61,000 and \$648,000 plus .79 and 19.9 acres of land for 10 and 90% BOD removals, respectively; corresponding operation and maintenance costs were about \$34,000 and \$68,000 per year. Capital costs for a 1 mgd flow were estimated to be about one-fifth of these.

Robe et al. (545) calculated a cost of \$.21 per 100 lbs oxygen added by surface aerators, compared to \$4 to 5 for the same amount from sodium nitrate.

Costs of an aeration system given by Lane (359) for treating 86.2 million gallons of peach waste in 658 operating hours were \$1,128 for materials, \$914 for electricity, and \$295 for labor. For treating 38.8 million gallons of pumpkin waste in 1028 operating hours the costs were, respectively, \$1,673, \$1,346, and \$1,009; capital costs were additional.

ACTIVATED SLUDGE - Costs were given for an activated sludge system handling 2.5 million gallons/day of mixed food processing and domestic wastes with a BOD of roughly 100 mg/l which worked well without primary clarification: construction, \$506,300; operation and maintenance, \$20/million gallons (254). These costs were much lower than for a conventional plant.

Esvelt and Hart (222 and 223) described a treatment plant for fruit wastes with detailed costs; capital costs were given as (a) $470,000 without and (b) $557,000 with sludge re-aeration and were estimated at 7% interest and 20 year life.

Item	(a)	(b)	power	nutrients	operation	maintenance	other
Annual cost, $1000	44.4	52.6	10.0	10.5	12.5	2.0	7.5

At 95% BOD removal total costs would be (a) $.061 and (b) $.067/ pound of BOD removed.

Activated sludge plant costs for a range of flow rates and purification efficiencies have been estimated (123). The 8 mgd plant estimates are in Table 26.

Table 26. Costs of Activated Sludge Treatment *

BOD, % removal	Acres required	Capital cost $1000	Annual O & M $1000
60	2.5	540	58
73	1.9	450	58
90	3.9	550	58
95	8.8	700	58

* Figures rounded

TRICKLING FILTERS - The costs for trickling filter treatment of wastes with 300 ppm BOD were estimated over a range of conditions (123). Estimates for 0.5 and 8 million gallons per day waste flows, respectively, including a two-hour detention in secondary clarifiers, are in Table 27.

Table 27. Costs of Trickling Filter Treatment*

Assumed BOD removal, %	Hydraulic loading**	Acres required	Capital $1000	O & M $1000
34	2	.09-.63	78-360	3.9-19
58	4	.14 1.6	120-640	3.9-19
69	10	.27 3.8	94-1100	4.0-29
76	30	.51-7.5	164-2000	4.0-29

* Figures rounded.
** Million gal. /acre/day.

CITY TREATMENT - The costs of city collection and treatment of waste flows from a peach and tomato cannery in 1964 and 1965 were given as $.0477 and $.0406 per standard No. 2-1/2 case of product (123). Roughly half of the costs were for collection.

Charges for a number of municipal treatment systems may be summarized as follows (470): Five cities charged from 15 to 75% of the plant's water bill, with a median of 50%. Twelve cities charged from $0.002 to $0.15 per 100 to 120 cubic feet of waste volume, with a median of $0.085. Some cities had added surcharges of $0.0035 to $0.005 per pound of BOD, generally for that BOD in excess of a given concentration (300 to 750 ppm). One city had an additional surcharge of $0.0072 per pound of BOD based on the previous year's maximum demand, and some cities added surcharges for SS.

SPRAY IRRIGATION - The capital cost of a 40 acre spray irrigation system to handle 360,000 gallons of waste per day, or 60 inches in a 180-day season, was given as $12,000 (1953 cost) by Bell (87). Operation required one full-time man; the alfalfa crop returned $5000 per year. Lane (359) reported a spray irrigation cost of $.01 per No. 2 case, and at another plant canning 40,000 cases of tomatoes, a capital cost of $2,030, both about 1954. Nelson (480) reported $.006/case; reference 51, $.01 to .05/case, for spray irrigation in the early 1950's.

For a 120 acre system with grass and alfalfa to handle 100 inches of waste per year, Haas (268) reported capital costs of $30,000 (plus land) and annual operation and maintenance costs of $40,000. The total costs of spray irrigation systems about 15 to 20 years ago were reported as: $15,000 for 84 wooded acres, 5-10 mgd, 8 months operation per year (399, 667); $15,000 for 48 acres in hay, 75,000 gal./day; $5,200 for 100 acres in pasture, 80,000 gal./day; and $5,000 for 40 acres in pasture, 400,000 gal./day. The latter three were for dairy wastes (574). Lawton et al. (361) reported costs for five other dairy plant spray irrigation systems, excluding land costs, as $400 to $2,300; the systems used 0.018 to 1.15 acres, mostly in grass cover crops, and handled 380 to 5,900 gallons of effluent per day.

SECTION VIII

RESEARCH NEEDS

WASTE SOURCES

The capability of reducing the pollution load in the effluent from fruit and vegetable processing depends largely on knowing the point of origin of the wastes, the causes for their occurrence, and their magnitude and characterization. With such information means to correct malfunction or unsatisfactory operation may be applied, or efforts made to develop alternative systems which minimize the loss of extracted solids or leachate. More importantly, efforts toward reduction in pollution load can be directed to those phases of operation where the generation of pollution load is relatively great. Complementary to identifying the important sources of pollution load is the application of monitoring systems by which these operations can be better defined.

Relatively few studies have been made on the magnitude and characterization of the wastes generated during specific processing steps; these include studies on apples, citrus, peaches, pears, beets, carrots, corn, peas, snap beans, and tomatoes. Additional information is needed on these crops and others. Examples of the potential benefits of such studies have been the development of fruit peelers which are more efficient in the separation of peel and skin with less loss of solubles (apple, pear, tomato, beet, carrot, and potato); characterization of the losses of suspended and soluble materials during water blanching; improved container fillers; and isolation of waste streams for conditioning and reuse. Efforts in the characterization of in-plant wastes should be greatly intensified so that other alternative processes may be developed.

WATER CONSERVATION

A major problem in the conservation of water in many food process operations is that it is considered the cheapest commodity available, and hence readily expendable in comparison with investment in sophisticated equipment and in labor. Efforts to encourage conservation of water have not been wholly successful except where it is critical in supply or where economies are apparent in its conservation.

The conservation of water in processing fruits and vegetables is important for several reasons; the volume of water used and discharged is directly related to capital and treatments costs for the effluent; water is a vector and extractant for solubles and suspended solids from products and from wastes; it is a vector for heat, which is relatively costly; and finally, it is costly per se, contrary to the popular evaluation that it is not.

Little data are available on the costs of water used in the processing of fruits and vegetables including not only the power and capital costs in making it available from wells, but also the costs of its distribution through the factory and of its treatment; little information is available on the leaching effects resulting in greater pollution loads from the excessive uses of water.

Studies should be undertaken to establish norms in the use of water for processing various fruit and vegetable products, to establish means of conservation where such will be effective in reducing pollution loads, and to develop better understanding by management of the costs of water.

Among subjects in need of study are the following:

1. Develop quantitative data on the loss of soil with various root crops during mechanical harvesting to focus attention on the magnitude of the problem and the necessity for engineering improvements in harvest machinery.

2. Develop experimental data on new concepts for field site wash stations to remove and recover soil from root and other crops, and on the related transport costs and product quality.

3. Develop quantitative data on water usage and costs, including energy and capital costs in water procurement and in its conveyance throughout the plant.

4. Develop energy balances in water usage, including water transport, to evaluate better the costs of water uses.

5. Develop data on the costs of waste effluent disposal in terms of actual (uncontrolled) water usage and conservative (controlled) water usage.

6. Develop experimental data on new concepts for cleaning raw products, including soak and hydraulic systems, cavitation, detergent wash, air stream separation, mechanical abrasion, and osmotically balanced washing.

7. Develop improved and new procedures for treating water to permit greater multiple use for fruit and vegetable processing, and particularly to compare economic values in the use of fresh and treated water.

Voluntary water conservation can best be implemented by establishing economic benefits.

RECONDITIONING WATER FOR REUSE

In addition to the conservation of water in processing fruits and vegetables, there is need for more reconditioning and reuse of water as a result of its decreasing availability and changes in its quality. A limited number of studies have been conducted, principally on tomatoes, indicating the feasibility of water reuse. Clean and sterile retort water, for example, may be directed upstream; product rinse water may be directed upstream to product washing. A number of procedures are available for reconditioning water; ion exchange, reverse osmosis, filtration, sedimentation, flocculation, and centrifugation. These have been little used in fruit and vegetable processing primarily because water generally is readily available and because the total costs of water are not known.

The potentials of reconditioning water have not been adequately determined. Studies are needed on the treatment of water from various in-process streams and on costs and efficiency. The hygienic acceptability of the conditioned waters must also be evaluated since this is an important criterion for foods.

BLANCHING

Blanching generates a significant pollution load and causes losses of nutrients and reductions in yield. The processes used for blanching have not been adequately investigated to permit maximum correction of the adverse effects. Determinative end points are not available to permit application of only the necessary degree of blanching (excessive blanching appears to be the rule), and possible alternative systems have not been adequately investigated. Among these may be cited the sequential timing of liquid and liquid/steam thermal processes; the use of osmotically balanced blanching media, hot air, infra red, and micro-wave; and sequences of these procedures.

The relatively low volumes of effluents from water or steam blanching have high concentrations of pollution load. These effluents can be separated from the total waste stream and treated by concentration and drying or removal otherwise, thereby significantly reducing pollution loads. Studies are needed to reduce pollution from blanching and to establish operational parameters in this process.

PEELING AND SOLID WASTES

Peel wastes are used to some extent; for example, in citrus, pineapple, and apple processing. For many peel wastes, however, there appears to be no market and their disposal is an operational burden. At least two phases of research are needed to reduce the pollution loads involved in peeling fruits and vegetables: 1) development of alternative systems of solid waste separation to reduce concurrent losses in solubles and suspended solids and to increase product recovery; and 2) characterization and evaluation of the material for recovery of potentially useful materials. Traditional disposal of the separated wastes include use as feed for animal or fowl, and on land. The possible utilization of these wastes has not been given adequate consideration in the light of modern food processing operations. Conversion of the wastes into alternate physical forms for use or disposal; extractants that may have market value as nutrients, chemicals, fertilizers, or other products; and consolidation of wastes from adjacent processing plants for economies in conversion and marketing should all be studied.

The recently developed dry caustic peeling of certain root crops appears to have benefits in minimizing the problem of liquid wastes and the concept should be extended; other procedures including comminution, concentration, and incineration should be evaluated to provide better disposal systems and reduce pollution loads in effluents.

Because the soil and peel loads in certain crops are large, consideration should be given to in-field washing and peeling during harvest; this would retain both soil and organic peel materials on the land. Although there appears to be objection to such concepts on hygienic grounds, these may be less serious than the problems in handling waste effluents.

LIQUID WASTE TREATMENT

There is a lack of information on the relative efficiency of simple screening and separation systems for the removal of colloidal and dispersed matter from effluents. The application of such procedures at various stages in the processing of fruits and vegetables is needed to reduce the pollution load in the plant effluent and permit reuse of the water. There are only limited published data on the use of screens, vacuum systems, centrifugal systems, and sedimentary systems for the treatment of selected effluent streams.

There is considerable engineering information on the disposal of effluent wastes upon soil. Soil type, pollution load, application rate, soil cover, and other conditions vary widely; the results have depended upon the experience of the participants in the projects. There is a dearth of information on the potential effects of the applications on the character of the soil from chemical interactions. A compendium of information for land disposal systems is needed.

There is a great need for information on establishing the optimum conditions for the biological degradation of the various types of effluents in lagoons to achieve maximum effect in the shortest time. The information should include flora, temperature, concentration, pH, nutrient supplement, and oxygen tension necessary to achieve maximum degradation. This information is needed to achieve efficiency in lagoon utilization and to minimize the hazard which may occur when the lagoons operate improperly. Lagoons are extensively used and are important tools in the treatment of wastes; the procedure is replete with problems in the light of increasing social and legal pressures.

The relationship of the composition of the effluent to its biodegradability is not clearly established; for example, the rates of degradation of effluents bearing different types of organic solids, such as vegetable starches and fruit acids.

The data should be implemented by information to attain complete and rapid biodegradation of the wastes to the point of permitting economic treatment and recycling/reuse of the water. New engineering concepts may be feasible in the use of waste energy from stack gases of thermal processes applied to specific wastes or to biodegrading systems.

The processing of effluents by such systems as yeasts and fungi Imperfecti and by trickling filters should be further examined to determine potentials in sequential treatment. This information is needed for the different types of wastes derived in processing fruits and vegetables to assist engineers in designing treatment systems.

WASTE POLLUTION EVALUATION

The concentration of pollution loads in process wastes is measured by other than simple tests, such as chemical oxygen demand (COD), or biochemical oxygen demand (BOD). These are not simple in the sense that for reliability in the values obtained trained personnel must supervise their application.

The COD test is the more quickly performed (several hours) and the BOD_5 test requires 5 days, each after procedures have been standardized. These tests are used as the basis of acceptability of effluents disposed into natural waterways and in part to determine sewer charges.

A number of laboratory tests and instruments have been devised for quantifying the properties of waters and wastes. These range from sophisticated instruments for analysis for various components in water or wastes to gross or proximate measurement of floc or precipitate. Many procedures have been applied in technical studies to characterize wastes and their degradation. Instrument manufacturers offer simplified forms of some tests to permit routine evaluation of some qualities of waters and wastes.

For routine surveillance by fruit and vegetable processors of the pollution loads in various steps of processing, there is a great need for at least two sets of evaluation procedures. The first is the need for data on the characterization of pollution load equivalent wastes of specific product processes as measured or interpreted by regular employees. Among these may be cited values obtained through laboratory instruments such as turbidimeters, refractometers, centrifuges, conductivity meters, oxygen concentration meters, pH meters, etc. Establishing values from such instrument readings is highly desirable and presumably would be effective for supervision of pollution control. The second is the need for simplified "quick and dirty" procedures for measuring with reasonable reliability directly or indirectly COD equivalents of waste effluent streams in various stages of processing. These should permit managers to monitor waste streams and treatments better than at present and should lead to better control of pollution problems.

SECTION IX

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SECTION X

REFERENCES

1. Aceto, N.C., Edwards, P.W., Eskew, R.K., Redfield, C.S., Hurley, R.F., and Hoersch, A., Jr., 1950. Production of Leaf Meals from Vegetable Wastes in Rotary Alfalfa Driers. USDA Eastern Reg. Lab., AIC-266, Philadelphia, Penn.

2. Adam, W.B., Horner, G., and Stanworth, J., 1942. Changes Occurring During the Blanching of Vegetables. Ind. Eng. Chem. 28, 595.

3. Adams, H.W., Hickey, F.D., and Willard, M.J., Jr., 1969. Lye-Pressure Steam Peeling of Potatoes and Other Products. Food Technol. 14, 1.

4. Adams, S.L., 1950, Utilization of Cannery Fruit Waste by Continuous Fermentation. Washington State Institute of Technology, Bull. No. 207.

5. Adrian, P.A., Fridley, R.B., and Claypool, L.L., 1968. Adapting Shake-Catch Method of Harvesting to Cling Peaches, Paper No. 67-141, Transactions of the ASAE 11, 159.

6. Agardy, F.J., and Spicher, R.G., 1967. Anaerobic Treatment of Cannery Wastes - A Bench Scale Study. San Jose State College, San Jose, Calif.

7. Agardy, F.J., Spicher, R.G., and Orlob, G.T., 1967. Cannery Waste Treatment Part II. Treatability. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

8. Agen, J.R., Willis, R.L. and Robe, K., 1965. Peas by Bump Truck = Big Savings. Food Processing 26.

9. Ahrens, G.G., 1969. Morrell Pioneers More Efficient Aeration. Food Eng. 41 (Aug.), 84.

10. Almanac of the Canning, Freezing, Preserving Industries, 1969. Edward Judge Publishing Co., Westminister, Md.

11. American Chemical Society, 1969. "Cleaning Our Environment - The Chemical Basis for Action", p. 95. A Report by the Subcommittee on Environmental Improvement, Committee on Chemistry and Public Affairs, Washington, D.C.

12. Ammerman, G.R., and Desrosier, N.W., 1958. Aeration Curbs Waste-Disposal Odors. Food Eng. 30 (Jan.), 115.

13. Anderson, D.R., Bishop, W.D., and Ludwig, H., 1966. Percolation of Citrus Wastes Through Soil. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

14. Angell, F.F., 1968. Tractor-Mounted Tomato Harvester. Maryland Processor's Report 14 (2), 1., Univ. of Maryland, College Park, Md.

15. Anon. 1937. How to Treat Wastes. Food Ind. (Aug.), 430.

16. Anon. 1940. Treatment Methods for Waste From Citrus Juice Canning Plants. Public Works 71(8), 7.

17. Anon. 1944. Asparagus Waste Fed to Microbes. Food Ind. 16, 713.

18. Anon. 1944. Asparagus Waste By-Product. Food Packer 25, 63.

19. Anon. 1944. Corn Cannery Waste Effectively Disposed. Food Packer 25 (Feb.), 28.

20. Anon. 1944. Food Plant Wastes Used to Clean Metal. Food Ind. 16 (Jan.), 91.

21. Anon. 1944. Lab. Extracts Feed Yeast from Citrus Waste. Food Ind. 16 (May), 644.

22. Anon. 1945. Use of Sodium Nitrate in Treating Cannery Wastes. Public Works 76 (Dec.), 48.

23. Anon. 1945. Vegetable Wastes by Dry Process. The Food Packer 26 (July), 32.

24. Anon. 1946. Citrus Processing Waste Used to Produce By-Product Feed Yeast. U.S. Dept. Ag. Report of Chief of Bureau of Ag. and Ind. Chem., Ag. Res. Adm. p. 35.

25. Anon. 1947. Citrus Waste Disposal Gets Test in Florida. Food Ind. 19 (Nov.), 130.

26. Anon. 1948. Study Citrus Waste as Fuel Gas Source. Food Ind. 20 (Mar.), 138.

27. Anon. 1949. Cannery Wastes Fermented by Continuous Process. Food Ind. 21 (Sept.), 1278.

28. Anon. 1952. Making Pear Waste Salable. Food Eng. 24 (Feb.), 136.

29. Anon. 1952. Plastic Pipe System Solves Cannery Water Disposal and Irrigation Problems. The Canner 115(23), 22.

30. Anon. 1952. Tomato Waste Converted to Animal Feed. Canner 114 (June).

31. Anon. 1953. Citric Acid From Lemons. Food Eng. 25, (July), 162.

32. Anon. 1956-1963. Derived from Annual Reports, City of Stockton, Calif., Treatment Plant.

33. Anon. 1954. Vibrating Screen Solves Pollution Problem. Canner 118 (24), 23.

34. Anon. 1963. Spray Irrigation Disposal. Compost Sci. (Spring), 38.

35. Anon. 1963. Ion-Exchange Removal of Sodium Nitrate Chloride from Water With Calcium Hydroxide as Recoverable Regenerant. Science 141, 1038.

36. Anon. 1963. Just How Effective are Lagoons. Compost Science 4 (Autumn), 25.

37. Anon. 1963. Ridge and Furrow Disposal Fields. Compost Science 4 (Spring), 39.

38. Anon. 1966. Harvesting, Hauling Costs. Amer. Fruit Grower 86 (Mar.), 29.

39. Anon. 1966. Water Re-Use, C&E Special Report. Chemical and Eng. News 44(12), 91.

40. Anon. 1967. Destroys Fluidized Waste Without Pollution. Food Eng. 69 (May), 204.

41. Anon. 1967. Vine Cleaning. Hydraulics and Pneumatics 20, 26.

42. Anon. 1968. Fluid Bed Incinerators Studied for Solid Waste Disposal. Environmental Science and Tech. 2 (7), 495.

43. Anon. 1968. Improve Quality of Frozen Vegetables. Food Processing 29 (Oct.), 80.

44. Anon. 1968. Incineration - A Practical and Scientific Approach. Environmental Science and Tech. 2(7), 524.

45. Anon. 1968. Offers Complete, Smokeless Burning of Waste. Food Eng. 70 (Mar.), 185.

46. Anon. 1968. Tomato In-Field Washing Stations. National Canners Association, Research Information No. 134, Berkeley, Calif., Jan.

47. Anon. 1968. Unpublished Data of a Canning Industry Committee.

48. Anon. 1968. Washington Laboratory Research on Water Re-Use. National Canners Association, Research Information No. 141, Washington, D.C., Aug.

49. Anon. 1969. Carbon Makes Debut in Secondary Treatment. Environmental Science and Technology 3(9), 809.

50. Anon. 1969. Clear Water From Wastes. Agricultural Research 18 (6), 10.

51. Anon. 1969. Controls Oxygen in Waste Water. Food Eng. 41 (Sept.), 221.

52. Anon. 1969. Fruit Processor Solves Community Relations Problem. Food Processing 30 (Oct.), 72.

53. Anon. 1969. Harvester and Consumer Use Same Criteria for Tomatoes. Canner/Packer 138 (Nov.), 37.

54. Anon. 1969. High Intensity Waste Aeration Process. Food Processing 30 (Sept.), 69.

55. Anon. 1969. More Cherries: Separating Sweet Stems, Buying by Volume, and Hope for a New Variety. Canner/Packer 138 (Aug.), 28.

56. Anon. 1969, New Process Purifies Raw Sewage. Research/Development 20(9), 6.

57. Anon. 1969. Novel Process Could Aid in Waste Disposal. Chemical and Engineering News 47 (Nov. 17), 43.

58. Anon. 1969. Polymers Vie for Water Treatment Role. Environmental Sci. and Tech. 3(8), 713.

59. Anon. 1969. Processes Tomatoes ... in the Field. Food Eng. 12 (Nov.), 76.

60. Anon. 1969. Waste Disposal Without Air Pollution. Food Eng. 71 (Dec.), 103.

61. Anon. 1970. Cleaning-up Waste Water. Food Eng. 42 (July), 65.

62. Anon. 1970. Continuous Process for Celery Oil. Ag. Research, U.S. Dept. of Ag. 18 (11), 15.

63. Anon. 1970. Deliver Tomatoes to Processor as Juice. Food Processing 31 (1), 29.

64. Anon. 1970. NCA Testifies on Wastes. Canner/Packer 139(5), 30.

65. Anon. 1970. New 'Super Sweeteners' Made From Citrus Peel. Foods of Tomorrow (Summer), F4. Special Tearout From Food Processing 31, 1970.

66. Anon., 1970. Proceedings First National Symposium on Food Processing Wastes, Sponsored by FWQA Pacific Northwest Water Laboratory, USDA Western Regional Research Laboratory, National Canners Association, Northwest Food Processors Association; Portland, Ore.

67. Anon. 1970. Process Treats Waste Water, Produces Algae. Chemical and Engineering News 48 (Mar. 23), 47.

68. Anon. 1970. Reverse Osmosis Separates Solids From Whey for 1c/lb. Food Processing (Jan.), 26.

69. Anon. 1970. SO_2 Should Help. Chemical and Engineering News 48 (Aug. 10), 15.

70. Anon. 1970. Squeezing the Peel Off Avocadoes. Ag. Research, (April) p. 15, U.S. Dept. of Ag., Washington, D.C.

71. Anon. 1970. Waste Processes: a Little More Oxygen. Chemical and Engineering News 48 (Mar. 23), 16.

72. Anon. 1970. Waste Sludge Will be Used to Fertilize Corn and Pasture Grasses. Chemical and Engineering News 78 (July 7), 37.

73. Aqua-Ion Corporation. 1969. Treatment of Saline Waste Effluents by Ion Exchange With Lime as a Recoverable Regenerant. Oakland, Calif.

74. Arnold, Dix, P.T., Becker, R.B., and Neal, W.M., 1941. The Feeding Value and Nutritive Properties of Citrus By-Products. II. Dried Grapefruit Pulp for Milk Production. Univ. of Fla. Ag. Expt. Sta. Bull. 354, Gainesville, Fla.

75. Asselbergs, E.A., and Powrie, W.D., 1956. The Peeling of Apples With Infra-Red Radiation. Food Technol. 10, 297.

76. Asselbergs, E.A., Mohr, W.P., Kemp, J.G., and Yates, A. R., 1959. Blanching Celery and Apples by Infra-Red Shows Flavor, Texture, Appearance Gains. Quick Frozen Foods 21 (Feb.) 45.

77. Asselbergs, E.A., Mohr, W.P., and Kemp, J.G., 1960. Studies on the Application of Infrared in Food Processing. Food Technol. 14, 449.

78. Atkeson, F.W., and Anderson, G.C., 1929-1934. Potatoes as a Feed for Dairy Cows. Idaho Ag. Expt. Sta Bull. No. 216. Univ. of Idaho, Moscow, Idaho.

79. Atkins, P.F., and Sproul, O.J., 1964. Feasibility of Biological Treatment of Potato Processing Wastes. 19th Ind. Waste Conf. Purdue Univ., Lafayette, Ind.

80. Atkins, C.D., Wiederhold, E., and Moore, E.L., 1945. Vitamin C Content of Processing Residue from Florida Citrus Fruits. The Fruit Prod. J. and Amer. Food Manufacturer 24, 260.

81. Bass, J.H., and Evans, R.R., 1951. Sedimentation and Flocculation Equipment for Treatment of Industrial Wastes. Sewage and Ind. Waste 23(12), 1523.

82. Becker, R.B., Davis, G.K., Kirk, W.G., Dix Arnold, P.T., and Hayman, W.P., 1946. Citrus Pulp Silage. Fla Ag. Expt. Sta. Bull. 423, Gainesville, Fla.

83. Beeman, J.F., Dean, W.W., Jr., and Halsey, L.H., 1965. Development of a Mechanical Celery Harvester. Paper No. 65-622, American Society of Agricultural Engineers, St. Joseph, Mich.

84. Beeman, J.F., Dean, W.W., Jr., and Halsey, L.H., 1966. Developing a Mechanical Celery Harvester. Ag. Eng. 47 376.

85. Beidler, J. W., 1952. Apple, Cherry, and Tomato Waste Treatment. 7th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

86. Bell, J., 1961. Spray Irrigation and Research of Canning Plant Wastes. Canadian Food Ind. 32 (Sept.), 31.

87. Bell, J.W. 1955. Spray Irrigation for Poultry and Cannery Wastes. Public Works 9 (86), III.

88. Bendixen, T.W., Hill, R.D., Schwartz, W.A., and Roebeck G.G., 1968. Ridge and Furrow Liquid Waste Disposal in a Northern Latitude. Proceedings of the American Society of Civil Engineers 94 (no. SA1), 147.

89. Bendixen, T.W., Hill, R.D., DuByne, F.T., and Robeck, G.G., 1969. Cannery Waste Treatment by Spray Irrigation Runoff. Journal WPCF 41 (3), (Mar.), 385.

89a. Ben-Gera, I., and Kramer, A., 1969. The Utilization of Food Industries Wastes. In Advances in Food Research 17. Academic Press, New York and London.

90. Ben-Sinai, I.M., Ben-Sinai, M. Ahmed, E.M., and Kramer, A., 1965. The Fodder and Fodder Value of Pea Plant Parts (Pisum Sativum l.) as Related to Harvest Time and Variety. Food Technol. 19, 856.

91. Beohner, H.L., and Mindler, A.B., 1949. Ion Exchange in Waste Treatment. Ind. and Eng. Chem. 41 (3), 448.

92. Bergsbaken, C, and Weckel, K.G., 1963. Waste Utilization: Charcoal Briquets from Cherry Pits. Canner/Packer 132 (Aug.), 25.

93. Berlage, A.G., and Yost, G.E., 1969. A Positive-Transfer Fruit Conveyor. Transactions of the ASAE 50, 258.

94. Berry, D.L., and Higgins, G.C., 1968. Operation of Plastic Media Trickling Filters at Sedalia. Burns and McDonnell Engineering Company, Kansas City, Missouri, and Dow Chemical Company, Midland, Mich.

95. Bishop, D.F., Marshall, L.S., O'Farrell, T.P., Dean, R.B., O'Connor, B.,Dobbs, R.A., Griggs, S.H., and Villiers, R.V., 1967. Studies on Activated Carbon Treatment. Environ. Sci. and Tech. 3(9), 823.

96. Black, Crow and Eidsness, Inc., 1967. Unpublished Report on Cannery Waste Water.

97. Black, H.H., 1942. Treating Corn Cannery Waste. Canning Age 23 (May), 325.

98. Bloom, R., Jr., Joseph, R.T., Friedman, L.D., and Hopkins, C.B., 1969. New Technique Cuts Carbon Regeneration Costs. Env. Sci. and Technology 3(3), 214.

99. Bolton, P. 1947. Cannery Waste Disposal by Field Irrigation. The Food Packer 28 (Aug.), 42.

100. Bolton, P., 1947. Disposal of Canning Plant Wastes by Irrigation. 3rd Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

101. Bondi, H.S., 1955. Food Wastes Made Into Profitable Product. Food Eng. 27 (Jan.), 84.

102. Bower, B.T., 1965. Unpublished Data.

103. Boyd, J.W., Yoshida, T., Vereen, L.E., Cada, R.L., and Morrison, S.M., 1969. Bacterial Response to the Soil Environment.

104. Boyle, W.C., and Polkowski, L.B., 1968. Aerated Lagoons for Treatment of Vegetable Cannery Wastes. Polkowski, Boyle & Associates, Madison, Wis.

105. Boyle, W.C., and Polkowski, L.B., 1968. Observations of Aerated Lagoons for the Treatment of Vegetable Cannery Wastes. Polkowski, Boyle and Associates, Madison, Wis. (April).

106. Bradakis, H.L., 1961. A Joint Municipal-Industry Spray Irrigation Project. Ind. Water and Wastes 6 (July-Aug.), 117.

107. Braverman, J.S., and Levi, A., 1960. Comminuted Orange, a Novel Process for its Manufacture. Food Technol. 14, 106.

108. Bregman, J. I., 1970. Membrane Processes Gain Favor for Water Reuse. Environ. Sci. and Tech. 4(4), 296.

109. Brooke, D., and Capel, G. L., 1958. An Economic Analysis of Alternative Methods of Cull Tomato Disposal in Dade County, Florida. Fla. Ag. Expt. Sta. Bull. No. 500.

110. Brown, H. D., Hale, H. H., and Sheets, W. D., 1955. Disposal of Cannery Waste by Irrigation, Part I. Food Packer 36 (Aug.), 28.

111. Brown, H. D., 1956. Disposal of Cannery Wastes in Ohio. The Canning Trade 78 (Jan. 2), 7.

112. Brunner, C. A., 1967. Pilot Plant Experiences in Demineralization of Secondary Effluent Using Electrodialysis. Journal WPCF 39(10, Part 2), R1.

113. Bryan, E. H., 1962. Two-Stage Biological Treatment Industrial Experience. Proceedings of the 11th Southern Municipal and Ind. Waste Conf., Univ. of N. Carolina, Chapel Hill, N. C.

114. Burbank, N. C., Jr., and Kumagai, J. S., 1965. A Study of a Pineapple Cannery Waste. 20th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

114a. Burch, J. E., Lipinski, E. S., and Litchfield, J. H., 1963. Technical and Economic Factors in the Utilization of Waste Products. Food Tech. 17(10), 1266-1272.

115. Burchinal, J. C., and Jenkins, C. R., 1969. Ditches Provide Efficient Treatment. Environmental Sci. and Tech. 3(11). 1170.

116. Burd, R. S., 1968. A Study of Sludge Handling and Disposal. U. S. Dept. of Interior, FWPCA, Pub. WP-20-4, Ohio Basin Region, Cincinnati, Ohio.

117. Busch, A. and Kalinske, A. A., 1957. In Biological Treatment of Sewage and Industrial Wastes, Vol. I, Edited by B. J. McCable and W. W. Eckenfelder, Reinhold.

118. Busch, P. L., and Stumm, W., 1968. Chemical Interactions in the Aggregation of Bacteria Bioflocculation in Waste Treatment. Environmental Sci. and Tech. 2(1), 49.

119. Buswell, A.M., 1947. Reaction of Sodium Nitrate in Stabilizing Organic Wastes. Sewage and Ind. Wastes 19(4), 628.

120. Buswell, A.M., Greenfield, R.E., and Shive, R.A., 1926. Chemical Characteristics of Some Trade Wastes. Ind. Eng. Chem. 18, 1082.

121. Buzzell, J.C., and Sawyer, C.N., 1967. Removal of Algae Nutrients From Raw Wastewater with Lime. Journal WPCF 39 (10, Part 2), R16.

122. Buzzell, J.C., Jr., Caron, A-L.J., Ryckman, S.J., and Sproul, O. J., 1964. Biological Treatment of Protein Water From Manufacture of Potato Starch--Parts I and II. Water and Sewage Works.

123. California State Water Resources Control Board, 1968. Cannery Waste Treatment, Utilization, and Disposal. Publication No. 39, Sacramento, Calif.

124. Canham, R.A., 1949. Anaerobic Treatment of Food Canning Wastes. Proceedings of 5th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

125. Canham, R.A., 1950. Anaerobic Treatment of Food Canning Wastes. The Canner 109 (Apr. 29), 10.

126. Canham, R.A., 1950. Anaerobic Treatment of Food Canning Wastes. Food Packer 31 (5), 32.

127. Canham, R.A., 1951. Anaerobic Treatment of Food Canning Wastes. Sewage and Ind. Wastes 23(5), 695.

128. Canham, R.A., 1958. Comminuted Solids Inclusion Spray Irrigated Canning Waste. Sewage and Ind. Wastes 30(8), 1028.

129. Canham, R.A., 1955. Some Problems Encountered in Spray Irrigation of Canning Plant Waste. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

130. Canham, R.A. 1957. Spray Irrigation for Disposal and Crop Growth, Ind. Wastes 2(3), 57.

131. Canham, Robert A. 1957. The Program of the National Canners Association on Waste Disposal. Food Tech. 11 (Dec.), 670.

132. Canham, R.A., 1957. A Study of Inclusion of Comminuted Solids With Canning Waste Handled by Spray Irrigation. Multilithed, National Canners Association.

134. Canham, R.A. 1965. Current Trends in Handling Canning Waste. Proceedings of the 5th Annual Water Symposium, Eng. Ext. Sta. Bull. No. 55, Louisiana Univ.

135. Canham, R.A., 1968. Stabilization Ponds in the Canning Industry. In Advances in Water Quality Improvement, Water Resources Symposium No. 1, edited by E.F. Gloyna and W.W. Eckenfelder, Jr., Univ. of Texas Pres

136. Canham, R.A., and Bloodgood, D.E., 1949. Anaerobic Pilot Plant Operation, Tomato and Pumpkin Wastes. 4th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

137. Canham, R.A., and Bloodgood, D.E., 1950. Anaerobic Digestion of Tomato and Pumpkin Wastes. Sewage and Industrial Wastes 22 (8), 1095.

138. Carl, C.E., 1961. Waste Treatment by Stabilization Ponds. J. Milk and Food Tech. 24, 147.

139. Carusi, A., 1945. Composition and Digestibility of Tomato Seed Cake. Ann. Ist. Zootee. Roma 3, 329.

140. Casten, J.W., 1964. Utilization and Disposal of Liquid and Solid Residues. In Joslyn and Heid, Editors, Food Processing Operations, Vol. III.

141. Caudill, H., Jr., 1968. Application of the Anaerobic Trickling Filter to Domestic Sewage and Potato Wastes. MS Thesis, Univ. of Washington.

142. Cawley, W.A., and Brouillette, R.W., 1962. Polyvinyl Chloride for Trickling Filters. Industrial Water and Wastes, (July-Aug).

143. Cedargreen, C.R., and Robe, K., 1964. Fluidized Handling in Bulk Storage of Frozen Foods. Food Processing 25.

144. Cedargreen, C.R., and Robe, K., 1967. 'Clumpless' IQF Handling. Food Processing 28 (April), 59.

145. Chace, E.M., 1925. By-Products from Citrus Fruits. Dept. Circ. 232, U.S. Dept. Agriculture, Washington, D.C.

146. Charley, V.L.S., 1963. British Comminuted Drink Production. Food Technol. 17, 987.

147. Charley, V.L.S., Hopkins, D.P., and Pollard, A., 1944. The Utilization of Surplus Carrots. The Fruit Products J. and American Food Man. 23 (Feb.), 180.

148. Chipperfield, P.N.J., 1967. The Development, use and Future of Plastics in Biological Treatment. Effluent and Water Treatment Convention, London, England.

149. Chipperfied, P.N.J., Askew, M.W., and Benton, J.H., 1970. Multi-Stage Plastic Media Treatment Plants. 25th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

150. Chong, G., and Cruess, W.V., 1949. Obtaining Juice From Waste Pear Peels and Cores. The Canner 109 (Oct.), 14.

151. Church, B.D., and Nash, H.A., 1970. Use of Fungi Imperfecti in Waste Control. In Reference 66.

152. Clevenger, M.A., 1949. California Canners Tackle Waste Problem. The Canning Trade 71 (Oct. 31), 7.

153. Cochran, B., and Baker, G., 1969. To Remove Trash From Sugar Cane. Ag. Eng. 50, 218.

154. Colorado State University, Sanitary Engineering Papers, Fort Collins, Colo.

155. Cook, R.W., Wang, J., Dougherty, P, Farrow, R.P., and Rhoads, A.T., 1969. Changes in Water Quality Factors During Recycling through a Water Recovery System While Canning Green Beans. Washington Research Lab. Research Report No. 1-69, National Canners Association, 1130 20th St., NW, Washinton, D.C., 20036.

157. Cooler, F.W., and Kramer, A., 1960. Water Handling of Tomatoes. Maryland Processor's Report 6(4), 8.

158. Cooley, A.M., Wahl, E.D., and Fossum, G.O., 1964. Characteristics and Amounts of Potato Wastes From Various Process Streams. 19th Ind. Waste Conf., Purdue, Univ. Lafayette, Ind.

159. Coppock, C.E., and Hedden, S.L., 1968. Design and Development of a Tree-Shaker Harvest System for Citrus Fruits. Transactions of the ASAE 11, 339.

160. Cornell, Howland, Hayes and Merryfield, 1966. An Engineering Report on Pilot Plant Studies, Secondary Treatment of Potato Process Water. For the Potato Processors of Idaho Assoc.

161. Cornell, Howland, Hayes and Merryfield, 1969. A Pilot Plant Study, Anaerobic Secondary Treatment of Potato Process Water. For the Potato Processors of Idaho Assoc.

162. Cruess, W.V., 1914. Utilization of Waste Oranges. Calif. Ag. Expt. Sta. Bull. 244.

163. Cruess, W.V. 1948. Commercial Fruit and Vegetable Products, McGraw-Hill Book Company, Inc., New York.

164. Cyrus, Wm. Rice and Co., 1969. Projected Wastewater Treatment Costs in the Organic Chemicals Industry, The Cost of Clean Water and its Economic Impact. Vol. IV, US Dept. of Interior, FWPCA.

165. Daugherty, M.H., 1964. Activated Sludge Treatment of Citrus Waste. J. Water Pollution Control Fed. 36(1), 72.

166. Davey, T., Enger, J., and Robe, K., 1969. Processes 40,000,000 lb/yr faster, more efficiently. Food Processing 30

167. Davis, G.B., and Hutchings, H.M., 1959. Costs and Efficiences in Pea Freezing Operations. Part I, Vining. Miscellaneous Paper 66 Oregon State College, Ag. Exp. Sta., Corvallis, Ore.

168. Davis, N.E., 1959. Control of Canning Waste Oxidation Ponds. Public Works 90(8) (Aug.), 133.

169. Davis, R.N., and Kremmerer, A.R., 1948. Lactating Factor for Dairy Cows in Dried Grapefruit Peel. Journal of Dairy Science 31, 973.

170. Day, R.O. and Furgason, R.R., 1965. Anaerobic Stabilization of Secondary Potato Wastes. Research Report, Univ. of Idaho.

171. Dean, R.B., 1968. Ultimate Disposal of Waste Water Concentrates to the Environment. Environmental Science and Technology 2, 1079.

172. Dennis, J.M., 1953. Spray Irrigation of Food Processing Wastes. Sewage and Ind. Wastes 25(5), 591.

173. Dickinson, D., 1947. Waste Waters From Canneries. Food 16 (Feb.), 45.

174. Dickinson, D., 1949. Purification of Cannery Wastes. Food 18 (Apr.), 104.

175. Dickinson, D., 1949. Performance of Recirculating Plant for the Purification of Cannery Wastes in Biological Filters. The Surveyor 108 (Feb. 11), 89.

176. Drehwing, F.J., and Nemerow, N.L., 1963. Aeration of 18th Ind. Waste Conf, Purdue Univ., Lafayette, Ind.

177. Dickinson, D., 1949. Performance of recirculating Plant for Purification in Biological Filters. Sewage and Ind. Wastes 21 (7) 757.

179. Dickinson, D., 1954. The Purification of Cannery Waste Waters in Biological Filters, J. Sci. Food Agri. 5 (2) (Feb. 5), 94.

180. Dickson, G., 1963. The Application of Stabilization Basins to Vegetable Cannery Wastes. 18th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

181. Dickson, G., 1965. A Multipond Flow-Through Lagoon System for Treatment of Cannery Waste. Proceedings of 12th Ind., Waste Conf., Univ. of Washington, Seattle, Wash.

182. DiGregorio, D., 1968. Cost of Wastewater Treatment Processes. The Advanced Waste Treatment Laboratory, U.S. Dept. of Interior, FWPCA, Cincinnati, Ohio.

183. Dietrich, W.C., and Neumann, H.J., 1965. Blanching Brussel Sprouts. Food Technol. 19, 1174.

184. Dostal, K.A., 1968. Progress Report on Aerated Lagoo Treatment of Food Processing Wastes. Report No. PR-5 Pacific Northwest Laboratory, FWPCA.

185. Dostal, K.A., 1968. Pilot Plant Studies on Secondary Treatment of Potato Processing Wastes. Symposium on Potato Waste Treatment, FWPCA and the Univ. of Idaho.

186. Dostal, K.A., 1969. Secondary Treatment of Potato Processing Wastes. Report No. FR-7, US Dept. of Interior, FWPCA.

187. Dostal, K.A., and Burm, R.J., 1970. Status of R&D Efforts on Food Processing Wastes. In Reference 66.

187a. Dostal, K.A., 1971. Personal Communication.

188. Dougherty, M.H., 1964. Activated Sludge Treatment of Citrus Waste. Journal WPCF 36(1), 72.

189. Dougherty, M.H., and McNary, R.R., 1958. Elevated Temperature Effect on Citrus Waste Activated Sludge. Sewage and Ind. Waste 30(10), 1263.

190. Dougherty, M.H., and McNary, R.R., 1958. Activated Citrus Sludge-Vitamin Content and Animal Feed Potential. Sewage and Industrial Wastes 30(9), 1151.

191. Dougherty, M.H., Wolford, R.W., and McNary, R.R., 1955. Citrus Waste Water Treatment of Activated Sludge. Sewage and Ind. Waste 27(7), 821.

192. Douglass, I.B., 1960. By-Products and Waste in Potato Processing. 15th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

193. Dow. 1965. Industrial Water and Wastewater Clarification With Purifloc. The Dow Chemical Company, Functional Products and Systems Dept., Midland, Mich.

194. Dowskin, P.B., Hester, O.C., Kerr, H.W., and Bayton, J.A., 1963. Instant Sweet Potatoes, U.S. Dept. Ag., Market Research Rept. No. 580.

195. Drake, J.A., and Bieri, F.K., 1950. Conversion to Freezing can Triple Canner's Needs. Food Packer 31 (Mar.), 28.

196. Drake, J.A., and Bieri, F.K., 1950. A Case History of Lagooning: Stabilization and Odor Control. Food Packer 31 (Apr.), 26.

197. Drake, J.A., and Bieri, F.K., 1951. Disposal of Liquid Wastes by the Irrigation Method of Vegetable Canning Plants in Minnesota 1948-1950. 6th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

198. Drehwing, F.J., Nemerow, N.L., 1963. Aeration of Pumpkin Cannery Wastes. 18th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

199. Dunstan, G.H., and Lunsford, J.V., 1955. Cannery Waste Disposal by Irrigation. Sewage and Ind. Wastes 27(7), 827.

200. Dyment, R., 1959. How Packers and Borough Solve Penn. Waste Disposal Problem. Canner/Packer 128 (May), 27.

201. Ebbert, S.A., 1958. Spray Irrigation of Food Plant Waste Waters. Presented at 30th Annual Meeting, Federation of Sewage & Industrial Wastes Associations. Eckenfelder, W. W., Jr., 1953. Instrumentation and Automatic Control Applications in the Activated Sludge Treatment of Industrial Wastes. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

201a. Eckenfelder, W.W., Jr., 1953. Instrumentation and Automatic Control Applications in the Activated Sludge Treatment of Industrial Wastes. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

202. Eckenfelder, W.W., Jr., 1956. Process Design of Aeration Systems for Biological Waste Treatment. Chem. Eng. Progress 52(7), 287.

203. Eckenfelder, W.W., Jr., 1958. Pilot Plant Investigations of Biological Sludge Treatment of Cannery and Related Wastes. 7th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

204. Eckenfelder, W.W., Jr., 1966. Sources and Characteristics of Industrial Wastes. In "Industrial Water Pollution Control," McGraw-Hill Book Company, New York.

205. Eckenfelder, W.W., Jr., Editor, 1970. Water Resources Management Series Vol. 1-Manual of Treatment Processes Environmental Science Series Corporation.

206. Eckenfelder, W.W., Jr. 1968. Industrial Waste Treatment - Canning, Freezing and Dehydrating. In "Industrial Waste Disposal", R.D. Ross, ed., Reinhold Book Corporation, New York.

207. Eckenfelder, W.W., Jr., and Ford, D.L., 1967. Engineering Aspects of Surface Aeration Design. 22nd Ind. Waste Conf., Part I, Purdue Univ., Lafayette, Ind.

208. Eckenfelder, W.W., Jr., and Ford, D.L., 1969. Economics of Wastewater Treatment. Chem. Eng. 76 (Aug. 25), 109.

209. Eckenfelder, W.W., Jr. and Grich, E.R., 1955. Ind. Waste Conf., Purdue Univ, Lafayette, Ind.

210. Eckenfelder, W.W., Jr., and Grich, E.R., 1956. Cannery Waste Oxidation by Activated Sludge, 4-6. In "Theory and Mechanism of Biological Waste Treatment", Part I, McCabe and Eckenfelder, ed., Reinhold Publishing Corp., New York.

211. Eckenfelder, W.W., Jr., and Hood, J.W., 1951. The Application of Oxidation-Reduction Potential to Biological Waste Treatment Process Control. 6th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

212. Eckenfelder, W. W., Jr. and O'Connoe, D.J., 1961. Biological Waste Treatment. Pergamon Press.

213. Eckenfelder, W.W.,Jr., Woodward, Dr., C., Lawler, J, P., and Spinna, R.J., 1958. Study of Fruit and Vegetable Processing Waste Disposal Methods in the Eastern Region. USDA Research and Marking Contract No. 12-14-100-482 (73), Civil Eng. Dept., Manhattan College, N.Y.

214. Edwards, P.W., Eskew, R.K., Hoersch, A., Jr., Aceto, N.C., Redfield, C.S.,1952. Recovery of Tomato Processing Wastes. Food Technol. 6, 383.

215. Eheart, M.S., 1969. Variety, Fresh Storage, Blanching Solution and Packaging Effects on Ascorbic Acid, Total Acids, ph and Cholorphylls in Broccoli. Food Technol. 23, 238.

216. Eidt, C. C., and MacArthur, M., 1944. The Peeling of Fruits and Vegetables for Processing. Food in Canada 4(7), 31.

216a. Eldridge, E. F., 1942. The Role of Chemicals in Industrial Waste Treatment. Water Works and Sewerage 89, 341-346.

217. Eldridge, E. F., 1947. Symposium on Industrial Wastes, Canning Industry. Ind. and Eng. Chem. 39 (5), 619.

218. Eliasson, R., and Tchobanoglous, G., 1968. Chemical Processing of Wastewater for Nutrient Removal. Journal WPCF 40 (5, Part 2), R171.

219. Englis, D. T., and Sekera, V. C., 1931. Effects of Water Blanching on the Canning of Whole Kernel Corn. Canner 72 (18), 11.

220. Esselen, W. B., Jr., and Fellers, C. R., 1939. Nutritive Value of Dried Tomato Pomace. Poultry Sci. 18, 45.

221. Esvelt, L. A., 1969. Aerobic Treatment of Fruit Processing Wastes. Federal Water Pollution Control Administration, Dept. of the Interior, Washington, D. C., 20242.

222. Esvelt, L. A., 1970. Aerobic Treatment of Liquid Fruit Processing Waste. In Reference 66.

223. Esvelt, L. A. and Hart, H. H., 1970. Treatment of Fruit Processing Waste by Aeration. J. Water Pollution Control Fed. 42(7), 1305.

224. Everts, W. W. 1944. Disposal of Wastes from Fruit and Vegetable Canneries. Sewage Works J. 16(5), 944.

225. Feaster, J. F., Mudra, A. E., Ives, M. and Thompkins, M. D., 1949. Effect of Blanching Time on Vitamin Retention in Canned Peas. Canner 108 (1), 27.

226. Fellers, C. R., Esselen, W. B., Jr., and Fitzgerald, G. A., 1940. Vitamin B_1 and Vitamin B_2 (G) Content of Vegetables as Influenced by Quick Freezing and Canning. Food Research 5, 495.

227. Felton, G., 1949. Use of Ion Exchangers in By-Product Recovery From Pineapple Waste. Food Technol. 3, 40.

228. Fenelon, E. S., 1943. How to Meet the Demand for Better Waste Disposal. Food Ind. 15 (July), 84.

229. Feustal, I. C., and Thompson, J. H., 1946. Pear Canning Waste May be Valuable for Yeast Culture. Western Canner and Packer 38 (Apr.), 60.

230. Fisher, A. J., 1943. New Vacuum Flotation Process Aids Liquid Waste Disposal. Food Ind. 15 (July), 87.

231. Fisk, W. W., 1964. Food Processing Waste Disposal. Water and Sewage Works 111 (Sept.), 417.

232. Fiske-Gay Associates, Inc., 1965. Engineering Report on Florida Citrus Processing Industry Waste Water Survey for Florida Citrus Commission.

233. Flay, R. B., 1953. Periodate Oxidation of Pea Cannery Wastes. Sewage and Ind. Waste 25(8), 953.

234. Formo, H. G., 1961. Problems and Approaches in the Treatment of Wastes from Potato Processing Plants. Proceedings 10th Pacific Northwest Industrial Waste Conference.

235. Fossum, G. O., Cooley, A. M., and Wahl, E. D., 1964. Stabilization Ponds Receiving Potato Wastes With Domestic Sewage. 19th Ind. Waste, Conf., Purdue Univ., Lafayette, Ind.

236. Francis, R. L., Chemist, North Dakota State Dept. of Health, Bismarck, N. D. Personal Communication in; Douglas, I. B., 1960. By-Products and Waste in Potato Processing. 15th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

237. Free, W. A., 1938. Nation-wide Picture of Cannery Waste Disposal Requirements. Canning Age 19 (June), 265.

238. Fridley, R. B., and Adrian, P. A., 1968. Evaluating the Feasibility of Mechanizing Crop Harvest. Transactions of the ASAE 11, 350.

239. Froehlich, C. W., 1944. Waste Disposal Problems at a Southern California Fruit and Vegetable Cannery. Sewage Works Journal 16(5), 940.

240. Gaden, E. J., Jr., Petsiavas, D. N., and Winoker, J., 1954. Microbiological Production of Riboflavin and Citric Acid from Citrus Molasses. Ag. and Food Chem. 2(12), 632.

241. Gallop, R. A., Cansfield, P. E., and Rastogi, R. K., 1970. Conservation, Reclamation and Re-Use of Solids and Water in Food Processing. Third International Congress of Food Sci. and Technol., Washington, D. C., Aug.

242. Gaston, H. P., and Levin, J. H., 1955. Transporting Red Cherries in Water from Ochard to Processing Plant. Mich. Quarterly Bull. 37(3), 437

243. Gaston, H. P., and Levin, J. H., 1956. Weighing Cherries that are Transported in Water. Mich. Quarterly Bull. 38(4), 606.

244. Gaston, H. P., Levin, J. H., and Hedden, S. L., 1960. Blueberries - Plums and Cherries Can be Harvested with Machines. Am. Fruit Grower 80 (Apr.), 14.

245. Germain, J. E., 1966. Economic Treatment of Domestic Waste by Plastic-Medium Trickling Filters. J. Water Pollution Control Fed. 38(2), 192.

246. Gilde, L. C., 1967. Water Pollution Problems Facing the Food Industry. Water Pollution: Industrial Problems and Current Research Trends, 83rd Meeting of Princeton Univ. Conf., pg. 47.

247. Gilde, L. C., 1967. Experiences of Cannery and Poultry Waste Treatment Operations. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

248. Gilde, L. C., 1968. Cannery and Poultry Waste Treatment. Water & Sewage Works, July.

249. Gilde, L. C., 1970. Food Processing Waste Treatment by Surface Filtration. In Reference 66.

250. Gjerde, E. 1969. The Incineration of Fume and Liquid Waste With Heat Recovery Applications. Gas Symposium for the Carolinas, Virginia Institutions and Industries, May 21-22.

251. Gloyna, E. F., and Eckenfelder, W. W., Jr., 1970. Water Quality Improvement by Physical and Chemical Process. Water Resources Symposium No. 3. Center for Research in Water Resources, Univ. of Texas Press, Austin, Texas.

252. Gooding, E.G.B., Tucker, G.B., and McDougall., 1960. Dehydration of Carrots. Food Manuf. 35 (6), 249.

253. Gould, W.E., Bash, W.D., Yingst, D.E., Geisman, J.R., Marlowe, G.A., and Brown, W.M., 1963. Handling and Holding Studies of Mechanically Harvested Tomatoes. National Canners Association Information Letter No. 1909, Washington, D.C., Jan. 31.

254. Graham, J.L. and Filbert, J.W., 1970. Combined Treatment of Domestic and Industrial Wastes by Activated Sludge. In Reference 66.

255. Graham, R.P., Huxsoll, C.C., Hart, M.R., Weaver, M.L., and Morgan, A.I., Jr., 1969. "Dry" Caustic Peeling of Potatoes. Food Technol. 23(2), 195.

256. Graham, R.P., and Shepherd, A.D., 1953. Pilot Plant Production of Low-Methoxyl Pectin from Citrus Ag. and Food Chem. 1, 993.

257. Grames, L.M. and Kueneman, P.W., 1969. Primary Treatment of Potato Processing Wastes With By-Product Feed Recovery. J. Water Pollution Control Fed. 41(7).

258. Gray, H.F., and Ludwig, H.F., 1943. Characteristics and Treatment of Potato Dehydration Wastes. Sewage Works Journal 15 (1), 71.

259. Gray, W.D., and Abou El-Seound, M.O., 1966. Fungal Protein for Food and Feeds. II. Whole Sweet Potato as Substrate. Econ. Botany 20, 119.

260. Green, R.L. 1970. Basic Considerations for a Spray Irrigation Disposal System. Maryland Processor's Report 16(3). Univ. of Maryland, College Park, Md.

261. Green Giant Co., 1969. Proposed Pilot Plant Installation for Use of Fungi Imperfecti on Vegetable Wastes. The Green Giant Company, Le Sueur, Minn.

262. Grieg, W.S., and Manchester, A.C., 1958. Cost of Peeling Potatoes by Lye and Abrasive Methods. USDA Report No. 225.

263. Guerrant, N.B., and Dutcher, A.R., 1948. Further Observations Concerning the Relationship of Temperature of Blanching to Ascorbic Acid Retention in Green Beans. Arch. Biochem. 18, 353.

264. Guerrant, N.B., Vavich, M.G., Fardig, O.B., Ellenberger, H.A., Stern, R.M., and Coonan, N.H., 1947. Nutritive Value of Canned Foods. Effect of Duration and Temperature of Blanch on Vitamin Retention by Certain Vegetables. Ind. Eng. Chem. 39, 1000.

265. Gulevich, W., Renn, C.E., and Liebman, J.C., 1968. Role of Diffusion in Biological Waste Treatment. Environ. Sci. and Tech. 2(2), 113.

266. Guttormsen, K., and Carlson, D.A., 1970. Status and Research Needs of Potato Processing Wastes. In Reference 66.

267. Guttormsen, K., and Carlson, D.A., 1969. Current Practice in Potato Processing Waste Treatment. US Dept. of Interior, FWPCA.

268. Haas, F.C., 1968. Spray Irrigation Treatment, Proc. Symposium Potato Waste Treatment. FWPCA and the Univ. of Idaho.

269. Hall, H.W., 1944. Disposal of Citrus Wastes. Civil Eng. 14 (1), 15.

270. Hall, J.E., and Bundell, C.C., 1946. In-Plant Chlorination. Food Ind. 18 (Apr.), 520.

271. Halvorson, H.O., Johnson, D.W., and Tsuchiya, H., 1940. The Treatment of Corn Canning Wastes. The Canner 90 (Jan. 20), 12.

272. Hamlin, G.H., 1962. Super-Rate Biological Filter. Ind. Water and Wastes 7 (Sept.-Oct.), 148.

273. Hanes, N.B., 1957. Aeration of Cannery Wastes. MS Thesis, Univ. of Wisconsin.

274. Hanks, F.J., Lambert, J.R., and Opliger, P.S., 1968. Hydrologic and Quality Effects of Disposal of Peach Cannery Waste. Transactions of the ASAE 11, 90.

275. Hard, M.M., and Ross, E., 1956. Dielectric Scalding of Spinach, Peas, and Snap Beans for Freezing Preservation. Food Technol. 10, 241.

276. Hart, S.A., Slurried Waste Disposal in Soil. Dept. of Ag. Eng., Univ. of Calif., Davis, Calif.

277. Hart, S.A., Flocker, W.J., and York, G.K., 1970. Refuse Stabilization in the Land. Compost Science 11(1), 4.

278. Hatfield, R., Strong, E.R., Heinsohn, F., Powell, H., and Stone, T.G., 1956. Treatment of Wastes from a Corn Industry by Pilot-Plant Trickling Filters. Sewage and Ind. Wastes 28 (10), 1240.

279. Hasfurther, W.A., 1951. Aeration Gives Low-Cost Waste Disposal. Food Ind. 23 (Feb.), 90.

280. Hays, F.A., 1919. Swine Production in Delaware. Delaware Univ. Ag. Expt. Sta. Bull. 124, 28.

281. Heberlein, D.G., Ptak, L.R., Medoff, S., and Clifcorn, L.E., 1950. Quality and Nutritive Value of Peas as Affected by Blanching. Food Technol. 4, 109.

282. Heid, J.L., 1945. Drying Citrus Cannery Wastes and Disposing of Effluents. Food Ind. 17 (Dec.), 109.

283. Helmers, E.N., Frame, J.D., Greenberg, A.E., and Sawyer, C.N., 1951. Nutritional Requirements in the Biological Stabilization of Industrial Wastes. Sewage and Ind. Wastes 23(7), 884.

284. Hendrikson, R., and Kesterson, J.W., 1921. Florida Lemon Seed Oil US Dept. of Ag. Bull. No. 927.

285. Henke, L.A., 1931. Pineapple Bran as a Feed for Livestock. Hawaii Ag. Expt. Sta. Circ. 2.

286. Herman, D., 1967. Biological Digestion of Tomato Wastes. Indiana Canners Tech. Conf., Indianapolis, Ind.

287. Hert, O.H., 1947. Tomato Canning Plant Waste. Food Packer 28(10), 40.

288. Hert, O.H., 1948. Research on Anaerobic Treatment of Canning Plant Waste. 4th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

289. Hert, O.H., 1950. Research in Anaerobic Treatment of Canning Plant Wastes. Sewage and Ind. Wastes 22(8), 1095.

290. HEW. 1965. Deep Well Injection of Liquid Waste. US Dept. of HEW, Public Health Service, Division of Water Supply and Pollution Control, Cincinnati, Ohio.

291. HEW. 1968. Special Studies for Incinerators. US Dept. of Health, Education and Welfare, Public Health Service, Publication No. 1748. U.S. Gov. Printing Office, Washington, D.C., 20402.

292. Hicks, W.M., 1952. Disposal of Fruit Canning Wastes by Spray Irrigation. 7th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

293. Higgins, F.B., Jr., Wohler, H.C., and Segall, S., 1970. Industry Contributes to Air Pollution But Can Also Help Solve National Problem. Candy Ind. (May 26), 77.

294. Hindin, E., and Dunstan, G.H., 1963. Anaerobic Digestion of Potato Processing Wastes. Journal of the WPCF 35(4), 486.

295. Hoag, D.L., and Hunt, D.R., 1965. Mechanical Stripping for Harvesting Strawberries. Paper No. 65-620, ASAE, St. Joseph, Mich.

296. Hoag, D.L., and Hunt, D.R., 1966. Mechanical Stripper to Harvest Strawberries. Ag. Eng. 47 (June), 320.

297. Hohl, L.A., Swanburg, J., David, J., and Ramsey, R., 1947. Cooling of Blanched Vegetables and Fruits for Freezing. Food Research 12, 484.

298. Holmquist, J.W., Clifcorn, L.E., Heberlein, E.G., and Schmidt, C., 1954. Steam Blanching of Peas. Food Technol. 8, 437.

299. Horner, G., 1936-1937. The Losses of Soluble Solids in the Blanching of Vegetables. Ann. Rept. Fruit Vegetable Preserv. Research St., Campden, Univ. Bristol.

300. Horton, B.D., and Twigg, B.A. A Preliminary Report on Use and Disposal of Water in Four Maryland Processing Plants. Water Resources Research Center, Univ. of Maryland, College Park, Md.

301. Howells, D.H., and Dubois, D.P., 1959. The Design and Cost of Stabilization Ponds in the Midwest. Sewage and Ind. Wastes 31(7), 811.

302. Huibers, D.T.A., McNabney, R., and Halfon, A., 1969. Ozone Treatment From Waste Water Treatment Plants. Robert A. Taft Water Research Center, Report No. TWRC-4, US Dept. of Interior, FWPCA, Ohio Basin Region, Cincinnati, Ohio.

303. Humphrey, H.J., 1940. Waste Treatment at a New York State Cannery. The Canner 94 (Mar. 30), 16.

304. Hundley, C.L., and Matulis, J.T., 1962. Deep Well Disposal. 17th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

305. Hunt, P.G., and Peele, T.C., 1968. Organic Matter Removal from Liquid Peach Waste Percolation Through Soil and Interrelations With Plant Growth and Soil Properties. Ag. J. 60 (May-June), 321.

306. Hunter, D.L., 1965. Design of Fruit Processing Plants to Reduce Waste Disposal Problems. Proceedings of 12th Pacific Northwest Ind. Waste Conf., Univ. of Washington, Seattle, Wash.

307. Hutchman, J.E., 1949. Gold From Citrus Waste. Chem. Digest 8 (Sept.), 6.

308. Hurwitz, E., 1963. Degradation of Organic Wastes by the Wet Air-Oxidation Process. Proceedings of 15th Research Conference American Meat Institute Foundation, Univ. of Chicago, Chicago, Ill.

309. Infilco Technical Data Bulletin No. TE-24.65-2. 1953. Report on Model Aero-Accelator Operation When Treating Cannery Wastes.

310. Ingalsbe, D.W., Clore, W.J., and Cone, W.W., 1967. Measurement and Removal of Dirt on Concord Grapes Grown in Central Washington in 1967. Washington Ag. Expt. Sta., College of Ag., Washington State Univ., Circ. 485.

311. Ingols, 1945. The Citrus Canning Waste Disposal Problem in Florida. Sewage Works Journal 17(2), 320.

312. Ingols, R.S., Dr., 1958. Treating Food Processing Wastes. Ind. Wastes 3 (July-Aug), 95.

313. Ingols, R.S., Hodgden, H.W., and Miller, H.E., 1954. Canning Plant Waste Problem Solves by Simplified Procedures. Water and Sewage Works 101 (May), 227.

314. Irish, J.H., 1923. Pear By-Products. U. of Calif. Ag. Expt. Sta. Circ. 259.

315. Jackson, F.A., 1957. Spray Irrigation Uses Cannery Wastes. Western Canner and Packer 45 (Nov.), 14.

316. Janicki, J., Szebiotko, K. and Stawicki, S., 1966. Potatoes and their Industrial Wastes as Media for Yeast Production. Symposium on the Utilization and Disposal of Potato Wastes, New Brunswick.

317. Jarl, K., 1969. Symba Yeast Process. Food Technol. 23, 1009.

318. Jarl, K., and Tveit, M., 1963. A Method for Removal of Starch From Industrial Waste Liquids by Symbiotic Cultivation of Yeasts. Socker, Handlinger II 18(2), 25.

319. Jenkins, R.R., Tressler, D.K., and Fitzgerald, G.A., 1938. Vitamin C Content of Vegetables. VIII. Frozen Peas. Food Research 3, 133.

320. Jenks, H.N., 1947. "Salad Bowl" Wastes Treated at Converted Plant. Sewage Works Engineering 18 (Aug.), 422.

321. Jenks, H.N., 1950. Aeration Ponds Handle Cannery Wastes. Sewage and Ind. Wastes Eng. 21 (Feb.), 62.

322. Jewell, W.J. and Eckenfelder, W.W., Jr., 1971. The Use of Pure Oxygen for the Biological Treatment of Brewery Waste Waters. 26th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

323. Johnson, C.C., and Bloodgood, D.E., 1958. Effect of Vegetable Oil and ABS on Anaerobic Digestion of Primary Sludge. In "Biological Treatment of Sewage and Industrial Wastes", Part II. McCabe and Eckenfelder, ed., Reinhold Pub. Corp., New York.

324. Jones, F.D., 1944. A Storage Lagoon for Wastes From Canning Company Plants. Public Works 75(4).

325. Jones, R.H., 1970. Lime Treatment and In-Plant Resuse of an Activated Sludge Plant Effluent in the Citrus Processing Industry. In Reference 66.

326. Jordan, L.M, 1939. Simple System Saves Water in Canning Plant. Food Ind. 11, 492.

327. Joyce, F., 1967. One-Crop Problems Solved by Novel, Low-Cost Treatment. Canadian Food Ind. 38 (Mar.), 22.

328. Jutras, P.H., and Coppock, G.E., 1963. Harvesting Citrus Fruit With an Oscillating Air Blast. Transactions of the ASAE 6, 192.

329. Kagan, J.J., Pilnik, W., and Smith, M.D., 1960. Lactic Acid Fermentation of Citrus Peel Juice. Ag. and Food Chem. 8(3), 236.

330. Kaloyereas, S.A., 1947. The Effect of Various Methods of Blanching on Ascorbic Acid and Soluble Solids in Cauliflower and Spinach. Effect of Rapid Freezing on Catalese Test. Fruit Products J. and Am. Food Manufacturer 26 (Jan.) 134.

331. Kaples, D.A., 1961. The Big Question: Can We Harvest by Machine. Am. Fruit Grower 81 (Jan), 16.

332. Keinath, T.M., and Weber, W.J., Jr. 1968. A Predictive Model for the Design of Fluid-Bed Adsorbers. Journal of WPCF 40(5) Part I, 745.

333. Kelley, E.G., 1950. Making Use of Vegetable Residues. In, "Crops in Peace and War", the Yearbook of Agriculture, 1950-1951, US Dept Ag. U.S. Government Printing Office, Washington, D.C.

334. Kelley, E.G., Wall, M.E., and Willaman, J.J., 1943. Vegetable Wastes as Animal Feedstuffs. Feedstuffs 26 (June), 18.

335. Kelly, C.F., 1967. Mechanical Harvesting. Sci. Amer. 217(11) 50.

336. Kemp, D.C., 1966. Cleaners for Vined Peas From Plot. J.Ag. Eng. Research 11(3), 224.

337. Kepner, R.A., and O'Brien, M., 1969. A Sorting and Trimming System for Mechanically Harvested Asparagus. Dept. of Ag. Eng., University of Calif., Davis, Calif. July.

338. Kimbal, J.H., and May, H.L., 1941. Developments in Cannery Waste Studies at Palo Alto. Sewage Works J. 13(4), 731.

338a. Kimberley, A.E., 1931. Status of Pea Canning Waste Treatment. Waterworks and Sewerage 78(5), 126-128.

338b. Kimberley, A.E., 1935. Vegetable Wastes, Wisconsin Experiments. Sewage Works J. 7(1), 144.

339. King, D.L., and Bunn, D.R., 1966. Comparison of Anaerobic-Aerobic and Aerobic Lagoon Treatment. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

341. Kingston, T.M.S., 1963. Catham, Ontario's Approach to Joint Municipal-Industrial Waste Treatment. Journal WPCF 35(4), 544.

342. Kirsh, J.T., 1953. Lagoon and Viner Stack Odor Control. The Canning Trade 76 (Apr.), 9.

343. Kline, L., MacDonnell, L.R., and Lineweaver, Hans, 1944. Bacterial Proteinase From Waste Asparagus Butts. Ind. and Eng. Chem. 36(12), 1152.

345. Knicely, D.R., Stout, B.A., and Ries, S.K., 1963. Harvesting Asparagus Mechanically. Mich. Ag. Expt. Sta. Quart. Bul., 45(4), 652.

346. Koenig, L., 1963. Ultimate Disposal of Advanced-Treatment Waste. The Advanced Waste Treatment Research Program, Basic and Applied Sciences Branch, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

347. Kraemer, J.R., 1952. Trends Speed Cannery Pace. Food Eng. 24 (Nov.), 98.

348. Kramer, A., and Smith, Mary H., 1947. Nutritive Value of Canned Foods. Effect of Duration and Temperature of Blanch on Proximate and Mineral Composition of Certain Vegetables. Ind. Eng. Chem. 39, 1007.

349. Kobayashi, K., Nagata, I., Nagata, M., and Iwata, H., 1964. Nutritional Studies on the Utilization of Distillers Stillage. J. Ag. Chem. Soc. Japan 33, 317.

350. Kefford, J.F., 1966. Composting Trials With Pear Canning Wastes. Compost Science 7 (Autumn-Winter), 24.

351. Kueneman, R.W., 1966. Performances of Primary Waste Treatment Plants in NW USA. Symposium on the Utilization and Disposal of Potato Waste. New Brunswick.

352. Lackey, J.B., Morgan, G.B., and Calaway, W.T., 1956. Citrus Waste Treatment, Experimental and Applied. 11th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

353. Lackey, J.B., Calaway, W.T., and Morgan, G.B., 1956. Biological Purification of Citrus Waste. Sewage and Ind. Wastes 28(4), 538.

354. Lamb, F.C., Pressley, A., and Zuch, T., 1946. Nutritive Value of Canned Foods. XII. Retention of Nutrients During Commercial Production of Various Canned Fruits and Vegetables. Food Research 12, 273.

355. Lamb, F.C., Lewis, L.D., and Lee, S.K., 1948. Effect of Blanching on Retention of Ascorbic Acid and Thiamine in Peas. Western Canner and Packer 40 (May), 60.

356. Lamb, F.C., Kawai, M., and Cortes, A., 1969. Study of Wastes from Canning of Starchy Foods - Progress Report. National Canners Association, Berkeley, Calif.

357. Lamb, P. and Havighorst, C.R., 1953. Top-Rank Quick-Freeze Operation. Food Eng. 25 (Jan.), 68.

358. Langford, C.T., 1948. Recent Advances in the Fermentation Field. Chem. Digest 7 (May), 4.

359. Lane, L.C., 1955. Disposal of Liquid and Solid Wastes by Means of Spray Irrigation in the Canning and Dairy Industries. 10th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

360. Lawrence, A.W., and McCarty, P.L., 1969. A Kinetic Approach to Biological Wastewater Treatment Design and Operation. Technical Report No. 23, Cornell Univ. Water Resources and Marine Science Center, Ithaca, New York.

361. Lawton, G.W., Engelbert, L.E., Rohlich, G.A., and Porges, N., 1960. Effectiveness of Spray Irrigation as a Method for the Disposal of Dairy Plant Wastes. Univ. of Winconsin.

363. Leavitt, P., and Ziemba, J.V., 1969. At Gerber Water Does Triple Duty. Food Eng. 41 (Sept.) 90.

364. Lee, Frank A., 1958. The Blanching Process. In "Advances in Food Research," Vol. 8, Eds, E.M. Mrak, and G.F. Stewart. p. 63. Academic Press Inc., Publishers, New York.

365. Lee, F.A., and Whitcombe, J., 1945. Blanching of Vegetables for Freezing. Effect of Different Types of Potable Water on Nutrients of Peas and Snap Beans. Food Research 10, 465.

366. Leete, G.V., Dunstan, G.H., and Lunsford, J.V., 1955. Blancher Waste Disposal by Trickling Filtration. Ind. Waste 1(2), 60.

367. Legault, R.R., Talburt, W.F., Hanson, H.L., and Leinbach, L.R., 1950. Effect of Steam Blanching on Quality of Frozen Peas. Food Technol 4, 194.

368. Lenker, D.H., and Hedden, S.L., 1968. Optimum Shaking Action for Citrus Fruit Harvesting. Transactions of the ASAE 11, 347.

369. Leo, M.A., Beisel, G., and Robe, K., 1969. Remove Fine Solids From Fast Flowing Waste Water. Food Processing 30 (Aug.), 16.

370. Lesperance, T.W., 1967. Market For Water Pollution Control Equipment Burgeons. Environmental Sci. and Tech. 1(10), 785.

371. Levin, J.H., and Gaston, H.P., 1954. Hydracooling and Transporting Red Cherries in Water. Mich. Ag. Expt. Sta. Quarterly Bulletin 36(4), 378.

372. Liner, G.H., and Stepp, J.M., 1968. Summary of Selected Literature on Lagoon and Spray Systems of Treating Fruit and Vegetable Processing Wastes. AE 316, South Carolina Ag. Expt. Sta., Clemson University, Clemson, S.C.

373. Ling, J.T., 1963. Pilot Study of Treating Wastes With an Aerated Lagoon. Journal WPCF 35(8), 963.

374. Livingston, L., 1969. Mainline: Airline for Flying Corn. Canner/Packer 138 (Mar.), 30.

375. Litsky, W., Gunner, H.B., and Kreplick, R., 1969. Technical Aspects of Joint Waste Treatment - Municipal/Industrial. Proceedings of an Institute held at Framingham, Mass. Publication of the Technical Guidance Center for Ind. Water Pollution, U. of Mass.

376. Loeb, S., 1966. A Composite Tubular Assembly for Reverse Osmosis Desalination. Water Resources Center Desalination Report No. 5, Dept. of Eng., U. of Calif., Los Angeles.

377. Logan, J.A., Matfield, W.D., Russel, G.S., and Lynn, W.R., 1962. An Analysis of the Economics of Waste Water Treatment. J. Water Pollution Control Fed. 34(1).

378. Logan, R.P., 1949. Scum Removal by Vacuator at Palo Alto. Sewage Works Journal 21(6), 799.

379. Logan, R.P., and LeVine, R.Y., 1948. Lime Treatment of Cranberry Packing Wastes. Sewage Works Engineering 19 (Dec.), 635.

380. Lorenzen, C., and Lamouria, L.H., 1964. Hydraulic Handling of Fruit in Processing Operations. Ag. Eng. 41, 258.

381. Lorenzen, C., and Fridley, R.B., 1966. Mechanizing Specialized Crops, Ag. Eng. 47, 336.

382. Ludwig, R.G., and Stone, R.V., 1963. Disposal Effects of Citrus By-Products Wastes. Water and Sewage Works 109, 410-415.

383. Ludwig, H.F., Ludwig, G.W., and Finley, J.A., 1951. Disposal of Citrus By-Products Wastes at Ontario, Calif. Sewage and Ind. Wastes 23(10), 1254.

384. Luley, H.G., 1963. Spray Irrigation of Vegetable and Fruit Processing Wastes. Journal WPCF 35(10), 1252-1261.

385. Lunsford, J.V., 1957. Effect of Cannery Waste Removal on Stream Conditions. Sewage and Industrial Wastes 29(4), 428.

386. Lunsford, J.V., and Dunstan, G.S., 1958. Thermophilic Anaerobic Stabilization of Pea Blancher Wastes. In "Biological Treatment of Sewage and Industrial Wastes," Part II, W.W. Eckenfilder and B.J. McCabe. p. 107. Reinhold Publishing Corp. New York.

387. Lutz, J.M., Findlen, H., and Hansen, J., 1955. Efficiency of Various Methods of Washing Red River Valley potatoes. American Potato Journal 32, 340.

387a. Lyons, E. H., Jr., 1969. An Investigation of a Method for Rapid Oxidation of Cannery Wastes. Proposal for a research contract to the Environmental Protection Agency from Lockheed Palo Alto Research Laboratory, LMSC/DO80712-1.

388. Magoon, C. A., and Culpepper, C. W., 1924. Scalding, Precooking, and Chilling as Preliminary Canning Operations. U. S. Dept. Agr. Dept. Bull. 1265.

389. Manfre, B. L., 1968. The Mechanical Harvesting of Tomatoes - for Profit. Transactions of the ASAE 11(3), 356.

390. Markward, E. D., 1967. Machine Harvesting and Handling of Apples for Processing in New York, p. 77. National Canners Association Information Letter No. 1202, Washington, D. C., Feb. 9.

391. Markwardt, E. D., Guest, R. W., Cain, J. C., and LaBelle, R. L., 1964. Mechanical Cherry Harvesting. Transactions of the ASAE 7, 70.

392. Markwardt, E. D., Longhouse, H. A., and Maynard, J., 1968. Effects of Tree Structure on Damage to Apples During Mechanical Harvesting. Paper No. 66-135, Transactions of ASAE 11, 360.

393. Marshall, D. E., and Hedden, S. L., 1969. Citrus Pick-Up Service. Ag. Research, U. S., Dept. Ag. Nov., 7.

394. Marshall, E. A., 1947. Effects of Beet Canning Wastes on Sewage Treatment Plant Operation. Sewage Works J. 19(2), 266.

395. Marshall, McNeil, and Hamann, D. D., 1968. Mechanical Apple Harvesting by the Shake and Catch Method. Paper No. J-005, ASAE, St. Joseph, Mich.

396. Marshall, McNeil, Hamann, D. D., Johnson, J. M., Wood, C. B. Barden, J. A., Rollins, H. A., Jr., and Williams, G. R., 1969. Mechanical Apply Harvesting by the Shake-Catch Method. Ag. 50, 355.

397. Masuda, H., Noritaka, and Maraki, H., 1964. Studies on Fermentative Processing of Apple Fruit. IV. Fermentation of Milled Apple in Cider Making. J. Ferment. Technol. 42, 379.

399. Mather, J. R., 1953. The Disposal of Industrial Effluent by Woods Irrigation. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

400. Mazzola, C.L., 1943. New Caustic Peeling Method Reduces Waste, Saves Labor. Food Ind. 15 (Jan.), 53.

401. McCarty, P.L., 1970. Biological Treatment of Food Processing Waste. In Reference 66.

402. McCarty, C.D., Kemper, W.C., and Lewis, L.N., 1965. Leaf and Twig Removal as Related to Mechanical Harvesting of Oranges, Calif. Citrograph 50(6), 208.

403. McCay, C.M., and Smith, S.E., 1940. Tomato Pomace in the Diet. Science 91, 388.

404. McDermott, F. A., and Walker, S.S., 1917. The Utilization of Cull Citrus Fruits in Florida, Fla. Ag. Expt. Sta. Bull. 135, Gainesville, Fla.

405. McGauhey, P.H., and Krone, R.B., 1967. Soil Mantel as a Wastewater Treatment System. Sanitary Eng. Research Lab., College of Eng. and School of Pub. Health, U. of Calif., Berkeley, Calif.

406. McElhinney, T.R., Becker, B.M., and Jacobs, P.B., 1942. Activated Carbon From Certain Agricultural Wastes. Iowa State College of Science 16, 227.

407. McIntosh, G.H. and McGeorge, G.G., 1964. Year Around Lagoon Operation. Food Processing, 82-86.

408. McKinney, R. E., and O'Brien, W.J., 1968. Activated Sludge-Basic Design Concepts. Journal WPCF 40(11, Part 1), 1831.

409. McKinney, R.E., Poliakoff, L., and Weichlein, R.G., 1954. Citrus Waste Treatment Studies. Water and Sewage Works 101 (Mar.), 123.

410. McNary, R.R., 1949. Disposal of Citrus Cannery Wastes. The Citrus Industry (June), 10.

411. McNary, R.R., Wolford, R.W., and Dougherty, M.H., 1953. Experimental Treatment of Citrus Waste Water. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

412. McNary, R.R., Wolford, R.W., and Dougherty, M.H., 1956. Sewage and Ind. Waste 28(7), 894.

413. McNary, R.P., and Dougherty, M.H., 1960. Citrus Vinegar. University of Florida Ag. Expt. Sta. Bull. 622, Gainesville, Fla.

414. Mead, S.W., and Guilbert, H.R., 1926. The Digestibility of Certain Fruit By-Products as Determined for Ruminants. Part I. Dried Orange Pulp and Raisin Pulp. Univ. of Calif. Expt. Sta. Bull. 409.

415. Mead, S.W., and Guilbert, H.R., 1927. The Digestibility of Certain Fruit By-Products as Determined for Ruminants. Part II. Dried Pineapply Pulp, Dried Lemon Pulp and Dried Olive Pulp. Univ. of Calif. Expt. Sta. Bull. 439.

416. Mehta, D.S., Davis, H.H., and Kingsbury, R.D., 1968. A new Design Tool for Plastic Media Trickling Filters. Ind. Water Eng. 5 (Sept.), 42.

417. Meiners, A. F., Lawler, E.A., and Morrison, J.I., 1968. An Investigation of Light-Catalyzed Chlorine Oxidation for Treatment of Wastewater. Report No. TWRC-3, U.S. Dept. of Interior, FWPCA, Cincinnati, Ohio.

418. Meller, F.H., 1969. Conversion of Organic Solid Wastes into Yeast. An Economic Evaluation. U.S. Dept. HEW, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Admin., Bureau of Solid Waste Management.

419. Melnick, D. Hochberg, M., Oser, B.L., 1944. Comparative Study of Steam and Hot Water Blanching. Food Research 9, 148.

420. Mercer, W.A., 1956. Aeration-Digestion-Sedimentation Treatment of Canning Waste Water. National Canners Association File 816-56.

421. Mercer, W.A., 1958. Comments on Lagooning as a Method of Cannery Waste Disposal. Multilithed, National Canners Association.

422. Mercer, W.A., 1964. Physical Characteristics of Recirculated Waters as Related to Their Sanitary Condition. Food Tech. 18.

423. Mercer, W.A., 1965. Canned Foods, Ch. 6. Industrial Wastewater Control, C.F. Gurnham, Ed., Academic Press, New York.

424. Mercer, W.A., 1967. Handling, Washing, and Utilization of Mechanically Harvested Tomatoes. National Canners Association Information Letter No. 1202, Washington, D.C., Feb. 9.

425. Mercer, W.A., 1969. Reconditioning and Reuse of Food Processing Brines. Report WPRD-144-01-68-1 National Canners Association, Berkeley, Calif.

426. Mercer, W.A., 1969. Treatment of Waste Streams From Food Processing, Pg. 29. In, Reverse Osmosis in Food Processing, ARS 74-51, Report of a Symposium, Jan. 23, Albany, Calif.

427. Mercer, W.A., Chapman, J.E., Rose, W.W., Katsuyama, A., and Dwinnell, F., Jr., 1962. Aerobic Composting of Vegetable and Fruit Wastes. Compost Science 3 (Autumn), 9.

428. Mercer, W.A., Maagdenberg, H.J., and Ralls, J.W., 1970. Reconditioning and Reuse of Olive Processing In Reference 66.

429. Mercer, W.A., and Rose, W.W., 1956. Studies on Tomato Washing Operations. National Canners Association Research Lab. Report No. 59-W-54, Berkeley, Calif.

430. Mercer, W.A., and Rose, W.W., 1968. Integrated Treatment of Liquid Wastes From Food Canning Operations. Research and Development Grant WPRD-151-01-68, National Canners Association Research Foundation, Washington, D.C.

431. Mercer, W.A., Rose, W.W., Butler, C.E., and Appleman. M.M., 1958. More Effective Product Washing With Less Water. National Canners Association, Information Letter No. 1666, Washington, D.C., Jan.

432. Mercer, W.A., Rose, W.W., and Katsuyama, A.K., 1968. Trickling Filter Treatment of Liquid Canning Wastes. 61st Annual Meeting, American Inst. of Chem. Eng., Los Angeles, Calif.

433. Mercer, W.A., and York, G. III., 1953. Water Reuse in Canning Peas. Parts I and II. Canner 117, (Aug. 10 and 24), 11 and 30.

434. Merkel, J.A., 1969. Methods of Liquid Waste Treatment. Maryland Processor's Report 15(3), 1.

435. Miller, L., 1937. The Problem of Cannery Waste Treatment. Canning Age 18 (May), 210.

436. Miller, L.B., 1947. Cannery Waste: An Example of Complete Treatment and Disposal. Public Works Mag. 78(2), 19.

437. Miller, P.E., 1953. Spray Irrigation at Morgan Packing Company. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

438. Mills, D.A., 1961. Depth and Loading Rates of Oxidation Ponds Water and Sewage Works 108 (Sept.), 343.

439. Mitchell, R.S., Board, P.W., and Lynch, L.J., 1958. Fluidized-Bed Blanching of Green Peas for Processing. Food Technol. 22, 717.

440. Mitchell, R.S., Lynch, L.J., and Casimir, D.J., 1969. Blanching of Green Peas. Food Technol. 23, 105.

441. Mohlman, F.W., 1950. Waste Disposal as a Factor in Plant Location. Chem. Eng. Progress 46 (7), 321.

442. Monson, H., 1953. Development of Vegetable Cannery Waste Disposal by Land Irrigation. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

443. Monson, H.G., 1953. Vegetable Cannery Waste Disposal. The Canner 12 (June 15), 14.

444. Monson, H.G., 1953. Cannery Waste Disposal, Part II. The Canner 112 (June 29), 35.

445. Monson, H., 1956. Successful Disposal of Cannery Waste Materials. Food in Canada 16 (Nov.), 42.

446. Monson, H., 1958. Cannery Waste Disposal by Spray Irrigation After 10 Years. 13th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

447. Moore, M.J., 1964. Mechanical Harvesting - Asparagus. Paper No. 64-122, ASAE, St. Joseph, Mich.

448. Morris, H.R., 3rd, 1944. Apple Syrup - A Promising Outlet for Cull Apples. Chemurgic Digest 3 (4), 57.

449. Morris, H. R., 3rd, 1946. Vegetable Wastes - Their Availability and Utilization. 22nd Ind. Waste Conf. Purdue Univ., Lafayette, Ind.

450. Morris, H. R., 3rd, Colker, D. A., and Chernoff, M. F., 1944. Vegetable Wastes Availability and Utilization. AIC-51, U. S. Dept. of Ag. Eastern Reg. Research Lab. Philadelphia, Penn.

451. Morris, G. L., VanDenBerg, L., Culp, G. L., Geckler, J.R., and Porges, R., 1963. Extended-Aeration Plants and Intermittent Water Courses. U. S. Dept of HEW, Pub. Health Service Publication No. 999-WP-8, Division of Water Supply.

452. Moyer, J. C., and Holgate, K. C., 1947. Cooling After Water and Electronic Blanching. Food Ind. 19, 1370.

453. Moyer, J. C., Robinson, W. B., and Kertesz, Z. I., 1949. Conserving Vitamin C in Peas During Processing. Canner 108 (17), 18.

454. Moyer, J. C., and Stotz, E., 1947. The Blanching of Vegetables by Electronics. Food Technol. 1, 252.

455. Moyer, J. C., and Tressler, D. K., 1943. Thiamin Content of Fresh and Frozen Vegetables. Food Research 8, 58.

456. Muckenheim, R. J., 1969. Private Communication. Univ. of Wisconsin, Dept. of Soils, Mar. 14.

457. National Canners Association - Some In-Plant Do's and Don'ts. Paper No. D-222, National Canners Association, Berkeley, Calif.

458. National Canners Association, 1951. Water Conservation. Multilithed Progress Report.

459. National Canners Association, 1956. Physical and Chemical Characterization of the Fresh Water Intake, Separate In-Plant Waste Streams, and Composite Waste Flows Originating in a Cannery Processing Peaches and Tomatoes. National Canners Association, Research Foundation, Washington, D. C.

460. National Canners Association, 1959. Unpublished Survey of Waste Costs in Canneries.

461. National Canners Association, 1964. Trickling Filter Treatment of Liquid Fruit Canning Waste. National Canner Association Research Foundation, 1133.

462. National Canners Association, 1965. Damage Comparisons - Tomatoes Harvested in Boxes and Bins. Report D-1515, Berkeley, Calif.

463. National Canners Association, 1966. Research Information, Paper No. 121, Washington, D. C., Dec.

463a. National Canners Association, 1966. Processes for Low-Acid Canned Foods in Metal Containers. Bull. 26-L, 10th Ed. Washington, D. C.

464. National Canners Association, 1968. Trickling Filter Treatment of Liquid-Processing Waste. Progress Report, Part III. National Canners Assoc. Research Foundation, Washington, D. C.

465. National Canners Association, 1968. Washington Laboratory research on Water Reuse. National Canners Association Information Letter No. 141, Washington, D. C., Aug.

466. National Canners Association, 1969. Evaluation of Controlled Temperature and Forced Aeration in Trickling Filter Treatment of Food Canning Waste Waters. Research and Development Grant WPRD-251-01-68, National Canners Association Research Foundation, Washington, D. C.

467. National Canners Association, 1969. Reduction and Treatment of Cannery Wastes. For the Federal Water Pollution Control Administration.

468. National Canners Association, 1969. Tomato In-Field Washing Station. National Canners Association Research Information No. 146, Berkeley, Calif. (Jan.)

469. National Canners Association, 1969. Tomato In-Field Washing Station Study. Report D-2167, Berkeley, Calif.

470. National Canners Association, 1969. Unpublished Data.

471. National Canners Association, 1970. Preliminary Summaries of a Survey of Solid Wastes From Canning and Freezing. For Bureau of Solid Waste Management, US Dept. of HEW.

472. National Canners Association, 1971. Reconditioning of Food Processing Brines. For the Water Quality Office, EPA, Grant No. WPRD-134-01-68.

472a. National Canners Association, 1971. Low Water Volume Peeling of Peaches, Pears, and Apricots for Reduced Liquid Waste Volume and Strength. With Environmental Protection Agency and USDA - Agr. Res. Service, Program 12060 FQE, Report D-2400.

473. National Research Council, 1968. Recommended Daily Allowances. Bull. No. 1694, Washington, D. C.

474. National Technical Task Committee on Industrial Waste, 1965. Water in Industry.

475. Neal, W. M., Becker, R. B., and Dix Arnold, P. T., 1935. The Feeding Value and Nutritive Properties of Citrus By-Products. Univ. of Florida Ag. Expt. Sta. Bull 275, Gainesville, Fla.

476. Nealy, W. A., 1941. Dollars From Cranberry Wastes. Western Canner and Packer 33 (Dec.), 22.

477. Nelson, F. G., 1948. Pretreatment of Carbohydrate Industrial Waste. Sewage Works Journal 20(3), 530.

478. Nelson, F. G., 1948. Pretreatment of Cannery Wastes. Sewage and Ind. Waste 20(3). 530.

479. Nelson, G., Senator, 1970. News Release. Wednesday, April 1, 1970, Washington, D. C.

480. Nelson, L. E., 1952. Cannery Wastes Disposal by Spray Irrigation. Wastes Engineering 23 (Aug.), 398.

481. Neubert, A. M., Graham, D. W., Henry, J. L., and Brekke, J. E., 1954. Recovery of Sugars From Pear-Canning Waste. Ag. and Food Chem. 2(1), 30.

482. Nolte, A. J., von Loesecke, H. W., and Pulley, G. N., 1942. Feed Yeast and Industrial Alcohol From Citrus Waste Press Juice. Ind. and Eng. Chem. 34(6), 670.

483. Nolte, A. J., and vonLoesecke, H. W., 1940. Grapefruit Seed Oil. Ind. and Eng. Chem. 32, 1244.

484. Norgaard, J. T., Hicks, R., and Reinsch, D. A., 1960. Treatment of Combined Sewage and Fruit Canning Wastes. J. Water Pollution Control Fed. 32(10) 1088.

485. O'Brien, M., Claypool, L.L., Leonard, S.J., York, G.K., and MacGillivray, J.H., 1963. Causes of Fruit Bruising on Transport Trucks. Hilgardia 35(6), 113.

486. O'Brien, M., York, G.K., MacGillivray, J.H., and Leonard, S.H. 1963. Bulk Handling of Canning Tomatoes. Food Tech. 96, 1050.

487. O'Connell, W.J., 1957. California Fruit and Vegetable Cannery Waste Disposal Practices. Sewage and Industrial Wastes 29(3) 268-280.

488. O'Connell, W.J., Jr., and Fitch, K.A., 1950. Waste Disposal. Food Ind. 22, 73.

489. O'Connor, D.J., and Eckenfelder, W.W., Jr., 1960. Treatment of Organic Wastes Aerated Lagoons. J. Water Pollution Control Fed. 32(4), 365.

490. Okey, R.W., and Stavenger, P.L., 1967. Membrane Technology: A Progress Report. Ind. Water Eng., (Mar.).

491. Okey, R.W., Stavenger, P.L., and Davies, D.S., 1967. Engineered Membrane Systems, a New Dimension in Waste Management. Central Operations Laboratories, Greenwich, Conn.

492. Oliver, G.E. and Dunstan, C.H., 1955. Anaerobic Digestion of Pea-Blancher Waste. Sewage and Ind. Wastes 27(10) 1171.

493. Olson, O.O. and Vennes, J.W., 1963. Mechanical Aeration of Potato Processing and Domestic Sewage. Park River Study, US Dept. of Interior, FWPCA.

494. Orlob, G.T., 1965. Progress Report for Cannery Waste Research Project. State Water Quality Control Board, Lafayette, Calif.

495. Olson, O. O., Van Heuvelen, W., and Vennes, J., 1964. Aeration of Potato Waste. 19th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

496. Olson, O.O., Van Heuvelen, W., and Vennes, J.W., 1966. Experimental Treatment of Potato Wastes in North Dakota, USA. Symposium, Utilization and Disposal of Potato Wastes, New Brunswick.

497. Ostrander, C., 1963. Waste Disposal....are Lagoons the Answer? Farm Tech. 19 (Oct.), 8.

498. Oswald, W.J., 1960. Stabilization Pond Research and Installation Experiences in California. Proceedings of a Symposium at Kansas City, Missouri. US Dept. of HEW Washington, D.C. August 1-5.

499. Outlook, 1968. The Cost of Clean Water. Environ. Sci. and Technol. 2(4), 257.

500. Pailthrop, R.E., and Filbert, J.W., 1968. Potato Processing Wastewater Treatment Costs. Cornell, Howland, Hayes and Merryfield, Corvallis, Ore.

501. Palmer, W.G., 1970. Cannery Waste Treatment by a High Solids Activated Sludge Process. In Reference 66.

502. Parker, C.D., 1966. Food Cannery Waste Treatment by Lagoons and Ditches at Shepparton, Victoria, Australia. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

503. Parker, M.E., and Litchfield, J.H., 1962. Sanitary Aspects of Water Supply, Ch. 7. Food Plant Sanitation, Reinhold Publishing Corp., New York.

504. Parker, D.S., Monser, J.R., and Spicher, R.G., 1969. Unit Process Performance Modeling and Economics for Canning Waste Treatment. 23rd Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

505. Pasveer, A., 1965. The Use of the Oxidation Ditch in the Purification of Domestic and Industrial Wastes. Symposium on the Utilization and Disposal of Potato Wastes, New Brunswick.

506. Pearl, R.C., 1963. 1962 Tomato Mechanical Harvest Research in California. National Canners Association Information Letter No. 1909, Washington, D.C., Jan. 31.

507. Pearson, G.A., Knibbe, W.G.J., and Worley, H.L., 1970. Composition of Effluents From Food Processing Plants. Typescript.

508. Pierce, D.M., 1960. Symposium on Waste Stabilization Lagoons. Water and Sewage Works 107 (Oct.), 408.

509. Pilorz, B., 1955. Peeling by Hot-Air Blast. Food Eng. 27(2) 68.

510. Pinder, K.L., and Gauvin. W.H., 1957. Applications of the Atomized Suspension Technique to the Treatment of Waste Effluent. 12th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

511. Poore, H.D., 1925. Citrus Pectin. USDA, Dept. Bull. No. 1323, Washington, D.C.

512. Popkin, R.A., and Bendixen, T.W., 1968. Improved Subsurface Disposal. Journal WPCF 40 (Aug.), 1499.

513. Popper, K., 1970. Possible Uses of Uni-Flow Filter. In Reference 66.

514. Popper, K., Bouthilet, R.J., and Slamecka, V., 1963. Ion-Exchange of Sodium Chloride From Water With Calcium Hydroxide as Recoverable Regenerant. Science 141 (3585), 1038.

515. Popper, K., Camirand, W.M., Watters, G.G., Bouthilet, R.J., and Boyle, F.P., 1967. Recycles Process Brine Prevents Pollution. Food Eng. 39, (April), 78.

516. Porges, R., 1952. Waste Loadings From Potato Chip Plants. Sewage and Industrial Wastes 24(8), 1001.

517. Porges, R., 1963. Industrial Waste Stabilization Ponds in the United States. Water Pollution Control Fed. 35 (4), 456.

518. Porges, N., Jasewicz, L., and Hoover, S.R., 1956. Principles of Biological Oxidation, 1-3. In "Biological Treatment of Sewage and Industrial Wastes", Part I. McCabe and Eckenfelder, ed., Reinhold Publishing Corp.

519. Potter, E.F., Bevenue, A., and McComb, E., 1948. Test Pear Cannery Waste for By-Product Values. Western Canner and Packer 40 (April), 56.

520. Powerl, S.T., 1939. Industrial-Waste Problems and Their Correction. Mechanical Engineering 61, 359.

521. Powers, T.J., III, Sacks, B.R., and Holdaway, J.L., 1967. National Industrial Wastewater Assesorment Manufacturing Year 1963. US Dept. of Interior, FWPCA.

522. Private Communication, 1966.

523. Proctor, B.E., and Goldblith, S., 1948. Radar Energy for Rapid Cooking and Blanching, and its Effects on Vitamin Content. Food Technol. 2, 95.

524. Proctor and Redfern, Civil and Consulting Engineers, 1961. Report on Industrial Waste--Potato Flaking Plant at Alliston, Ontario.

525. Pulley, G. N., and von Loesecke, H. W., 1940. Drying Method Changes Composition of Grapefruit By-Product. Food Ind. 12 (6), 62.

526. Quackenbush, H. E., Stout, B. A., and Ries, S. K., 1962. Pneumatic Tree-Fruit Harvesting. Ag. Eng. 39, 388.

527. Rabak, F., 1908. Peach, Apricot and Prune Kernel By-Products of the Fruit Industry of the United States, U.S. Dept. Ag. Bur. Plant Ind. Bull No. 133.

528. Rabak, F., 1916. The Utilization of Cherry By-Products. U.S. Dept. of Ag. Bull. No. 350.

529. Rabak, F., 1917. The Utilization of Waste Tomato Seeds and Skin USDA Bull. No. 632., Washington, D.C.

530. Ramage, W.D., 1950. Waste Utilization. The Canner 111 (July 8), 9.

531. Ramage, W.D., and Thompson, J.H., 1949. Producing Yeast from Processing Wastes. Food Packer 30 (May), 33.

531a. Rambo, R.S., 1968. Vegetable Canning Process Wastes. Thesis, Univ. of Wisconsin, Madison, Wis., 157 pp.

532. Randall, C., 1970. Basic Considerations for a Lagooning Disposal System. Maryland Processor's Report 16 (May), 8. University of Maryland, College Park, Md.

533. Ratzesberger, L., Jr., 1964. Enough Clean Water For All. Food Technol. 18, 1895.

534. Reeder, M.D., 1962. Problems Encountered in the Use of Mechanical Harvesters for Tomatoes. National Canners Association Information Letter No. 1813, Washington, D.C., Jan. 31.

535. Regan, W.M., and Mead, S.W., 1927. The Value of Orange Pulp for Milk Production. Univ. of Calif. Ag. Expt. Sta. Bull. 427.

536. Regester, R.T., 1940. The Canning Industry's Waste Disposal Problem. The Canning Trade 62 (Jan. 15), 30.

537. Reichmann, I., 1945. Ways to Save Water in the Food Plant. Food Ind. 17 (11 and 12), 98 and 114.

538. Reid, J. T., and Brantley, B. B., 1963. Mechanical Harvesters for Southern Peas. Ga. Ag. Expt. Sta. N. S. Circ. 36.

539. Reiser, C. O., 1954. Torula Yeast From Potato Starch Wastes. Ag. and Food Chem. 2(2), 70.

540. Reynolds, T. D., 1967. Aerobic Digestion of Waste Activated Sludge. Water and Sewage Works 114 (Feb.), 37.

541. Rhoads, A. T., Disposal Systems for Food Processing. Journal of Milk and Food Tech. 28, 392.

542. Riedesel, P. W., and Lawson, W. R., 1945. Freezing as a Factor in the Stabilization of Corn Cannery Wastes. Sewage Works J. 17(5), 952.

543. Richter, G. A., 1970. Aerobic Secondary Treatment of Potato Processing Waste. In Reference 66.

544. Ries, S. K., and Stout, B. A., 1962. Bulk Handling Studies With Mechanically Harvested Tomatoes. Am. Soc. Hort. Sci. Proc. 81, 479.

545. Robe, K., Bock, R. O., and Batina, R., 1968. Eliminates Waste. Food Processing-Marketing 29 (Mar.), 54.

546. Robeck, G. G., Bendixen, T. W., Schwartz, W. A., and Woodward, R. L., 1964. Factors Influencing the Design and Operation of Soil Systems for Waste Treatment. Journal WPCF 36(8), 971.

547. Robert R. Zall Research Associates, 1967. The Role of Irrigation in Food Processing Waste. Multilithed Report to Water Resources Center, Cornell University.

548. Rogus, C. A., 1966. Control of Air Pollution and Waste Heat Recovery From Incineration. Public Works (June), 100.

549. Rose, W. W., 1970. Trickling Filter Treatment of Food Canning Waste Waters. In Reference 66.

550. Rose, W. W., Chapman, J. E., Roseid, S., Katsuyama, A., Porter, V., and Mercer, W. A., 1965. Composting Fruit and Vegetable Refuse. Compost Science 6 (summer), 13.

551. Rose, W. W., and Mercer, W. A., 1958. Current Research on Canning Waste Problem. 12th Ind. Waste Conf., Univ. of Washington, Seattle, Wash.

552. Ross, R.D., 1968. Incineration, Ch. 4. In "Industrial Waste Disposal", Reinhold Book Corp. New York.

553. Rudolfs, W., 1953. Industrial Wastes, Their Disposal and Treatment. Reinhold Book Corp. New York.

554. Rudolph, V.J., and Dils, R.E., 1955. Irrigating Trees With Cannery Waste Water. Michigan Quarterly Bull. 37(3), 407.

555. Rudolfs, W., and Heukelekian, H., 1952. Sure Methods for Disposing Food Wastes. Food Eng. 24 (Aug.), 104.

556. Runyan, M.W., 1957. Columbia River Dilution Simplifies Treatment of Sewage-Cannery Waste. Wastes Eng. 28 (Jan.), 20.

557. Rutherford, D.M., 1948. What Happens to Surplus Oranges? The California Citrograph 33, 424.

558. Ryan, W.A., 1940. Effect of Cannery Wastes on Operation of Sewage Treatment Plants. Sewage Works J. 12(1), 99.

559. Ryan, W.A., 1945. Experiences With Sodium Nitrate Treatment of Cannery Wastes. Sewage Works Journal 17(6), 1227.

560. Ryan, W., 1950. Industrial Waste Lagoons. Sewage and Ind. Waste 22 (1), 71.

561. Sak, J.G., 1967. New Wrinkle in Trickling Filters. Ind. Water Eng. 4 (Aug.).

562. Sak, J.G., 1967. Plastic Biological Oxidation Media for Industrial Waste Treatment Needs. 14th Ontario Ind. Waste Conf., Niagara Falls, Canada.

563. Sammet, L.L., 1952. Efficiency in Fruit Marketing, Orchard-to-Plant Transportation. Calif. Ag. Expt. Sta., Giannini Foundation of Ag. Ec., Mimeograph Report No. 131, July.

564. Sanborn, N.H., 1939. New Information on Canning Waste Disposal. The (Convention) Canner 96 (Feb. 25), 71.

565. Sanborn, N.H., 1941. Nitrate Treatment of Cannery Waste. The Canner 92 (Mar. 22), 12.

566. Sanborn, N.H., 1941. Nitrite Treatment of Cannery Wastes. The Canning Trade, March.

567. Sanborn, N.H., 1941. Nitrate Kills Odor in Waste. Food Ind. 13 (April), 57.

568. Sanborn, N.H., 1942. Treatment of Vegetable Cannery Wastes. Ind. and Eng. Chem. 34(8), 911.

569. Sanborn, N.H., 1945. Food Canning Waste Utilization. Proceedings of the 1st Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

570. Sanborn, N.H., 1945. Canning Wastes Bring Dollars. The Food Packer 28 (Jan.), 35.

571. Sanborn, N.H., 1946. Canning Factory Wastes and Methods of Disposal. The Canner 103 (Mar. 23), 18.

572. Sanborn, H.H., 1952. Spray Irrigation as a Means of Cannery Waste Disposal. National Canners Association Information Letter No. 1371, Washington, D.C.

573. Sanborn, N.H., 1952. Spray Irrigation as a Means of Cannery Waste Disposal. The Canning Trade 74, (Mar. 3), 17.

574. Sanborn, N.H., 1953. Disposal of Food Processing Wastes by Spray Irrigation. Sewage and Ind. Wastes 25(9), 1034.

575. Schaefer, D.A., 1968. Report to Select Committee on Nutrition and Related Human Needs, U.S. Dept. Ag., Ag. Research Service, Hyattsville, Md.

576. Schertz, C.E., and Brown, G.K., 1968. Basic Considerations in Mechanizing Citrus Harvest. Transactions of the ASAE 11(3), 343.

577. Schraufnagel, F.H., Waste Disposal by Ridge and Furrow Irrigation. Univ. of Wisconsin Eng. Expt. Sta. Research Report No. 20.

578. Schraufnagel, F.H., 1962. Ridge-and-Furrow Irrigation for Industrial Waste Disposal. Journal WPCF 34(11), 1117.

579. Schraufnagel, F.H., 1959. Disposal of Industrial Wastes by Irrigation. Public Health Reports 74(2), 133.

580. Schroeder, E.D., and Busch, A.W., 1967. The Role of Nitrate Nitrogen in Bio-Oxidation. 22nd Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

580a. Schultz, W.G., Graham, R.P., Rockwell, W.C., Bomben, J.L., Miers, J.C., and Wagner, J.R., 1971. Field Processing of Tomatoes. 1. Process and Design. Journal of Food Science 36 (3), 397-399.

581. Scientia Research Laboratories, Inc., 1964. Analysis of the Behaviour of Ferndale Industrial Waste Treatment Facility, for Infilco.

582. SCS Engineers, 1971. Interim Report, Industrial Waste Study Canned and Frozen Fruits and Vegetables. Contract No. 68-01-0021. for U.S. EPA, Long Beach, Calif.

583. Seabrook, B.L., 1957. Disposes Billion Gallons of Water Annually. Food Eng. 29 (Nov.), 112.

584. Secretary of Agriculture and Director, Office of Science and Technology, 1969. Control of Agriculture-Related Pollution. Washington, D.C.

585. Selders, A.W., Kleis, R.W., Hayes, K.M., and Lord, W.J., 1967. Harvesting Processing Apples Mechanically. Ag. Eng. 44, (Dec.) 718.

586. Sen, B.P., and Bhaskaran, T.R., 1962. Anaerobic Disgestion of Liquid Molasses Distillery Wastes. Journal WPCF 34 (10), 1015.

587. Shaffer, C.A., 1928. Important Facts Revealed by Experiments on Corn Waste Disposal. The Canner 78 (Jan. 7), 19.

588. Shannon, S., Vittum, M.T., and Gibbs, G.H., 1968. Irrigating With Waste Water From Processing Plants. N.Y. State Ag. Expt. Sta. Res. Circ. 10, Cornell Univ., Geneva, N.Y.

589. Shaw, R., 1966. Recovery of Edible and Industrial Products from Effluent Streams of Potato Processing Plants. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

590. Sherman, W.C., and Koehn, C.J., 1948. Beta-Carotene From Sweet Potatoes. Ind. and Eng. Chem. 40(8), 1445.

591. Shrader, J.H., and Rabak, F., 1921. Commercial Utilization of Waste Seed From the Tomato Pulping Industry. USDA Bull No. 927.

592. Siebert, C.L., and Allison, C., 1948. Some Rights and Wrongs of Cannery Waste Treatment. Water and Sewage Works 95, 227.

593. Skrinde, R.T., and Dunstan, G.H., 1963. Aerobic Treatment of Pea Processing Waste. Air and Water Pollution 5 (2/4).

594. Smith, R., and McMichael, W.F., 1969. Cost and Performance Estimates for Tertiary Processes. U.S. Dept. of Interior, FWPCA, Advanced Treatment Research Lab., Robert A. Taft Water Research Center, Cincinnati, Ohio.

595. Smith, S.E., 1941. Tomato and Tomato Products for Feeding Fur Animals. N.Y. State Ag. Expt. Sta. Rec. 81, 93.

596. Smock, R.M., and Neubert, A.M., 1950. "Apples and Apple Products." Interscience Pub., Inc. New York.

597. South Dakota Dept. of Health. 1965. Wastewater Stabilization Ponds in South Dakota. Division of Sanitary Engineering, S.D. Dept. of Health, Pierre, S.D.

598. Southwell, B.L., and Blak, W.H., 1948. Dehydrated Sweet Potatoes for Fattening Steers. Georgia Agr. Expt. Sta. Bull. 45.

599. Spicher, R.G., Agardy, F.J., and Orlob, G.T., 1967. Cannery Waste Treatment. Part I. In-Plant Characterization. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

600. Splittstoesser, D.F., and Downing, D.L., 1969. Analysis of Effluents From Fruit and Vegetable Processing Factories. NY State Agric. Station Research Circular No. 17, Cornell Univ.

601. Sproul, O.J., 1966. Potato Processing Waste Treatment Investigation at the Univ. of Maine. Symposium on the Utilization and Disposal of Potato Wastes, New Brunswick.

602. Spurny, K.R., Lodge, J.P., Jr., Frank, E.R., and Sheesley, D.C., 1969. Aerosol Filtration by Means of Nucleopore Filters Structural and Filtration Properties. Environmental Sci. and Tech. 3 (May), 453.

603. Staff, 1955. Air Flotation Can Economize Your Waste Water Treatment. Food Eng. 27 (Sept.), 107.

604. Stavenger, P., 1970. The Food Industry and Pollution. Food Technol. 124 (Feb.), 16.

605. Stephenson, K.Q., 1964. Mechanical Tomato Harvester. Ag. Eng. 41, 250.

606. Stevens, T.H., and Cole, G.L., 1969. Economics of Water Use and Waste Disposal in Delaware Vegetable Processing. Univ. of Delaware Agri. Station Bull. 380.

607. Streebin, L.E., Reid, G.W., and Hu, A., 1970. Cannery Waste Treatment by Two-Stage Aeration Process. In Reference 66.

608. Stone, H.J., Batina, R.T., and Downing, D.R., 1968. Libby, McNeill & Libby Waste Treatment Experience, Aerated Lagoon, Hartford Wisconsin. Libby, McNeill & Libby, Operations Engineering, 11800 South Ashland Avenue, Chicago, Ill.

609. Stout, B.A., and Cline, C.K., 1968. Predicting Economic Feasibility of Mechanical Vegetable Harvesting Systems. Transactions of the ASAE 11(3), 353.

610. Stout, B.A., and Ries, S.K., 1960. Development of a Mechanical Tomato Harvester. Ag. Eng. 37 (Oct.), 682.

611. Sussman, C.H., 1969. The Characteristics of Some Anaerobic Bacteria From Digesting Sludge. School of Public Health ESE Notes 6(3), 4, Univ. of North Carolina, Chapel Hill, N.C.

612. Swope, D.A., 1969. What Americans Are Eating as Shown by USDA Nationwide Survey. Presented at the Wisconsin Canners and Freezers Convention, Milwaukee, Wis., Nov. 13.

613. Templeton, C.W., 1945. Dehydrating Tomato Wastes. Food Packer 28 (Nov.), 53.

614. Templeton, C.W., 1951. Cannery Waste Treatment and Disposal. Sewage and Ind. Wastes 23(12), 1540.

615. Tenney, M.W., and Stumm, W., 1965. Chemical Flocculation of Microorganisms in Biological Waste Treatment. Journal WPCF 37 (10), 1370.

616. Teot, A.S., and Daniels, S.L., 1969. Flocculation of Negatively Charged Colloids by Inorganic Cations and Anionic Polyelectrolytes. Environmental Sci. and Tech. 3 (9), 825.

617. Thomas, R.L. Coarse Filter Media For Artificial Recharge. Dept. of Ed. and Registration, State Water Survey. Peoria, Ill.

618. Thornthwaite Associates, 1969. An Evaluation of Cannery Waste Disposal by Overland Flow Spray Irrigation. Publications in Climatology 22(2) Elmer, New Jersey.

619. Tolman, S.L., 1962. The Mechanics of Mixing and Flocculation. Public Works 93 (Dec.), 88.

620. Tomhave, A.E., 1931. Dried Tomato Pomace in the Dairy Ration. Delaware Univ. Agr. Expr. Sta. Ann. Report 172, 23.

621. Tomhave, A.E., 1932. Dried Tomato Pomace in the Dairy Ration. Delaware Univ. Agr. Expt. Sta. Ann Rept. 179, 23.

622. Tressler, D.K., Mack, G.L., Jenkins, R.R., and King, C.G., 1937. Vitamin C in Vegetables. VII. Lima Beans. Food Research 2, 175.

623. Tsao, G.T., and Cramer, W.D., 1968. Waldhorf Type Fermentors in Disposal of Food Wastes. American Institute of Chem. Engineers, New York.

624. Twigg, B.A., 1961. Water Handling of Tomatoes. National Canners Association Information Letter, No. 1814, Washington, D.C., Jan. 31.

625. Uber, W.J., and Rogers, H.G., 1951. Dairy and Food Processing Wastes Predominate in Minnesota. Wastes Eng. 22 (Oct.), 538.

626. Uhlmann, P.A., 1943. Three Years' Treatment of Sewage at Celina, Ohio. Pub. Works 74 (Mar.), 13.

627. Uhlmann, P.A., 1944. Charges to Industries for Treating Their Wastes in a Municipal Plant. Public Works 75 (Dec.), 23.

628. University of Idaho, and FWPCA Pac. NW Lab. Potato Waste Treatment, Proceedings of a Symposium, U.S. Dept. of Int., FWPCA, NW Reg., Pac. NW Water Lab., Corvallis, Ore.

629. United States Dept. of Agriculture, 1956. Chemistry and Technology of Citrus, Citrus Products, and By Products. Agriculture Handbook No. 98, USDA, Washington, D.C.

630. U.S. Dept. of Agriculture, 1963. Composition of Foods. Agricultural Handbook No. 8, Washington, D.C.

631. U.S. Department of Agriculture, 1965. In "Losses in Agriculture". U.S. Govt. Printing Office, Washington, D.C.

632. U.S. Dept. of Agriculture, 1969. Proceedings of the 19th National Potato Utilization Conference. USDA, ARS 73-65, Philadelphia. Penn.

633. U.S. Dept. of Agriculture, 1970. Proceedings of the Conference on the Treatment and Disposal of Wastes from Vegetable Processing. Progress and Research Needs. Agricultural Research Service, U.S. Dept. of Ag., ARS72-80, New Orleans, La.

634. U.S. Dept. of HEW, 1962. Fruit Processing Industry-An Industrial Waste Guide. Public Health Service Pub. 952.

635. U.S. Dept. of HEW, 1965. Advanced Waste Treatment Research, P. 8. Summary Report, Public Health Service Publication No. 999-WP-24, Robert A. Taft Engineering Center, Cincinnati, Ohio.

636. U.S. Dept. of HEW, 1965. Summary Report, The Advanced Waste Treatment Research Program. U.S. Dept. HEW, Public Health Service, Division of Water Supply and Pollution Control, Washington, D.C.,

636a. U.S. Dept. of HEW, 1969. Conversion of Organic Solid Wastes into Yeast. Public Health Service Bureau of Solid Waste Management, Contract No. PH86-67-204.

637. U.S. Dept. Int., 1967. The Cost of Clean Water, Vol. III. Industrial Profile. No. 6. Canned and Frozen Fruits and Vegetables. U.S. Dept. of Int., FWPCA, Washington, D.C.

638. U.S. Dept. of Interior, 1968. The Cost of Clean Water, Vol. II, Detailed Analysis. U.S. Dept. of Int., FWPCA, Washington, D.C.

639. U.S. Dept. Int., 1967. Summary Report Advanced Waste Treatment.

640. U.S. Dept. Int., 1968. The Cost of Clean Water, Vol, I, Summary Report. U.S. Dept. of Int., FWPCA, Washington, D.C.

641. U.S. Dept. Int., 1968. Summary Report Advanced Waste Treatment. FWPCA Publication WP-20-AWTR-19, Cincinnati, Ohio.

642. U.S. Dept. Int., 1969. Summary and Conclusions - The Current Position of User Charges. Reprint From "The Cost of Clean Water and its Economic Impact", Vol. 3, 1969 Sewerage Costs.

643. U.S. Dept. Int., 1969. Ozone Treatment of Secondary Effluents from Wastewater Treatment Plants. FWPCA Report No. TWRC-4, Robert A. Taft Water Research Center, Cincinnati, Ohio.

644. U.S. Dept. Int., FWPCA, 1969. The Cost of Clean Water and its Economic Impact, Vol. I The Report.

645. U.S. Dept. Int., FWPCA, 1970. The Economics of Clean Water-Vol. I Detailed Analysis.

646. Van Antwerpen, F.J., 1941. Utilization of Citrus Wastes. Ind. and Eng. Chem. 33, 1422.

647. Van Heuvelen, W., Smith, J.K., and Hopkins, G.J., 1960. Waste Stabilization Lagoons - Design, Construction, and Operation Practices Among Missouri Basin States. Journal of WPCF 32 (9), 909.

648. Van Patten, E.M., and McIntosh, G.H., 1952. Waste-Pollution Problem Solved by Engineering the "Ounce of Prevention". Food Eng. 24 (April) 61.

649. Van Patten, E.M., and McIntosh, G.H., 1952. Corn Products Manufacture, Ind. and Egn. Chem. 44(3), 483.

650. Vecchiotti, G.G., and Piva, G., 1964. Amino Acid Levels in Tomato By-Products. Proc. Congr. Soc. Ital. delle Sci. Vet., P. 279.

651. Veldhuis, M.K., and Gordon, W.O., 1948. Experiments on Production of Feed Yeast From Citrus Press Juice. The Citrus Industry 29 (Jan), 7.

652. Vennes, J.W., and Olmstead, E.G., 1961. Stabilization of Potato Wastes. Official Bulletin North Dakota Water and Sewage Works Conference.

653. Vincent, D.B., 1951. Processing Citrus Cannery Waste. 6th Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

654. Vincent, D.B., 1967. Waste Heat Evaporates Waste. Food Eng. 39 (Feb), 84.

655. von Loesecke, H.W., 1950. Citrus Cannery Waste, Its Use and Disposition. AIC-290, Bureau of Ag. and Ind. Chem., U.S. Dept. of Ag., Washington, D.C.

656. von Loesecke, H.W., Pulley, G.N., Nolte, A.J., and Goresline, H.E., 1941. Experimental Treatment of Citrus-Cannery Effluent in Florida. Sewage Works Journal 13(1), 115.

657. Wagner, J.R., Strong, F.M., and Elvehjem, C.A., 1947. Nutritive Value of Canned Foods. Effects of Commercial Canning Operations on the Ascorbic Acid, Thiamine, Riboflavin, and Niacin Content of Vegetables. Ind. Eng. Chem. 39, 9885.

658. Wakefield, J.W., 1952. Semi-Tropical Industrial Waste Problems. 7th Ind. Waste Conf. Purdue, Univ. Lafayette, Ind.

659. Wakefield, J.W., O'Neal, B.F., and Kelso, F.S., Mrs., 1954. Citrus Waste Disposal Practices and Research. 9th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

660. Waring, F.H., 1927. Progress in Ohio in the Disposal of Industrial Wastes. The Canner 77 (Jan. 8), 19.

661. Warrick, L.F., 1927. Lime in the Treatment of Pea Cannery Wastes. Ind. and Eng. Chem. 19(5), 577.

662. Warrick, L.F., 1938. The Disposal of Food Plant Wastes. Food Ind. 10 (Jan.), 20.

663. Warrick, L.F., and Beatty, E.J., 1936. The Treatment of Industrial Wastes in Connection With Domestic Sewage. Sewage Works J. 8(1), 122.

664. Warrick, L.F., Wisniewski, T.F., and Sanborn, N.H., 1945. Cannery Waste Disposal Lagoons. Bulletin 29-L, National Canners Association.

665. Water Resources Engineers, Inc., 1966. Evaluation of the Technical and Economic Feasibility of In-Plant Separation and/or Treatment of Cannery Waste Flows. Lafayette, Calif.

666. Webster, L.F., 1967. Oxidation Ditch Treats Tomato Waste. Water and Pollution Control.

667. Webster, L.R., 1954. Discussion of Seabrook Farms. Sewage and Industrial Wastes 26(2), 133.

668. Webster, M.H., 1970. The Reuse of Waste Waters in Food Production. Third International Congress of Food Sci. and Technol., Washington, D.C., Aug.

669. Webster, R.A., 1953. Vegetable Processing Wastes, Pilot Plant Studies. Sewage and Ind. Wastes 25(12), 1432.

670. Weckel, K.G., 1970. Unpublished Data.

671. Weckel, K,G., and Keusel, D.C., 1955. Quality and Yield of Fresh and Processed Peas. Univ. of Wisconsin Agr. Expt. Sta. Res. Bull. 186, Madison, Wis.

672. Weckel, K.G., and Lee, H.D., 1960. Composition of Cherry Seed and Cherry Seed Oil. Food Technol. 14(3), 151.

673. Weckel, K.G., Rambo, R.S., Veloso, H., and vonElbe, J.H., 1968. Vegetable Canning Process Wastes. Research Report 38, College of Agric. and Life Sciences, Univ. of Wisconsin.

674. Weiss, F.J., 1944. Microorganisms Can Convert Waste Materials into Food. Food Ind. 16 (July), 525.

675. White, J.W., Jr., Weil, L., Naghski, J., Della Monica, E.S., and Willaman, J.J., 1949. Protoplasts from Plant Materials 40(3), 293.

676. Wiegand, E.H., 1944. Dollars From Factory Waste, Part II. Canner 98 (Feb. 12), 20.

677. Wiegand, E.H., 1945. Utilization of Fruit Wastes. Chem. Digest 4, 127.

678. Wiegand, E.H., Dr., 1948. Cannery Residues. An Analysis of Progress in Utilization and Disposal in the Processing of Food. Chemurgic Digest 7 (Jan.), 9.

679. Will, R.T., 1915. Some Phases of the Citrus By-Product Industry in California. Ind. and Eng. Chem. 8(1), 78.

680. Willaman, J.J., and Eskew, R.K., 1949. Utilization of Vegetable Wastes. Chem. Digest 8 (April), 15.

681. Willard, M.J., 1969. Pilot Plant Study of the USDA-Magnuson Infrared Peeling Process. Proceedings of the Nineteenth Potato Utilization Conference, Ferris State College, Big Rapids, Mich.

682. Willenbrink, R.V., and Staley, A.E., 1967. Waste Control and Treatment by a Corn and Soybean Processor. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind.

683. Willoughby, E., 1969. Select the 'right' Waste Treatment System. Food Eng. 71 (Aug.), 74.

684. Winter, F., and Coffelt, R.J., 1970. Progress Report. Cooling Vegetables After Blanching. Food Sci. and Technol. Dept., Univ. of Calif., Davis, Calif.

685. Wisniewski, T.F., 1948. Waste Disposal Methods. Food Packer, 29 (June), 25.

686. Wisniewski, T.F., 1961. Irrigation Disposal of Industrial Wastes. Public Works 92 (July), 96.

687. Wittenberger, R., and LaBelle, R.L., 1969. Effects of Mechanization and Handling on Cherry Quality. Fruit and Vegetable Mechanization, Michigan State Univ., 699.

688. Whittlesey, N.K., and Duff, J.B., 1967. An Economic Analysis of Alternative Methods of Harvesting Green Peas in Eastern Washington and Eastern Oregon. Wash. Ag. Expt. Sta. Bull. 684, Wash. State Univ., Pullman, Wash.

689. Wolnak, B., and Miner, C.S., Jr., 1954. Dried Activated Sludge as a Fermentation Accelerator. Ag. and Food Chem. 2(15), 790.

690. Woodley, R.A., and Moore, S.L., 1966. Deep Well Disposal of Industrial Wastes in Indiana. Journal of Milk and Food Tech. 29, 211.

691. Woodruff, J.B., Cecil, S.R., Shelor, E., and Cecil, I.A., 1948. Peeling With Lye. Food Ind. 20, 862.

692. Woodward, C., Dr., Lawler, J.P., Spinna, R.J., and Eckenfelder, W.W., Jr., 1958. Study of Fruit and Vegetable Processing Waste Disposal Methods in the Eastern Region. USDA Research and Marketing Contract No. 12-14-100-482(73), Civil Engineering Dept., Manhattan College, New York, N.Y.

693. Wright, C.E., 1951. Solves Waste Problem; Saves Too. Food Eng. 23 (Sept.), 107.

694. Wright, R.C., and Whiteman, T.M., 1949. Tests Show Which Potatoes Have Least Peeling Loss. Food Ind. 12, 1567.

695. Wuhrmann, K., 1956. Factors Affecting Efficiency and Solids Production in the Activated Sludge Process, 1-4. In "Theory and Mechanism of Biological Waste Treatment", Part I, McCabe and Eckenfelder, ed. Reinhold Publishing Corp., New York.

696. Yall, I., Boughton, W.H., Knudsen, R.C., and Sinclair, N. A., 1970. Biological Uptake of Phosphorous by Activated Sludge. Applied Microbiology (July), 145.

697. Yang, H.Y., 1958. Vodka From Pear Wastes. Food Eng. 38 (Jan.) 87.

698. Young, C.H., 1943. Treatment of Cherry Waste Water. Public Works 74 (Nov.), 25.

699. Young, H.H., 1949. Nitrate Treatment of Lagoons. 4th Ind. Waste Conf., Purdue Univ. Lafayette, Ind.

700. Young, J.C., 1967. The Anaerobic Filter for Waste Treatment. 22nd Ind. Waste Conf., Part II, Purdue Univ., Lafayette, Ind.

701. York, G.K., O'Brien, M., Winter, F.H., Tombropoulos, D, and Leonard, S.J., 1964. Sanitation in Mechanical Harvesting and Bulk Handling of Canning Tomatoes. Food Tech. 18(1), 97.

702. Zickefoose, C.S., 1963. Pea Wastes and City Sewage Treated in Parallel Plants. Wastes Engineering 34 (May), 242.

SECTION XI

GLOSSARY

BOD — (1) Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter by bacteria in a specified time (usually 5 days), at a specified temperature (20°C), and under specified conditions. (2) A standard test used in assessing wastewater strength.

By-product — A useful product made from material that would otherwise be waste.

Cs — Abbreviation for "case", a quantity of finished product containing a number (often 24) of consumer-size units.

COD — Abbreviation for chemical oxygen demand. A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specified test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with BOD. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

O and M — Abbreviation for "operation and maintenance"; the annual costs of a facility excluding capital costs.

pH — The negative logarithm of the hydrogen ion content; a measure of the functional acidity or alkalinity of a liquid.

Raw product — The quantity of a commodity delivered to a food processor; also referred to as "raw tons".

Residual — Material left over from processing a primary product; either used as a by-product or wasted.

Settleable solids — Insoluble material measured by settling.

SS — Abbreviation for suspended solids. Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

TDS — Abbreviation for total dissolved solids. The total amount of soluble material, organic and inorganic, contained in water or wastewater.

TS — Abbreviation for total solids. The solids in wastewater, both suspended and dissolved.

SECTION XII

APPENDIX

Table A1. Total Wastes from Canned and Frozen Fruits and Vegetables

	Raw Product	Wastewater		BOD_5		Suspended Solids		Solids Residuals	
	1000 tons	10^3gal /ton*	mil. gal. **	lbs /ton*	mil. lbs **	lbs /ton*	mil. lbs**	lbs /ton*	1000 tons**
FRUIT									
Apple	1,050	2.1	2,200	36	38	6	6	580	290
Apricot	120	8.7	1,000	71	9	16	2	240	16
Cherry	190	2.4	400	26	5	5	1	280	26
Citrus	7,800	1.8	19,000	16	125	3	23	790	3,080
Peach	1,100	5.6	6,200	62	68	13	14	530	290
Pear	410	3.0	1,200	42	17	12	5	660	140
Pineapple	900	0.5	500	20	18	8	7	890	400
Other fruit	460	8.0	3,700	20	9	10	5	--	70
Fruit sub-total	12,030		34,200		289		63		4,312
VEGETABLES									
Asparagus	120	13.3	1,300	7	1	8	1	700	42
Bean, lima	120	9.0	1,100	25	3	80	10	320	19
Bean, snap	630	7.6	4,800	22	14	15	9	420	130
Beet	270	3.8	1,000	135	36	53	14	670	90
Carrot	280	3.7	1,000	50	14	29	8	1,000	140
Corn	2,480	2.2	5,500	44	110	22	55	1,310	1,620
Pea	580	5.3	3,100	61	35	22	13	260	74
Pumpk, squash	220	1.5	300	41	9	11	2	500	55
Sauerkraut	230	0.4	100	14	3	1	0	660	76

Table A1. Total Wastes from Canned and Frozen Fruits and Vegetables (continued)

	Raw Product	Wastewater		BOD5		Suspended Solids		Solid Residuals	
	1000 tons	10^3gal /ton*	mil. gal. **	lbs /ton*	mil. lbs **	lbs /ton*	mil. lbs **	lbs /ton*	1000 tons**
Spin., greens	240	8.4	2,000	28	7	18	4	280	33
Sweet potato	150	2.6	400	98	15	39	6	(in other veg.)	
Tomato	5,000	2.7	14,500	14	70	7	35	180	400
White potato	2,400	3.4	8,200	47	110	53	130	760	910
Other vegetables	1,400	4.0	5,600	60	84	30	42	--	460
Vegetable sub-total	14,120		48,900		511		329		4,049
Total	26,150		83,100		800		392		8,361

* Units are 1000 gallons or pounds per ton of raw product

** Estimated total annual waste generation for the United States

Table A2. Mechanical Harvesting of Fruits and Vegetables

Product	Problem	Ref.
Apples	Bruising	390
Apples	Boom-shaker, conveyor collection	585
Apples	Shaker - deceleration strip damage	392
Apples	Shake-catch - effect on bruising - economics	395, 396
Asparagus	Snapping units - types - comparisons	345
Asparagus	Selective - sensor - compressed air - problems	447
Asparagus	Rotating knives - sort - trim - uniform cut	337
Celery	Types - damage comparison requirements	83, 84
Cherries	Catch frame -pruning - stems - damage - efficiency	391
Cherries	Mechanization effect	687
Citrus	Tree-shaker - tractor - catch frame -performance	159
Citrus	Oscillating air blast - fruit maturity - leaf damage	328
Citrus	Inertia-shaker - stem and fruit removal	368
Citrus	Mass-harvest - injury individual harvest - selection	576
Fruit,tree	Blueberry - plum - cherry cost reduction	244
Fruit,tree	Harvester types - savings problems	331
Oranges	Mechanical harvest - leaf and twig loss - yield effect	402
Peach	Shake-catch - modify tree production costs	381
Cling peaches	Shake-catch - selectivity - percent bruise - yield	5

Table A2. Mechanical Harvesting of Fruits and Vegetables (continued)

Product	Problem	Ref.
Peas	Harvester development - design - damage - adaptation to crops	538
Peas	Methods - comparison - costs - vining station	688
Strawberries	Mechanical stripping - selective	295
Tomatoes	Once-over harvest - yield - bruises	610
Tomatoes	Compare damage of hand and mechanical	544
Tomatoes	Effect of field layout - yields - damage	534
Tomatoes	Damage - dirt	506
Tomatoes	Mechanical harvest - microbial contamination - fruit condition	701
Tomatoes	Selective - color - separation - shaking	605
Tomatoes	Damage - hand and mechanical harvest - containers	462
Tomatoes	Effects on BOD quantities	665
Tomatoes	Harvest whole plant - sort belt	335
Tomatoes	Tractor-mount - pickup - conveyor - fruit condition	14
Tomatoes	Bed shape - uniform stand optimum conditions	389
Tomatoes	Large operator - speed - clean fruit - less damage - color sort	53
Tree fruit	Pneumatic - force required physical character	526
Tree crops	Economics - fruit loss - harvest rate - degree mechanization	238
Vegetable	Economic feasibility - once-over harvest - multiple harvest - break-even yields	609

Table A3. In-field Processing of Fruits and Vegetables

Product	Process system	Ref.
Citrus	Trash eliminator - conveying	393
Peas	Vining - conveying - on-stream	357
Peas	Field and plant vining - costs	167
Peas	Plot cleaner - trash removal	336
Sugar Cane	Trash removal	153
Tomatoes	Mechanical harvester - culls in-field - grader	109
Tomatoes	Field grade - washing - sanitation	701
Tomatoes	Vine cleaning - field disposal	41
Tomatoes	Washing - spraying - sorting damage - spore counts	424
Tomatoes	Harvester - color grading - cull removal	53
Tomatoes	Acidified break - juice extraction	59
Tomatoes	Acidified field break - efficiency	63, 580a
Tomatoes	Washing - damage - spores	468, 469

Table A4. Hauling of Fruits and Vegetables from Field to Plant

Product		Ref.
Cherries	Water transport - comparison to lug	371
Cherries	Water transport - cost - simplifies - retains quality	242
Cherries	Water transport - weighing - weight change	243
Cherries	Pallet tanks - water - shrinkage	55
Citrus	Haul and loading costs	38
Citrus	Pick-up - conveyors - bins - trucks	393
Fruit	Efficiency - labor - equipment - comparisons	563
Fruit	Transport truck - vibrations - bruising	485
Fruit	Positive transfer - padded belts	93
Peas	Dump truck	8
Tomatoes	Water handling	157
Tomatoes	Water - condition after haul	624
Tomatoes	Compare types of boxes	544
Tomatoes	Bulk - bin - water - storage effect	486

Table A5. Transfer of Fruits and Vegetables during Processing

Product	Conveyance system	Ref.
Apricot	Water - labor reduction - system description	380
Peas	Fluming in reused water	423
Tomatoes	Hydraulic conveying - bacteria count	422
Vegetable (frozen)	Pneumatics - frozen product - cost efficiency	143
Vegetable (frozen)	Pneumatics - clumping prevention	144
Vegetable (frozen)	Fluidized freezing - conveyor - less bacteria	43
Vegetable (fresh & frozen)	Pneumatics	166
Vegetable (fresh & frozen)	Pneumatics - negative air air conveyor	374

Table A6. Reuse of Water in Fruit and Vegetable Processing

Process		Ref.
Recirculation	Reuse for drain flush	326
Conservation	Cut usage in process	537
4 stage counter-flow	In pea canneries	433
Recirculation	Cool water for washing, fluming, reuse screened flume water	213
Recirculation		431
Conservation	Tomato washing studies	433
Conservation	Reduction in peeling, washing, cleaning	503
Recirculation	Hydraulic system, bacteria count	422
Reuse	Reuse refrigeration and uncontaminated process water	306
Reuse	Can cooling and flume water	665
Recycling	Process brine	515
Countercurrent	Reuse in preceding wash and flume	465
Recycling	Reuse for washing	155
Triple-loop water economy circuit		363
Reuse	Lye rinse and process water as makeup	426
Counterflow	In tomato, sweet potato processing	300
Recirculated	Reuse volume per year	471

Table A7. Treatment of Water for Reuse in Processing Operations

Treatment	Parameter studied	Ref.
Activated carbon adsorption	Organic removal	290
Activated carbon adsorption	Organic removal	332
Activated carbon adsorption	Organic removal	641
Activated carbon	Dissolved organics removal	11
Activated carbon	Reconditioning brine	425
Activated carbon adsorption		290
Air stripping	Ammonia removal	641
Biological denitrification	Nutrient removal	641
Brine disposal		11
Chemical oxidation	Refractory organic materials removed	290
Chemical oxidation		39
Chemical oxidation	Dissolved inorganics	11
Chlorination		433
Chlorination		39
Coagulation-sedimentation	Suspended solids removal	11
Coagulation-sedimentation	Suspended solids and dissolved solids removal	155
Disinfection		11
Distillation	Inorganic and organic removal	290
Distillation	Inorganic removal	641
Electrodialysis		290
Electrodialysis	Demineralize secondary effluent	112
Electrodialysis	Inorganic removal	641
Electrodialysis	Dissolved inorganics removal	11
Freezing		290
Freezing	Inorganic removal	641
Ion exchange		290
Ion exchange		39

Table A7. Treatment of Water for Reuse in Processing Operations (continued)

Treatment	Parameter studied	Ref.
Ion exchange		641
Ion exchange	Dissolved inorganics removal	11
Ozone sterilization		363
Ozone treatment		302
Ozone treatment	Reduction of COD	641
Precipitation	Nutrient removal	641
Reverse osmosis		290
Reverse osmosis	Inorganic removal	583
Reverse osmosis	Dissolved inorganic removal	11
Reverse osmosis		426
Reverse osmosis		108

Table A8. Waste Generation (Percentages) from Unit Processing Operations on Fruits and Vegetables *

	Clean	Peel	Cut, pit	Pulp	Fill, ht, syrup	Exhaust, seal, cook
Apple (4)**						
water	20-30***	5-20	10-25	10	40-65	
B/COD	5-20	10-40	5-40	70	10-80	
SS	2-15	15-40	3-35	85	10-80	
Apricot (3)						
water	20-95	-	5-40	-	15-15	25-40
B/COD	20-20	-	40-55	-	15-30	10-10
SS	30	-	40	-	20	10
Cherry (3)						
water	30-60	-	3-6	-	35-65	
B/COD	10	-	80	-	10	
SS	35	-	60	-	5	
Peach (3)						
water	15-20	25-50	15-35	-	10	10-20
B/COD	5-10	35-50	30-50	-	5-10	2-5
SS	5-10	30-60	25-55	-	5	2-5
Pear (3)						
water	30-60		7-30	-	10-13	30-40
B/COD	50-78		10-40	-	5-10	2-5
SS	45-83		10-45	-	5-5	2-5

	Clean	Peel	Cut	Blanch	Fill, brine, seal, cook	Fill, freeze
Asparagus (2)						
water	20-40	-	10-20	25-30	15-40	5
B/COD	20	-	10	60	10	5
SS	50	-	10	30	10	5
Beans, snap (4)						
water	30-40	-	0-40	10-45	20-50	5-10
B/COD	10-60	-	0-20	40-60	0-20	5
SS	30-80	-	0-30	20-30	0-10	5
Beet (2)						
water	10-30	30-40	20-26	-	20-24	-
B/COD	15-20	50-60	20-20	-	5-10	-
SS	15-30	50-70	10-20	-	0-5	-

Table A8. Waste Generation (Percentages) from Unit Processing Operations on Fruits and Vegetables * (continued)

	Clean	Peel	Cut	Blanch	Fill, brine, seal, cook	Fill, freeze
Carrot (2)						
water	12-30	30-40	20-28	0-5	15-20	-
B/COD	16-20	50-60	20-21	0-10	0-3	-
SS	10-18	40-65	15-40	0-10	0-2	-
Corn, canned (2)						
water	30-40		40-41	-	20-29	-
B/COD	20-30		50-75	-	5-20	-
SS	10-15		70-80	-	5-20	-
Corn, frozen (2)						
water	19-40		26-30	25-50	-	5-5
B/COD	10-18		30-68	13-55	-	1-5
SS	10-15		70-80	5-15	-	0-5
Pea (3)						
water	50-60	-	-	10-30	20-40	5-10
B/COD	45-55	-	-	40-45	5-10	5
SS	55-65	-	-	30-35	5-10	5
Potato, sweet (1)						
water	30	35	15	-	20	-
B/COD	25	50	20	-	5	-
SS	25	40	30	-	5	-
Pumpkin, squash (1)						
water	10	20****	20	20	30	-
B/COD	15	30****	35	10	10	-
SS	10	25****	50	10	5	-
Spinach, greens (4)						
water	20-60	-	0-10	10-40	15-55	5-10
B/COD	15-30	-	10-30	30-60	10-20	5
SS	30-60	-	10-40	20-20	10-10	5
Tomato, whole (2)						
water	50-80	10-40	-	-	10-10	-
B/COD	60	35	-	-	5	-
SS	70	30	-	-	0	-

Table A8. Waste Generation (Percentages) from Unit Processing Operations on Fruits and Vegetables * (continued)

	Clean	Peel	Cut	Blanch	Fill, brine, seal, cook	Fill, freeze
Tomato, pulped (3)						
water	30-85	5-30****	-	-	10-60	-
B/COD	95	5****	-	-	0	-
SS	95	5****	-	-	5	-

* "Clean" includes washing, sorting, shaking, blowing, etc.; "peel" and "blanch" include related steps such as rinsing; "cut" includes slicing and dicing.

** Number of estimates in ().

*** Where two or more estimates were available, the highest and lowest are shown.

**** Pulping operation (not peeling).

Table A9. The pH of Fruit and Vegetable Effluents

Product	pH Range	pH Median	Ref.
Apple	4.1-8.2	5.3	600
Cherry	5.2-7.9	6.4	600
Grape	5.2-9.5	7.2	600
Olive storage	4.0-4.3	4.2	428
Peach	(6.2)*-10.6	9.6	420, 421, 432, 458
Bean, lima	5.7-7.0	5.9	507
Bean, snap	5.2-8.6	6.5	507, 600
Beet	5.6-11.9	8.0	309, 600
Carrot	7.4-10.6	8.2	600
Corn	(3.9)-8.0	6.4	181, 507, 600
Pea	4.9-9.2	6.6	181, 184, 507, 600
Pumpkin, squash	(4.2)-7.2	6.6	420, 458, 507, 600
Sauerkraut	3.6-6.8	5.0	600
Sweet potato	5.8-11.4	10.5	507
White potato	(3.6)-12.6	8.4	160, 267, 351, 507, 543, 601
Tomato	4.5-11.3	6.6	123, 327, 507, 600

* In ( ), possibly not typical

Table A10. Peel Waste from Fruits and Vegetables

Product	Peel waste, % of raw weight	Ref.
Apples (peel and core)	35	569
Apples (mechanical peel)	15-18	216
Apples (infra red peel)	2	75
Grapefruit	58	569
Grapefruit (peel and rag)	83	80
Orange (peel and rag)	74	569
Peaches (lye peel)	9-26	691
Pears (peel and core)	42	569
Potatoes (abrasion)	3-12	258
Potatoes (lye)	12-30	400
Potatoes (mechanical peel)	7-31	694
Potatoes (abrasion peel)	25	262
Potatoes (lye peel)	22	262
Potatoes (steam peel)	18	262
Potatoes (lye/steam peel)	15	3
Potatoes (abrasion peel)	14-25	192
Potatoes (steam peel)	11-19	192
Potatoes (lye peel)	11-23	192
Potatoes (lye peel)	18	681
Potatoes (infra red peel)	13	681
Potatoes (steam peel)	10	681
Potatoes (infra red peel)	10	681
Sweet potatoes (lye peel)	10-29	691
Tomatoes (hot air blast)	--	509
Tomatoes (total waste)	25	569
Tomatoes (total waste)	8	471

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This study estimates that the 1800 plants in the U.S. canned and frozen fruits and vegetables industry annually utilize 26 million tons of raw product, discharge 83 billion gallons of water, and generate 800 million pounds of biochemical oxygen demand, 392 million pounds of suspended solids, and 8 million tons of solid residuals. Increased mechanical harvesting is increasing problems in product damage, soil, and loss in yields. Water is extensively recirculated in food processing plants but additional water savings by reconditioning and reuse are needed. High pollutional loads are generated in blanching and peeling operations and large amounts of relatively clean water are discharged from cooling and condensing operations. Solids are commonly removed from waste water by screening. The solid residuals from some commodities are used in large quantities for animal feed. Biological processes are widely used to treat food processing waste water. Anaerobic, aerobic, and aerated lagoons, activated sludge, trickling filter, and other treatment systems are discussed. Roughly half of the canning and freezing plants discharge their waste waters to city treatment systems and about one-fifth use spray irrigation for liquid waste disposal.

Abstractor Norman A. Olson

Institution National Canners Association

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