:PA-660/2-74-058
June 1974

Environmental Protection Technology Series

Proceedings Fifth National Symposium on Food Processing Wastes

National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

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PROCEEDINGS FIFTH NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES

April 17-19, 1974
Monterey, California

INDUSTRIAL WASTES BRANCH
Pacific Northwest Environmental Research Laboratory
Environmental Protection Agency
Corvallis, Oregon

Co-sponsored by:

NATIONAL CANNERS ASSOCIATION

CANNERS LEAGUE OF CALIFORNIA

Roap/Task 21 BAB 102
Program Element #1BB037

Prepared for
NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH & DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

FOREWORD

The Fifth National Symposium on Food Processing Wastes was co-sponsored with the National Canners Association and the Canners League of California.

These symposia were instituted for the purpose of disseminating the latest information obtained from research, development and demonstration projects to industry, consultants and government. There was a definite need to shorten the time between completion of the projects and making the information available to the potential users.

As noted in the Proceedings from the Fourth Symposium, a greater emphasis is being placed upon process modifications and by-product recovery in an attempt to reduce end-of-pipe treatment costs. In addition, one paper discusses effluent polishing and partial reuse back in the processing plant. Additional projects such as this will be initiated during the next few years.

With continued cooperation between the various entities, the desired water quality goals will be achieved in an optimal manner within the economic and time constraints imposed.

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OPENING REMARKS BY MR. BRUNO A. FILICE *

I am most pleased that this Symposium is taking place in California and that the Canners League of California is a co-sponsor. On behalf of the Officers and members of the Canners League, I welcome you--and, most especially, those who do not enjoy the privilege of year-round living in our Golden State. We hope that you enjoy your stay in this historic Monterey Bay area and that you go home recharged, refreshed, and a bit envious of us natives.

The importance of this Symposium as a medium for the disclosure of new research results--as well as a forum of exchange of unpublished results, creative insights, and solutions to problems--is recognized by the industries and their associations.

I would like to state briefly some of the concerns felt by the canning industry in California. The members of the Canners League are responsible for approximately thirty per cent of the canned foods packed in the United States, and naturally, we feel that our input to environmental planning is important to us and to the nation. The canning industry endorses environmental protection; in fact, the industry is completely dependent on adequate supplies of high-quality water to process its products. Disposal of solid residuals from canning seasonal commodities is a major problem for California food processors. We want to do everything which is prudent and effective to protect our water, our air, and our land resources.

We in industry are concerned about the contradictory demands of the several federal agencies which regulate the food processing industry. For example, FDA and USDA tell us that we should be using more water in processing to reach higher levels of sanitation, while EPA regulations are met most economically by using minimum amounts of water. The employee safety considerations imposed by OSHA make both FDA and EPA regulations more difficult to meet at practicable levels of capital expenditures. A solution to this dilemma could result from a series of discussions by policy-making officials of the various agencies involved. Hopefully, guidelines compatible to all interests would be forthcoming from such meeetings. We would be willing to pinpoint problem areas, as we see them, if this would be helpful to such deliberations.

A second area of concern for our industry is effluent guidelines, which are now being developed and published for comment by EPA. We recognize the impossible nature of the task imposed on EPA in the deadlines

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* President, Canners League of California

established by Public Law 92-500, also known as the Federal Water Pollution Control Act Amendments of 1972. The recent court actions setting dates for publication of certain final regulations reflect a misunderstanding on the part of the judiciary of the magnitude of the challenge faced by EPA. Given the limited time-frame in which to work, EPA had no choice but to use contractors to compile data and to make economic evaluations. The result of all of this activity and expense has been identification of the best operations in a given industry (in terms of BOD and SS discharged) and use of these performances as the basis for effluent guidelines. We feel that this approach does not fully consider important differences among various food processing commodities and plants. We recognize and compliment the EPA for establishing sub-categories that have been used so far. My colleagues with research and development responsibilities in the canning industry tell me that an EPA Advisory Committee has recommended a "matrix approach" for establishing guidelines which is more solidly based scientifically than the present system. The matrix model includes such considerations as economic equity, production variations, waste treatment processes, and climatic conditions. We in the canning industry urge EPA to give further consideration to the matrix approach for guideline setting which has been recommended to them by their Advisory Committee chaired by Dr. Martha Sager. We feel that the use of the matrix format for guideline setting will be more equitable and more protective of the public interest than the present "single number" format. I might also add that personal experience in food research and quality control has demonstrated that the statistical analysis of our problems has resulted in the most lasting solutions to these problems; therefore, I wholeheartedly support the "matrix approach" in this situation.

The third and last area of concern I want to raise this morning is that much more research and development work on specific industry problems is needed if we are going to meet the 1983 goals of best available technology most effectively. We appreciate the substantial support, in terms of funding of research grants, which EPA has provided to universities, trade associations, and industrial companies. The results from these projects are being used, or will be used, to help the canning industry meet its responsibility for environmental protection. A most notable example of application of research results is dry caustic peeling. However, much more research is needed, and promising technology must be demonstrated with in-plant installations operated under commercial conditions. To do this, we in industry need continuing and increased financial support from EPA and other federal agencies. The canning industry is spending almost all of its available dollars on in-plant changes to provide essential food at reasonable costs to the consumer without polluting the environment. We simply do not have additional dollars to support large scale research projects beyond our long-standing practice of matching every seven EPA dollars with three dollars from the industry, funnelled through our trade associations or by our support of university research projects. We expect to continue this financial support in the years ahead.

I appreciate this opportunity to speak frankly about some of the concerns of the food canning industry. We in industry want to be good environmental citizens, and we look forward to closer cooperation with EPA to protect the environment. All of us--our children--must live in this world, which is the only one we have--space exploration notwithstanding--and it must be properly protected. At the same time, we all have a responsibility to help use resources and tax dollars most wisely.

Thank you--and have an excellent Symposium.

EXPERIENCE WITH LAND TREATMENT
OF FOOD PROCESSING WASTEWATER

by

Ronald W. Crites*, Charles E. Pound*, and Robert G. Smith*

BACKGROUND

Food processing wastewaters have been applied to the land through engineered systems for more than 25 years. Major interest began in the late 1940s with the objective being primarily waste disposal. In 1934, corn and pea canning wastewater was applied to the land using the ridge and furrow method at Hampton, Iowa[1]. Bolton[1] reported that in a 1942 study, the treatment capability of this soil system was investigated for the first time and was found to be on the order of 50 to 80 percent removal of BOD at a BOD loading of 650 lb/acre/day.

Since then a wide variety of food processing wastewaters has been applied to the land. Grape stillage was reported[2] in 1947 to be applied by flooding at a rate of 3.7 in./day followed by 6 days of resting. Spray irrigation of cannery waste was first reported[3] in 1947 at Hanover, Pennsylvania. Drake and Bieri[4] reported on 4 spray irrigation and 2 ridge and furrow irrigation systems in Minnesota in 1951. In 1950 a large, high-rate, spray irrigation system was put in operation at Seabrook Farms, New Jersey[5]. Cannery wastewater was applied to a wooded area at a rate of 8 in./day. Although the existing trees on the sandy soil have been mostly replaced by marsh grass, the operation continues successfully today[6].

In 1951 citrus wastes were reported[7] to be successfully applied to the land in California using a modified ridge and furrow technique called "back-furrows." In 1955 sugar beet wastewater was applied to grassland by flooding at Bayard, Nebraska[8] and a reduction of 67 percent of the BOD applied was found in the runoff. Wastewater was also being applied to cash crops as Bell[9] reported that poultry wastes were used to spray irrigate 40 acres of alfalfa in Lowell, Arkansas.

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*Metcalf & Eddy, Inc., Palo Alto, California

Many of these early installations were loaded on the basis of successful experience elsewhere, without proper regard for different soil and drainage characteristics. As a result many systems failed and in the process land treatment began to receive some adverse publicity. Today's "zero discharge" requirements, however, coupled with improved understanding of the capabilities and limitations of soil systems have renewed interest in land treatment.

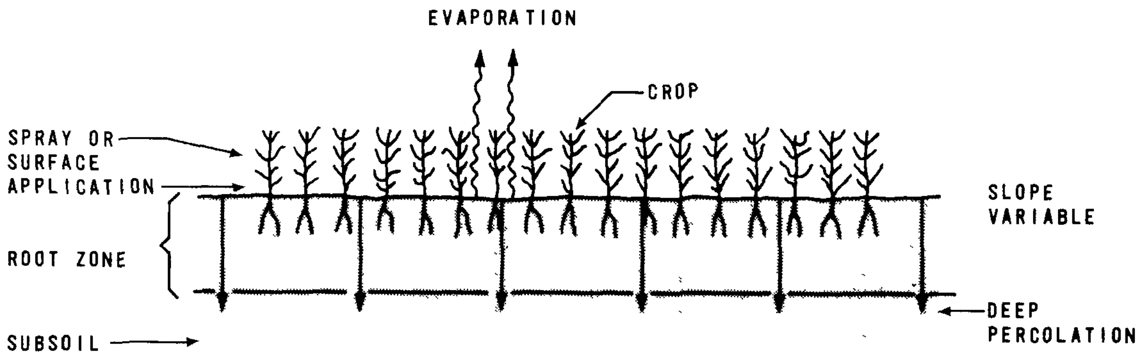
A survey(10) in 1964 resulted in the identification of 844 systems applying food processing wastewater to the land. Pennsylvania had the largest number of systems (143) followed by Wisconsin (141) and California (131). In 1972 as a result of surveys and studies by the American Public Works Association (APWA)(11) and Metcalf & Eddy, Inc.(6), data on more than 85 operating systems were collected. These reports serve as the basis for much of the information presented in this paper.

LAND TREATMENT PROCESSES

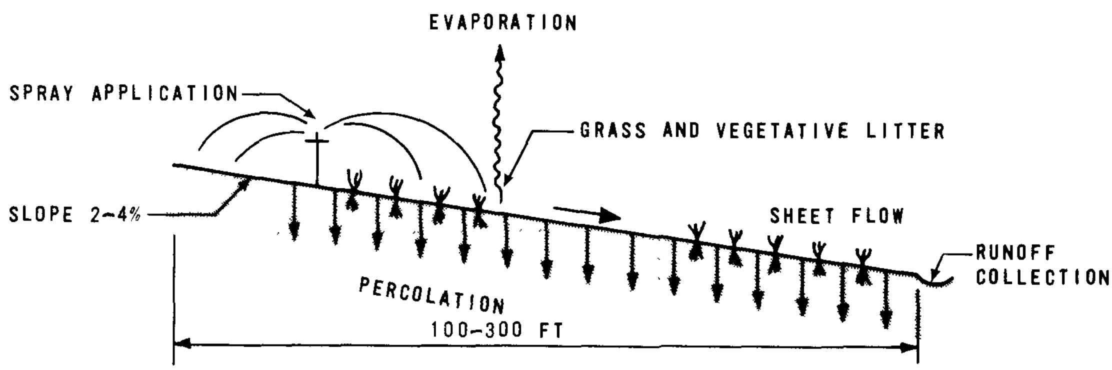
Land application systems for treatment and disposal of food processing wastes are normally categorized into three types of systems based on differences in liquid loading rates and therefore land area requirements as well as differences in the interaction of the wastewater with vegetation and soil. These three categories are referred to as (1) irrigation, (2) overland flow, and (3) infiltration-percolation. Selection of the type of system at a given site is primarily governed by the drainability of the soil because it is this property that largely determines the allowable liquid loading rate. Schematic diagrams indicating the major process characteristics of each of the systems is shown in Figure 1. A summary of the comparative characteristics of the three systems is presented in Table 1.

Table 1. Comparative Characteristics of Land Treatment Systems

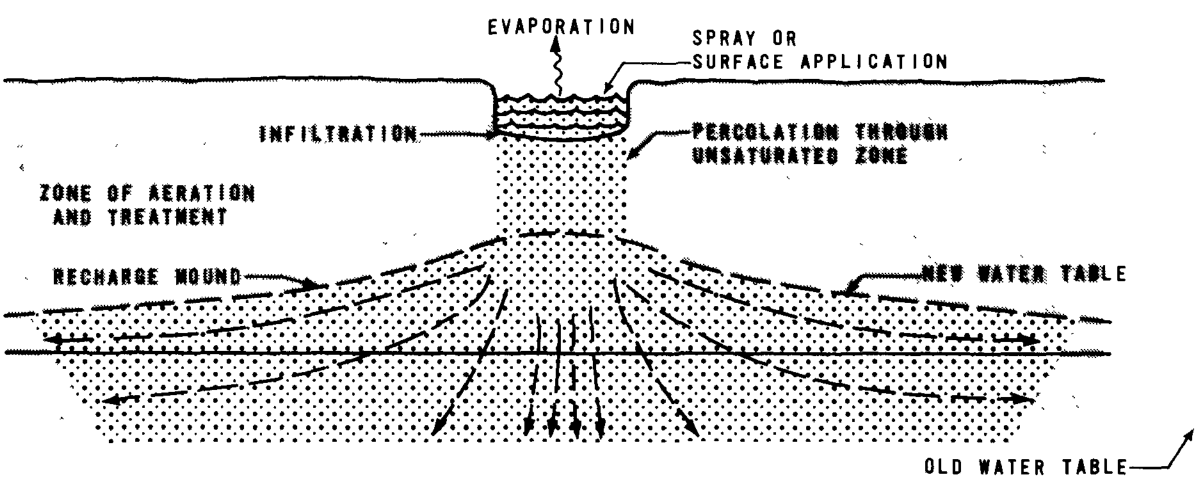
	Type of treatment system		
Factor	Irrigation	Overland flow	Infiltration-percolation
Liquid loading rate, in./day	0.1 to 0.6	0.25 to 0.7	Greater than 0.6
Land required, acre/mgd	60 to 370 plus buffer zone	50 to 150 plus buffer zone	Less than 60
Soil type	Moderately permeable, loamy sand to clay	Slowly permeable, clay loam and clay	Rapidly permeable, sands to sandy loam
Application method	Spray or surface	Spray	Spray or surface



(a) IRRIGATION



(b) OVERLAND FLOW



(c) INFILTRATION-PERCOLATION

FIGURE 1
LAND APPLICATION APPROACHES

Irrigation

Irrigation is considered to include those systems where wastewater is applied to land by either spray or surface techniques at normal agricultural irrigation rates or somewhat in excess of those rates. Liquid loading rates generally range from about 0.1 in./day to 0.6 in./day. At these loading rates, land requirements range from about 60 to 370 acres per mgd of wastewater, plus a buffer zone.

Loamy, well-drained soil is most suitable for irrigation systems, particularly where crop production is a major goal of the operation. However soil types from clays to sands have been found to be acceptable. A minimum soil depth of 5 feet above groundwater is preferred to prevent saturation of the root zone. Underdrain systems have been used successfully to adapt to high groundwater or impervious subsoil conditions.

The objective of most irrigation systems for food processing wastewaters is to maximize hydraulic loadings rather than crop production. The result is that most systems use a water tolerant perennial grass as a cover crop. A few systems use higher valued crops, such as alfalfa or corn, for cover vegetation, but these have only been successful when standard irrigation practices have been followed.

Cover vegetation plays an important role in irrigation systems. This is particularly true in spray application systems where the cover vegetation prevents soil erosion and sealing of the soil surface due to the action of water droplets. The root structure of cover vegetation also aids in maintaining the infiltrative capacity of the surface by expanding the soil and promoting dispersion of clogging materials. Plants are also largely responsible for removal of nutrients such as nitrogen and phosphorus. Removal of the organic materials in the wastewater is accomplished primarily by microorganisms residing in the soil.

A few systems employing surface application techniques, such as border strip or ridge and furrow irrigation, do not use cover crops because the wastewater is either toxic to plants or contains a high suspended solids load that would be trapped by a cover crop at the head of an irrigated strip.

In irrigation systems most of the applied wastewater is either consumed through evapotranspiration or percolates through the soil to become groundwater. Evaporative consumption generally is equal to or greater than percolation.

A portion of the applied wastewater may appear as surface runoff. Failure to adequately control this runoff is a common source of problems at existing systems.

Overland Flow

The overland flow technique is an adaptation of spray irrigation to impermeable or poorly drained soils. The technique was pioneered in 1954 by the Campbell Soup Company at Napoleon, Ohio, and was studied in depth at the Campbell installation at Paris, Texas(12, 13). Until recent studies with municipal wastewaters were performed(14), its application had been restricted to the food processing industry. Overland flow differs from spray irrigation primarily in that a substantial portion of the wastewater applied is designed to run off and must be collected and discharged to receiving waters, or in certain cases where wastewater is produced only during part of the year, stored for deferred application. An overland flow system therefore functions more as a land treatment system than a land disposal system.

Wastewater is applied by sprinklers to the upper two-thirds of sloped terraces that are 100 to 300 feet in length. A runoff collection ditch or drain is provided at the bottom of each slope. Treatment is accomplished by bacteria on the soil surface and within the vegetative litter as the wastewater flows down the sloped, grass-covered surface to the runoff collection drains. Ideally, the slopes should have a grade of 2 to 4 percent to provide adequate treatment and prevent ponding or erosion. The system may be used on naturally sloped lands (such as the two Campbell Soup Company installations at Napoleon, Ohio, and Paris, Texas) or it may be adapted to flat agricultural land by reshaping the surface to provide the necessary slopes.

Higher liquid loading rates are possible with the overland flow technique than with conventional spray irrigation. These rates may range between 0.25 to 0.7 in./day, resulting in a land requirement of about 50 to 150 acres plus buffer zone for each mgd applied.

As mentioned previously, the system is especially suited to use with slowly permeable soils such as clays or clay loams. With this type of soil very little water percolates to the groundwater. Most of it appears as surface runoff or is consumed by evapotranspiration.

A cover crop is essential with the overland flow system to provide slope protection and media for the soil bacteria as well as to provide nutrient removal by plant uptake.

A water tolerant perennial grass such as Reed canary grass or tall fescue has been found to be suitable to the high liquid loading rates.

Infiltration-Percolation

Infiltration-percolation systems are characterized by percolation of most of the applied wastewater through the soil and eventually to the groundwater. The method is restricted to use with rapidly permeable soils such as sands and sandy loams. This type of system is normally thought to be associated with recharge or spreading basins although in food processing applications high-rate spray systems have been used to provide distribution of the wastewater. In actual practice there is not a definite division between irrigation systems previously described and high-rate spray infiltration-percolation systems, but rather a complete spectrum of operations with liquid loading rates ranging from 0.1 in./day to 12 in./day. For purposes of discussion, an average loading rate of 0.6 in./day is used as an arbitrary dividing point between the two types of systems. At this minimum loading rate, infiltration-percolation systems would require about 60 acres plus a buffer zone for each mgd applied.

The use of recharge or spreading basins for treatment and disposal of food processing wastewaters has been limited primarily due to the high organic strength and high solids concentration of typical wastewaters. These constituents clog the soil surface and make it difficult to maintain consistently high soil infiltration rates.

Vegetation is essential in high-rate spray systems to protect the infiltrative surface. For spreading basins cover vegetation would normally not be used for wastewaters containing a high solids concentration because it would tend to entrap solids and prevent satisfactory distribution in the basin.

In infiltration-percolation systems, plants play a relatively minor role in terms of treatment of the applied wastewater. Physical, chemical, and biological mechanisms operating within the soil are responsible for treatment. The more permeable the soil, the further the wastewater must travel through the soil to receive treatment. In very sandy soils this minimum distance is considered to be approximately 15 feet.

WASTEWATER QUALITY AND PRETREATMENT REQUIREMENTS

Wastewater Characteristics

The characteristics of food processing wastewaters that must be considered with regard to land treatment include BOD and COD, suspended solids, total fixed dissolved solids, nitrogen, pH, temperature, heavy metals, and the Sodium Adsorption Ratio (SAR). These characteristics vary widely among food processing wastes applied to the land. Ranges of values observed at existing land treatment systems for these characteristics are listed in Table 2. The possible effects of these characteristics are discussed in the following paragraphs.

Table 2. Characteristics of Various Food Processing Wastewaters Applied to the Land

Constituent	Unit	Value range
BOD	mg/l	200 - 4,000
COD	mg/l	300 - 10,000
Suspended solids	mg/l	200 - 3,000
Total fixed dissolved solids	mg/l	less than 1,800
Total nitrogen	mg/l	10 - 400
pH	--	4.0 - 12.0
Temperature	deg. F	less than 150

BOD and COD - The ratio of BOD to COD is a measure of biodegradability of the wastewater. Most food processing wastewaters are readily degradable and exhibit a high BOD to COD ratio. The soil is a highly efficient biological treatment system, therefore, liquid loading rates at land treatment operations are normally governed by the hydraulic capacity of the soil rather than the organic loading rate. This operational independence from BOD loading is a distinct advantage of land treatment systems over conventional in-plant systems in treating high-strength wastewaters.

There are limits, of course, to the organic loading that can be placed on the land without stressing the ecosystem in the soil. The effects of organic overloads on the soil include damage to or killing of vegetation, severe clogging of the soil surface, and leaching of undegraded organic materials into the groundwater. Defining the limiting organic loading rate for a system must be done on an individual basis. However, rule-of-thumb rates have been developed based on experience. A maximum BOD loading rate of 200 lb/acre/day has been suggested as a safe loading rate for pulp and paper wastewaters[15]. A somewhat higher rate can normally be used with food processing wastewaters containing a higher percentage of sugars rather than starchy or fibrous material. Substantially higher loading rates (greater than 600 lb/acre/day) have been used on a short-term seasonal basis for infiltration-percolation systems. For overland flow systems, organic loadings in the range of 40 to 100 lb/acre/day have been used successfully[6].

Suspended Solids - Solids are generally the major source of operational problems such as clogged sprinklers and clogged soil surface. Pretreatment to remove solids will normally minimize these problems.

Nitrogen - Nitrogen in food processing wastewaters is normally not of major concern because it is usually present in such concentrations that it is almost completely removed by bacterial assimilation or crop uptake. Notable exceptions are feed-lot, dairy, potato processing, and meat packing wastes. The latter have been found to contribute a significant nitrate load to groundwaters.

pH - Wastewaters that have a pH between 6.0 and 9.5 are generally suitable for continuous application to most crops and soils. Wastewaters with pH below 6.0 have been successfully applied to soils that have a large buffering capacity.

Temperature - High temperature wastewaters from cooking operations can sterilize the soil and prevent growth of cover vegetation.

Heavy metals - The soil has a large capacity to adsorb heavy metals. Once this capacity is exceeded, however, the metals may be leached to the groundwater (under acid soil conditions) or inhibit plant growth.

Sodium Adsorption Ratio (SAR) - The ratio of sodium to other cations, primarily calcium and magnesium, can adversely effect the permeability of soils, particularly clay soils. Wastewaters with a SAR below 8 are considered safe for most soils. Sandy soils can tolerate higher SAR values[6].

Pretreatment

Pretreatment is required in most cases to eliminate frequent operating difficulties and avoid adverse effects on the terrain environment.

Screening - Screening with rotary or vibration screens has been almost universally employed as a form of pretreatment to separate coarse solids from food processing wastewaters. Such solids can cause serious problems with wastewater distribution, particularly with spray applications. Fine screens at pump intakes or in-line screens in the discharge piping have also been employed as an added precaution against sprinkler nozzle clogging.

Lagooning - The use of lagoons or settling ponds prior to land application of industrial wastewaters has been prevalent. Such lagoons serve to remove silt and other suspended particles which may contribute to clogging of the distribution system as well as hasten the clogging of soil pore space. This form of pretreatment is normally used when applying wastewaters to vegetated fields by flood irrigation techniques.

pH Adjustment - Industrial wastewaters with sustained flows outside the pH range of 6 to 9.5 should be neutralized prior to land application if the site is to be vegetated. Wastewaters with widely fluctuating flows can be self-neutralizing if an equalization basin is provided prior to land application. In other cases a continous pH control system may be necessary.

Cooling - For wastewaters below 150 deg F, application by sprinkling normally provides sufficient cooling to protect vegetation and soil. Such cooling may be enhanced by the use of sprinklers that produce small spray droplets or that have large spray diameters. Wastewaters with temperatures much above 150 deg F generally should be cooled prior to spraying if vegetation is desired.

Nutrient Addition - Nutrient addition in the form of nitrogen or phosphates may be necessary for nutrient deficient wastes unless the fields are adequately fertilized.

EXISTING LAND TREATMENT SYSTEMS

The design and management as well as common operating problems of the different types of systems described above are discussed through descriptions of several selected existing operations.

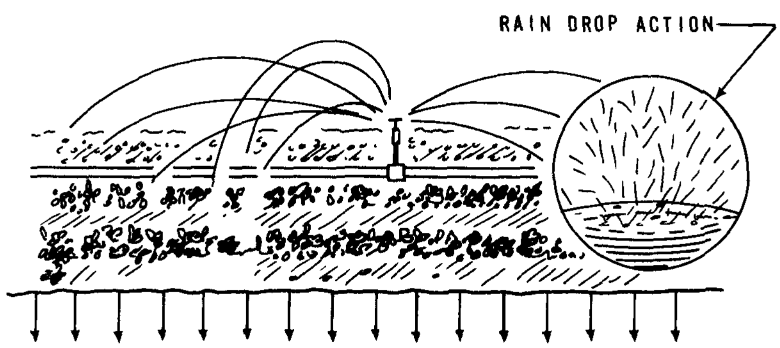
Irrigation Systems

Under the category of irrigation the two basic techniques of wastewater application employed are spray irrigation and surface irrigation. Under spray irrigation, variations that have been observed include solid set sprinklers, portable sprinklers, and tower spraying. Surface techniques include border strip flood irrigation with or without crops and ridge and furrow irrigation also with or without crops. Schematic diagrams of these three methods of application are shown in Figure 2.

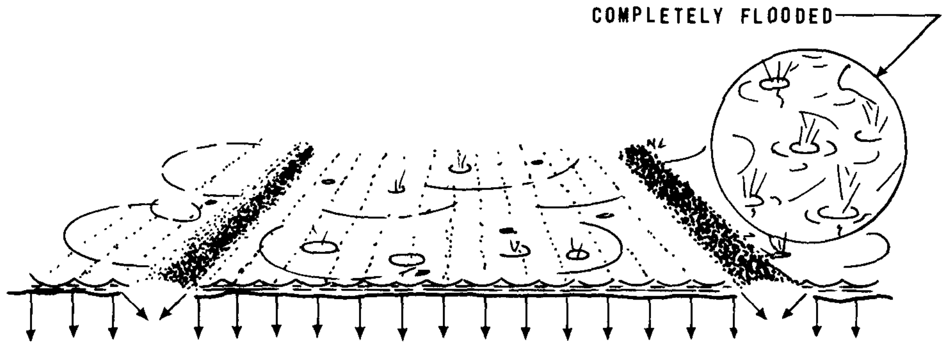
A selected list of spray irrigation systems handling a wide variety of food processing wastewaters is presented in Table 3 along with the major operating characteristics. A similar list for surface irrigation systems is presented in Table 4. Typical systems employing each of the various application techniques are described below.

Solid Set Sprinkler Irrigation - An example of solid set spraying is the system of the *Idaho Supreme Potato Company in Firth, Idaho.* The distribution system is buried with risers spaced on 80-foot squares discharging at 80 to 100 psi. The spray fields are planted to a mixture of Reed canary grass, meadow foxtail, and alta fescue with the yield of hay being 5 tons/acre annually. Potato washing wastewater passes through vacuum filters with the mud going to lagoons and the filtrate to the spray fields where it is mixed with screened wastewater from the potato peeling and cutting operations. The system is well managed with wastewater applied in 12 hours followed by 8 to 9 days of resting in the summer. The system continues to operate during the winter with ice mounds building up to heights of 5 feet. The only change in operation is that spraying lasts for 24 hours followed by 16 to 18 days of resting.

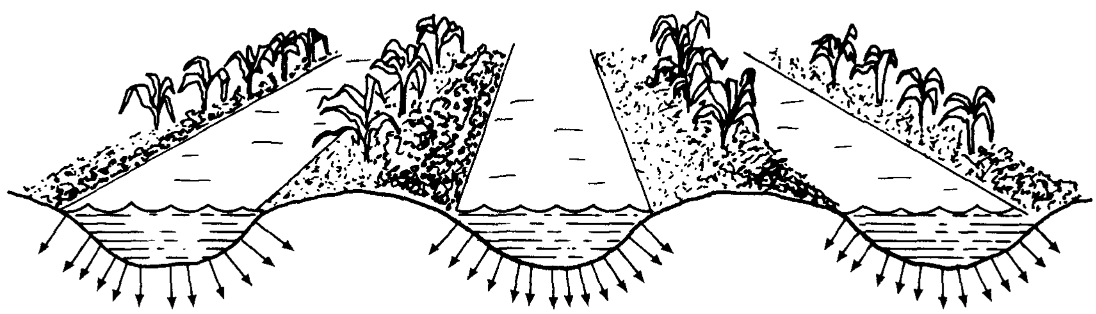
Another interesting example of a solid set spray system is the *California Canners and Growers* tomato processing installations at *Thornton, California.* This system is unique in that high-pressure, high-capacity sprinkler guns are used. These guns are spaced at 170 to 200 foot intervals on a 60-acre site and have a discharge capacity of approximately 300 gpm. This type of system results in a lower



(a) SPRINKLER



(b) FLOODING



(c) RIDGE AND FURROW

FIGURE 2
BASIC METHODS OF APPLICATION

Table 3. SELECTED SPRAY IRRIGATION SYSTEMS

Location	Type of wastewater	Avg flow, mgd	Irrigated area, acres	Average application rate, in./day	Crops	Soil type
California Canners & Growers Thornton, California	Tomato	2.5	270[a]	0.34	Grass, alfalfa	Fine sandy loam
Sebastopol Coop Sebastopol, California	Apple	0.3	54	0.20	Grass	Clay loam
Tri Valley Growers Stockton, California	Tomato	3.0	165	0.67	Grass	Clay loam
Western Farmers Assoc. Aberdeen, Idaho	Potato	0.5	90	0.20	Grass	Clay loam
Idaho Supreme Potato Co. Firth, Idaho	Potato	0.6	80	0.29	Grass	Silt loam
Chesapeake Foods Cordova, Maryland	Poultry	0.5	40	0.50	Grass	Sandy loam
Gerber Products Co. Fremont, Michigan	Food processing	0.8	90	0.33	Grass	Sand
Michigan Milk Prod. Ovid, Michigan	Milk	0.25	26	0.35	Grass	Sand
Stokely-Van Camp Fairmont, Minnesota	Food processing	1.5	400	0.14	Corn, peas, grass	Clay
Green Giant Co. Montgomery, Minnesota	Corn, peas	1.2	360	0.12	Grass	Silty clay loam
Libby, McNeill & Libby Liepsic, Ohio	Fruit	0.66	130	0.19	Alfalfa	Clay
Cobb Canning Co. Cobb, Wisconsin	Vegetables	0.2	22	0.34	Grass	Silt loam

a. 60 acres in spray fields.

Source: APWA and Metcalf & Eddy surveys.

Table 4. SELECTED SURFACE IRRIGATION SYSTEMS

Location	Type of wastewater	Method of application	Avg flow, mgd	Average application rate, in./day	Soil type
Libby, McNeil & Libby Gridley, California	Fruit	Flood	2.5	0.48	Clay loam
California Canners & Growers Thornton, California	Tomato	Flood	2.5	0.29	Fine sandy loam
J.R. Simplot Co. Boise, Idaho	Potato	Flood	3.0	--	--
Green Giant Co. Buhl, Idaho	Corn	Ridge and furrow	1.0	0.27	Silty loam
Idaho Fresh Pak Lewisville, Idaho	Potato	Flood	1.06	0.30	Silty loam
Armour Food Co. Hereford, Texas	Meat processing	Ridge and furrow	1.15	--	--
Alto Coop Creamery Astico, Wisconsin	Milk	Ridge and furrow	0.12	0.15	Clay
Big Horn Canning Co. Cowley, Wyoming	Canning	Ridge and furrow	0.50	0.46	--

capital cost but sacrifices good distribution of wastewater. This nonuniform distribution contributes to ponding problems when operating at high liquid loading rates. The spray field is planted to water grass but not harvested. Prior to spraying, the raw wastewater is screened and sent through lagoons to provide settling and flow equalization.

Before expansion of the facilities in 1973, wastewater was applied to the spray field sections each day on a rotating basis for 1/2-hour intervals every 3-1/2 hours. The result was a loading rate of more than 1 in./day. This rate exceeded the infiltrative capacity of the soil and resulted in substantial runoff. Although runoff collection and disposal facilities were provided, inadequate land leveling resulted in widespread ponding. The ponding caused severe mosquito propagation problems which were compounded by the very tall grass. In addition, the runoff, which was discharged to a local waterway, did not meet discharge quality requirements. These conditions were successfully corrected by the addition of a 150-acre surface irrigation system that is discussed under that category.

Portable Sprinkler Irrigation - The spray system at *Tri Valley Growers* tomato processing installation near *Stockton, California*, is a good example of a portable sprinkler system. The spray field consists of 165 acres with 90 acres planted to water grass and 75 acres planted to Sudan grass. The sprinkler system consists of 16-inch portable aluminum mains and 4-inch portable laterals with sprinklers on a 60-foot grid. Although the system is portable, it is operated as a solid set system without moving the laterals prior to the end of the season. Pretreatment of the wastewater consists of coarse screening, a holding pond for equalization and sedimentation, plus in-line screens in the discharge lines of the spray system pumps.

Prior to the addition of the 75 acres to the spray fields in 1973, approximately 3 mgd of tomato processing wastewater was applied to 90 acres with each of nine 10-acre sections receiving full flow for approximately 3 hours at a time. The resulting average liquid loading rate was in excess of 1.2 inches per day on a clay loam soil. This application rate was far in excess of the infiltrative rate of the soil and the evapotranspiration demand of the cover crop. Therefore approximately 30 percent of the applied water appeared as runoff. The runoff was collected and channeled back to the pumping station for recirculation over the system. Runoff was not discharged to local receiving waters because of particularly stringent discharge requirements of 15 mg/l BOD and 15 mg/l suspended solids. The recirculated runoff, therefore, accumulated and was actually stored on the field surface and in the drainage ditches. The flooded conditions that developed led to odor and mosquito propagation problems. The crop was allowed to grow throughout the season and became quite tall. This tall grass impeded drying of the soil surface and produced sheltered habitat for mosquito breeding.

The flooded condition was partially relieved in 1973 by the addition of 75 acres of spray field and regrading the existing 90 acres. The resulting loading rate was 0.67 in./day. In addition, the cover crop was harvested as part of the field management. Prior to harvesting, the field was allowed to dry for a period of 7 days. The grass was mowed and removed as green chop in one cutting during the 1973 season. For 1974, the expected flow is 2 mgd as a result of the separation of cooling water and the resulting application rate would be reduced to 0.45 in./day.

Tower Spray Irrigation - A unique spraying system has evolved at the *Stokeley-Van Camp* installation at *Fairmont, Minnesota*. In the early 1950s a portable solid-set system was used, but the labor required to move the laterals proved too expensive. This system was replaced by a boom-type center pivot irrigation rig which also was too demanding of labor for maintenance. Finally, a fixed tower system was designed with fog nozzles operating at high pressure. The system now operates successfully using towers at 500-foot centers that are about 25-feet high(11).

Flood Irrigation - The *California Canners and Growers* installation at *Thornton, California*, previously described under spray irrigation, is also a good example of surface irrigation systems because border strip flood irrigation is employed both with and without cover crops. The vegetated section consists of 60 acres planted to water grass. The wastewater is distributed onto the strips by means of gated aluminum pipe. This distribution system is coupled to and operates in rotation with the high pressure spray system. Prior to the expansion in 1973, wastewater was applied to this section for 4 to 6 hours each day without any resting periods. The cover crop was not harvested. Inadequate land leveling in the area resulted in ponding and along with the tall grass contributed to the mosquito problems previously described.

In 1973 the treatment system was expanded to include 150 acres of nonvegetated flood irrigation strips. Each strip is 60 feet wide and up to 1,500 feet long. The wastewater distribution system consists of a combination of gated aluminum pipe and concrete-lined ditches with slide gates. Wastewater is applied to several strips (2 to 4) until flow reaches the end of the strip. The only significant operating problem encountered was erosion along the borders and, eventually, standing water at those points. This problem could be avoided by forming the borders using dike construction methods rather than the ridging method commercially used in agriculture. The runoff is collected in a tailwater return system and pumped back to the distribution ditch. The first operating season was too short to establish equilibrium application rates. However, with the expanded system the average application rate for the entire system was reduced to about 0.35 inches per day.

A second example of flood irrigation is the *Idaho Fresh Pak* system at *Lewisville, Idaho*. The land has been graded into 2.5-acre plots for border strip irrigation. Potato-peel wastewater passes through a vacuum filter and the filtrate is pumped 4.5 miles to the site. In the summer, grass is grown and harvested for hay. In the winter the 50 deg F wastewater melts the snow and ice and percolates into the soil. Some odors exist and more land is being acquired by the company.

The *Libby's* cannery in *Gridley, California*, is beginning construction of a nonvegetated surface irrigation system to treat peach and pumpkin processing wastewaters. Border strip flood irrigation without crops was selected to eliminate the need for settling prior to application and to guard filtering out settleable material by the cover crop at the head end of the irrigation strips. Wastewater will be pumped from the plant to the irrigation site located about 4 miles to the south. Prior to pumping, the wastewater will pass through coarse screens and a grit removal chamber. Grit removal is considered necessary to prevent deposition in the conveyance force mains. Application of the wastewater will be managed to provide drying of the soil surface within 24 hours of application to prevent mosquito propagation.

Ridge and Furrow Irrigation - This form of irrigation has been replaced, for the most part, by spray irrigation. Whereas Schraufnagel[16] reported about 50 ridge and furrow systems in 1962, Sullivan[11] reported only one ridge and furrow system out of the 56 responding to the APWA questionnaire. That system was the *Green Giant Company* installation at *Buhl, Idaho*, where corn-processing wastewater is screened and used as supplemental irrigation water for corn. In addition to the systems listed in Table 4, other systems reported in existence by an APWA mail survey are five creameries in Wisconsin and three food processing plants in Indiana.

Overland Flow Systems

The overland flow systems described below are examples of how the system may be adapted to different site conditions. A list of existing systems with operating characteristics is presented in Table 5.

Table 5. Selected Overland Flow Systems

Location	Avg flow, mgd	Field area, acres	Average application rate, in./day	Soil type
Hunt-Wesson Foods Davis, California	3.25	250	0.5	Clay loam
Campbell Soup Co. Chestertown, Maryland	0.7	70	0.4	Clay
Campbell Soup Co. Napoleon, Ohio	4.0	335	0.45	Silty clay
Campbell Soup Co. Paris, Texas	3.5	385	0.35	Clay loam

The *Hunt-Wesson Foods* cannery in *Davis, California,* employs the overland flow technique to treat approximately 3.25 mgd of tomato processing wastewater from July through September, plus smaller volumes of wastewater from other products during the remainder of the year. The system consists of a series of sloped terraces with collection ditches at the toe of each slope. The terraces were constructed on a slope of 2.4 percent with a length of 175 feet. A considerable amount of earthwork was required to form the slopes (over 300,000 cu yd) since the site was originally flat agricultural land. The slopes were planted to a combination of Reed canary grass, tall fescue, Italian rye grass, and trefoil with the anticipation that Reed canary grass would eventually dominate. The distribution system consists of a solid set sprinkler system with risers spaced at 100-foot intervals and 65 feet from the top of each slope.

Spraying is preceeded by coarse screening. The application of wastewater is controlled automatically by clock timers that actuate pneumatic valves in the field. During peak season, however, the spray rotation is controlled manually with an effort to minimize runoff. The runoff, which amounted to about 10 percent of the applied flow during the 1973 season, is collected and conveyed to an effluent pumping station for discharge to receiving waters. Treatment efficiency in terms of BOD removal is excellent. A raw waste BOD ranging from 400 to 800 mg/l is reduced to less than 12 mg/l by the season's end.

The cover crop is harvested once each year in late April or early May. Since the operation is seasonal, additional cuttings are not warranted. The yield of hay is approximately 1.6 ton/acre.

The overland flow system at the *Campbell Soup Company* plant in *Paris, Texas*, is the most thoroughly studied of the existing systems(12). This site was originally severely eroded sloping land that was reshaped into a network of sloping terraces with widths ranging from 200 to 300 feet and grades ranging from 1 to 12 percent. Subsequent studies revealed the optimum slope grade to range from 2 to 6 percent (13). Wastewater is applied at the approximate rate of 0.1 in./hr to the upper portion of a slope for 6 to 8 hours continuously, followed by a resting period of twice the application time. Runoff is collected and discharged to a natural waterway. Approximately 60 percent of the water appears as runoff. The quality of runoff has been consistently excellent as evidenced by the removal efficiencies shown in Table 6.

Table 6. Removal Efficiencies for Overland Flow at Paris, Texas

Parameter	Influent, mg/l	Effluent, mg/l	Removal, % [a]
BOD	490.0	8.0	98
Suspended solids	245.0	24.0	90
Total nitrogen	19.0	3.0	85
Total phosphorus	8.5	4.0	55

a. Based on concentrations.

The cover crop management consists of harvesting two or three times beginning in the spring. Yields are in the range of 3.5 to 4 tons/acre.

Infiltration-Percolation Systems

Under the category of infiltration-percolation, two methods of wastewater application are employed. These are spreading basins or percolation beds and high rate spraying. A selected list of existing installations is presented in Table 7. Examples of systems employing the two application techniques are described below.

Table 7. Selected Infiltration-Percolation Systems

Location	Method of application	Avg flow, mgd	Average application rate, in./day	Soil type
Tri Valley Growers Modesto, California	Flood	2.5	1.5	Sand
Hunt-Wesson Foods Bridgeton, New Jersey	Spray	3.0	2.5	Sand
H.J. Heiz Co. Salem, New Jersey	Spray	1.3	1.6	Sandy silt
Seabrook Farms Seabrook, New Jersey	Spray	14	8.0	Sand
Campbell Soup Co.[a] Sumter, South Carolina	Spray	3.5	0.9	Sand
Yakima, Washington	Spray	4.0	1.2	Sandy loam

a. System is underdrained at a depth of 5 feet.

Tri Valley Growers' Plant No. 2 near *Modesto, California*, is one of the few processing plants where classical spreading basins are employed for infiltration-percolation. A wasteflow of approximately 2.5 mgd is generated from the processing of tomatoes, peaches, and pears with the canning season normally extending from July through September. The infiltration-percolation site consists of 70 acres of spreading basins and 20 acres of wine grapes. The grapes are irrigated with wastewater using normal application rates with no adverse effects on grape quality. The soil at the site is primarily sand and loamy sand.

The infiltration-percolation site is divided into one-acre basins. Most of the basins receive wastewater from concrete-lined ditches equipped with slide gates, while the remainder are served by a buried-pipe system with flood valves. This pipe must be flushed with fresh water after each application to prevent release of odors. The application schedule and loading rates have been developed by trial and error, since each basin was found to have a different percolation capacity. The differences are due to hardpan layers in the subsoil. This situation is a good example of why subsurface soil conditions should be determined as part of a site investigation for infiltration-percolation systems. Applications range from 50,000 to 500,000 gallons per acre depending on the basin. Each application is followed by 7 to 10 days of resting. The applications are regulated to achieve elimination of standing water within 24 hours of the start of application. This avoids both odor and mosquito problems.

During the summer no cover crop is used on the basins. After each application the basins are disked to allow the soil to aerate and maintain its infiltrative capacity. As the season proceeds, the infiltrative capacity drops somewhat due to clogging by solids in the wastewater. Following the canning season, the basins are planted to oats which are harvested in the following spring. The oats serve to take up some of the nitrogen that was contained in the wastewater and held in the soil structure, as well as to restore the infiltration capacity of the soil.

Research on the system's long term effect on the groundwater is being sponsored by Tri Valley Growers and conducted by the University of California Agricultural Extension Service. Permanent soil sampling stations have been established at several locations that allow extraction of water samples from various depths.

As mentioned previously, the infiltration-percolation system using high-rate spraying at *Seabrook Farms* has been in continuous operation since 1950. In each of the three New Jersey systems listed in Table 7, the soils are very permeable and the vegetation that survives the high-liquid loadings is totally wild. At Seabrook Farms in 1950 the site was wooded with oaks, cedars, ironwood, gum, and dogwood trees(6). As a result of the high-rate spraying the dominant form of vegetation is now marsh grass. The areas that have proven to be permeable now receive as much as 12 in./day over a 12-hour period.

COSTS

At present the availability of useful cost data on land treatment systems is limited, but efforts are underway at Metcalf & Eddy to develop a cost reference through a contract with the EPA. The cost data presented herein are based primarily on the APWA report[11] and are supplemented with information on a few systems in California.

Spray Irrigation

Costs for selected spray irrigation systems are given in Table 8. Construction costs include costs for pumping stations, force mains, land preparation, and distribution systems, except as noted, and depend on the year constructed as well as many local conditions. Land costs have been separated because of their variability and are presented in Table 9. In addition to the cost of land when purchased, the estimated value of the land in 1972 is included in Table 9. In all cases the value of the land is at least as high as when it was purchased and in several cases land values have appreciated substantially. The total capital cost is the sum of the costs for land and construction plus easements, pretreatment facilities, monitoring facilities, and administrative, engineering, and legal fees. In the case of the Libby operation at Liepsic, Ohio, the land for spray irrigation is leased.

Operating costs are also given in Table 8. The annual budget was divided by the total annual flow to obtain the cost in cents per thousand gallons. The period of operation ranged from 4 months for the Green Giant Company operation at Montgomery, Minnesota, to 12 months for the Gerber operation at Fremont, Michigan[11].

Surface Irrigation

Costs for surface irrigation depend a great deal on the existing topography. Consequently the cost of preparing the land for irrigation must be balanced against the purchase price of the land. For example, the Libby's system at Gridley did not entail any land preparation costs because the fields were leveled previously for irrigation. However, the land cost was $1,400 per acre. On the other hand, for the California Canners and Growers system at Thornton, costs for land preparation and the distribution

Table 8. Construction and Operating Costs for Selected Spray Irrigation Systems

Location	Avg flow, mgd	Construction cost: Cost, $	Year made	Cost $/gpd	Cost $/acre	Operating cost: Annual cost, $	¢/1,000 gal.[a]
Sebastopol Coop Sebastopol, California	0.3	88,100[b] (34,700)[c]	1972	0.29[b]	1,630[b] (640)[c]	3,400	7.1
Western Farmers Assoc. Aberdeen, Idaho	0.5	95,000[b]	1971	0.19	1,050	25,000	18.2
Idaho Supreme Potato Co. Firth, Idaho	0.6	64,000[b]	1969	0.10	800	--	--
Gerber Products Co. Fremont, Michigan	0.8	75,000	1953	0.09	830	65,000	22.3
Stokely-Van Camp Fairmont, Minnesota	1.5	100,000	1965- 1972	0.07	250	23,000[d]	7.2
Green Giant Co. Montgomery, Minnesota	1.2	72,000	1949	0.06	200	28,000	23.3
Libby, McNeill & Libby Liepsic, Ohio	0.7	45,000	1972	0.06	350	50,000[e]	31.1
Lamb-Weston Connell, Washington	1.6	210,000 50,000	1971 1972	0.13 0.03	800 190	179,000	30.0
Cobb Canning Co. Cobb, Wisconsin	0.2	8,500	1960	0.04	390	3,000	12.4

a. Depends upon period of operation.

b. Total cost includes pretreatment, transmission, land preparation, and distribution but excludes land costs.

c. Distribution and land preparation only.

d. Total cost not including return from sale of crops.

e. Includes $17,000 annual lease but not return from sale of crops.

Table 9. Land Costs for Selected Spray Irrigation Systems

Location	Land area, acres	Year purchased	Cost, $/acre	Estimated value in 1972, $/acre
Sebastopol Coop Sebastopol, California	54	1972	800	800
Western Farmers Assoc. Aberdeen, Idaho	90	1971	450	450
Idaho Supreme Potato Co. Firth, Idaho	80	1969	600-800	800
Green Giant Co. Belvidere, Illinois	160	1960	600	5,000
Duffy-Mott Co. Hartford, Michigan	40	1967-8	600	1,000
Lamb-Weston Connell, Washington	265	1970	225	650
American Stores Dairy Co. Fairwater, Wisconsin	200	1942	110	400
Libby, McNeill & Libby Janesville, Wisconsin	50	1952	250	1,500

system totalled $450 per acre (total construction cost shown in Table 10). Adding this to the land cost of $870 per acre yields a total of $1,320 per acre at Thornton, as compared to the $1,400 per acre at Gridley. Of course, many of the local conditions were different. However, the combination of land cost and land preparation cost is an especially important consideration for surface irrigation systems. Additional land costs are given in Table 11.

Table 10. Construction and Operating Costs for Selected Surface Irrigation Systems

Location	Avg flow, mgd	Construction cost				Operating cost	
		Cost, $	Year made	Cost, $/gpd	Cost, $/acre	Annual cost, $	¢/1,000 gal.[a]
Libby, McNeill & Libby Gridley, California	2.5	360,000	1974	0.14	1,875	--	--
California Canners & Growers Thornton, California	1.2	146,000	1973	0.12	970	--	--
Green Giant Co. Buhl, Idaho	1.0	1,200	1963	0.001	9	7,400	12.4
Alto Coop Creamery Astico, Wisconsin	0.12	17,000	1961	0.14	566	--	--

a. Depends upon period of operation.

Table 11. Land Costs for Selected Surface Irrigation Systems

Location	Land area, acres	Year purchased	Cost, $/acre	Estimated value in 1972, $/acre
Libby, McNeill & Libby Gridley, California	192	1973	1,400	1,400
California Canners & Growers Thornton, California	173	1973	870	870
Green Giant Co. Buhl, Idaho	135	1963[a]	--[a]	1,000
Alto Coop Cannery Astico, Wisconsin	30	1959	240	--

a. Land leased for $55 per acre.

Overland Flow

Construction cost items for overland flow include earthwork, pretreatment, transmission, distribution, and collection(6). Clearing of land, grading of slopes, and planting is generally equal in cost to the distribution system. The available costs for distribution systems and land preparation for two operating systems are given in Table 12. The operating costs shown are total costs not including the return from the sale of hay. The return on the sale of hay is approximately 8 to 10 percent of the total annual operating cost.

Table 12. Construction and Operating Costs for Overland Flow Systems(6)

Location	Average flow, mgd	Construction cost, $/acre	Operating cost, ¢/1,000 gal.
Hunt-Wesson Foods Davis, California	3.25[a]	1,500	5-10
Campbell Soup Co. Paris, Texas	3.5[b]	1,006	5

a. 3-month operating season, constructed in 1971.

b. Year-round operation, constructed in 1964-1965.

Infiltration-Percolation

For infiltration-percolation systems, the costs per gpd, as shown in Table 13, are relatively low compared to spray irrigation. Similarly, the operating costs are lower due also to the high-rate applications and low land requirements. The only available land cost was $400 per acre in 1961 for the Hunt-Wesson system at Bridgeton, New Jersey.

Table 13. Construction and Operating Costs for Selected Infiltration-Percolation Systems

Location	Average flow, mgd	Construction cost			Operating cost ¢/1,000 gal.[a]
		Year made	Cost, $/gpd	Cost, $/acre	
Hunt-Wesson Foods Bridgeton, New Jersey	3.0	1961	0.08	5,460	3.6
H.J. Heinz Co. Salem, New Jersey	1.3	1955	0.077	3,340	--
		1970	0.038	1,670	
		1972	0.031	1,330	
Seabrook Farms Seabrook, New Jersey	14	1950	--	--	4.8
Yakima, Washington	4.0	1964	0.027	1,500	--

a. Depends upon the period of operation.

APPLICABILITY AND POTENTIAL OF LAND APPLICATION

It is apparent from the descriptions of the various existing systems that land application can be adapted to a wide range of soil types and site drainage conditions. One of the keys to a successful system is to determine the site characteristics--soil type, soil drainage, subsurface conditions, topography, and climatic conditions--and then adapt the most suitable technique to them. Equally important to successful operation is conscientious field management to avoid stressing or overloading the system.

Of particular interest to the food processing industry is the ability of land application techniques to meet "zero discharge" requirements at a reasonable cost. As more food processing activity becomes centered in rural areas the economic advantages of land application will become more evident.

Land application, however, is not a panacea. Many uncertainties still remain regarding long-term effects of wastewater on soils, plants, and groundwater. Research in this regard is being carried on at several locations. Dr. Jay Smith of the USDA in Kimberly, Idaho, is conducting a 3-year study of land application of potato processing wastewaters in Idaho. EPA has sponsored considerable research on overland flow with some findings to be discussed later in the conference. As mentioned previously under infiltration-percolation, the California Agricultural Extension Service is conducting a study on the treatment efficiency at Tri Valley Growers Plant No. 2 and the results will be published this summer in *California Agriculture.*

The food processing industry has taken the lead in developing land application as an economic alternative to conventional treatment methods. This is evidenced by the fact that over one-third of all the land application systems in the United States serve the industry. Active interest, such as the research efforts mentioned above, indicates that the industry will continue to be at the forefront of future development.

REFERENCES

1. BOLTON, P. Disposal of Canning Plant Wastes by Irrigation. Proceedings of the 3rd Industrial Waste Conference. Lafayette, Purdue University. pp 272-281 (1947).
2. COAST LABORATORIES. Grape Stillage Disposal by Intermittent Irrigation. Prepared for the Wine Institute, San Francisco (June 1947).
3. WATER RESOURCES ENGINEERS, INC. Cannery Waste Treatment, Utilization and Disposal. California State Water Resources Control Board Publication No. 39 (1968).
4. DRAKE, J.A., AND BIERI, F.K. Disposal of Liquid Wastes by the Irrigation Method at Vegetable Canning Plants in Minnesota; 1948-1950. Proceedings of the 6th Industrial Waste Conference. Lafayette, Purdue University. pp 70-79 (1951).
5. MATHER, J.R. The Disposal of Industrial Effluent by Woods Irrigation. Proceedings of the 8th Industrial Waste Conference. Lafayette, Purdue University. pp 439-353 (1953).
6. POUND, C.E. and CRITES, R.W. Wastewater Treatment and Reuse by Land Application - Vol. II. Office of Research and Development, Environmental Protection Agency (August 1973).
7. LUDWIG, H. ET AL. Disposal of Citrus Byproducts Wastes at Ontario, California. Sewage and Industrial Wastes 23: 1255 (1951).
8. PORGES, R. and HOPKINS, G. Broad Field Disposal of Sugar Beet Wastes. Sewage and Industrial Wastes 27: 1160 (1955).
9. BELL, J.W. Spray Irrigation of Poultry and Canning Wastes. Public Works 86: 111 (1955).
10. HILL, R.D., BENDIXEN, T.W. and ROBECK, G.G. Status of Land Treatment for Liquid Waste--Functional Design. Presented at the Water Pollution Control Federation Conference, Bal Harbour, Florida (October 1964).

11. SULLIVAN, R.H. ET AL. Survey of Facilities using Land Application of Wastewater. Office of Water Program Operations. Environmental Protection Agency (July 1973).

12. GILDE, L.C. Food Processing Waste Treatment by Surface Filtration. Proceedings of the First National Symposium on Food Processing Wastes. Portland, Oregon. pp 311-326 (April 1970).

13. C.W. THORNTHWAITE ASSOCIATES. An Evaluation of Cannery Waste Disposal by Overland Flow Spray Irrigation. Publications in Climatology, Vol. 22 (September 1969).

14. THOMAS, R.E. Spray-Runoff to Treat Raw Domestic Wastewater. Presented at the International Conference on Land for Waste Management. Ottawa, Canada (October 1973).

15. BLOSSER, R.O. and OWENS, E.L. Irrigation and Land Disposal of Pulp Mill Effluents. Water and Sewage Works, 111: 424 (1964).

16. SCHRAUFNAGEL, F.H. Ridge-and-Furrow Irrigation for Industrial Wastes Disposal. Journal WPCF 34: 1117 (1962).

USE OF A MUNICIPAL PERMIT PROGRAM FOR ESTABLISHING FAIR WASTEWATER SERVICE CHARGES

by

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INTRODUCTION

Historically, permit programs have served public wastewater agencies as a means of enforcing regulations. Permits have been issued to ensure compliance with structural standards and as a means of keeping a record of the sewer connections from private property to the public sewer system. More recently, permits have been issued to insure user compliance with standards established in industrial waste ordinances.

The newly increased emphasis on permit programs by municipal agencies is a direct result of Federal Regulations;in particular, the national permit system created by the Water Pollution Control Act Amendment of 1972(1). This permit program for the first time, is a national permit program that is applicable to municipal sewers. The terms and conditions of these permits now being issued to municipal agencies often contain requirements for industrial users such as effluent limitations, monitoring and reporting the industrial users. Previously many states had permit programs and the federal government, through the U. S. Army Corps of Engineers, had issued some permits for discharges under the 1899 Refuse Act. The previous federal programs only affected about 20,000 industrial discharges. New federal regulations such as the provisions of Industrial Cost Recovery(2) from industrial waste users and the enforcing of pretreatment standards will affect more than 100,000 industrial users of municipal systems.

These new requirements, will result in municipal agencies across the country adopting permit programs to enforce pretreatment standards and source control regulations. These federal requirements also offer an opportunity to the municipal agency to adopt a permit program that can be used to equitably recover revenue.

Historical Perspective

Special District No. 1 of the East Bay Municipal Utility District was created in 1944 to treat and dispose of the sanitary sewage and industrial wastes from the cities of Oakland, Berkeley, Alameda, Albany, Piedmont and Emeryville in Alameda County in California. Presently, the District also

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serves the Contra Costa County cities of El Cerrito, Kensington and parts of Richmond. The population at the 1970 census was 618,000 and the geographical area is 83 square miles. The total number of sewer connections or "users" as they are referred to is about 167,000. Of particular interest is the large number of industries that discharge wastewater. Using a commonly accepted definition of industry as all processing and manufacturing operations, there are approximately 1,000 separate industrial users.

When one considers industrial users as defined in the Industrial Cost Recovery Regulations(2) this number rises to 2,000. Within these regulations an "industrial user" has been defined as "any non-governmental user of publicly-owned treatment works identified in the Standard Industrial Classification Manual, 1972, Office of Management and Budget(3), as amended and supplemented under the following divisions: (a) Division A, agriculture, forestry and fishing; (b) Division B, mining; (c) Division C, manufacturing; (d) Division E, transportation communications, electric, gas, and sanitary services; (e) Division I, services. A user in the Divisions listed may be excluded if it is determined that it will introduce primarily segregated domestic wastes or wastes from sanitary conveniences."

Within Special District No. 1 there are 114 known users with over 200 connections to the sewer system that have been categorized within the food processing division (major division SIC 2000, Food Processing). The food processing division is interesting because it provides an example of a category of users where there is little need to enforce a source control program in a large municipal system. The pollutants discharged are regarded as "compatible" with the sewage treatment plant because they can be adequately described in terms of the treatable constituents of suspended solids and biochemical oxygen demand. Table I (Food Processing Industries within Special District No. 1) shows a listing of the industrial categories within the food processing division and the number of industries in the District within each category. The table (Table I) indicates that most of the industry's within the food processing division have small wastewater volume. The number of "major contributory industries" shows this fact. (A major contributory industry has been defined by the Environmental Protection Agency as primarily one that discharges more than 50,000 gallons of wastewater on an average work day or has a flow greater than 5 percent of the flow carried by the municipal system receiving the waste.) Pretreatment standards are applicable to these larger industries if they are discharging incompatible pollutants.

Within most public agencies, significant portions of the compatible pollutants of suspended solids and biochemical oxygen demand will be removed in the treatment process. Consequently pretreatment by food processing industries will not be required. However, the municipal agency must still adopt an equitable system of cost recovery. (In the case of a large industry in relation to a small treatment plant, the agency would be required to enforce some source control to prevent the discharger causing an overload or upset of the treatment process.)

Rates and Charges

The revenue requirements of Special District No. 1 are derived from a combination of use charges and taxes. Those costs allocable to the excess capacity provided for future growth and to the treatment and disposal of stormwater and infiltrated ground and surface water are obtained from ad valorem taxes: all other costs are paid from use charges. Until 1973, the use charge was based solely on volume of wastewater discharged. Table II (Unit Rates Within Special District No. 1) shows the present unit rates for volume and wastewater strength.

Charges on "Quality and Volume" vs. "Surcharges"

In collecting charges from users, the District had to squarely confront the question of equity. The literature and the Federal Revenue Guidelines(2) suggest either charges based on volume and quality, or surcharges as being equitable.

Table I provides an insight into the reason for selection of a rate schedule on quality and volume. Of the 114 users in the food processing category only 26, or less than 23% of the industries are major contributing industries. Past laboratory test results had concluded that the relatively high loading experienced at the treatment plant (suspended solids, 270 mg/l and BOD, 285 mg/l) was due almost entirely to the smaller users. The introduction of a surcharge ordinance would necessitate the sampling and monitoring of a large number of discharges at great expense. Moreover, if the surcharge rate schedule ignored the smaller industries, the rate schedule would have been useless because of the relatively weak strength of most of the large industries. An attempt to enforce a surcharge rate schedule on just large industries would be discriminatory and worst of all, would not provide the equity which had been a fundamental goal. The solution was to group smaller industries by their type of operation. A comprehensive sampling and testing program prior to the establishment of the rates had shown that industries within any one category had similar waste strength characteristics. Table III (Strength Values for Food Processing Industry) lists the average waste strength for various industrial categories within the food processing division of the S.I.C. During the six month period prior to the establishment of the rates, more than 7,000 laboratory tests were made to determine the characteristics of the wastewater for industries within Special District No. 1.

Consequently, in addition to the inclusion of unit rates for each parameter in the District's schedule of rates and charges, a charge was adopted for each user category that reflected the average wastewater strength for that category (See Table IV, Charges for Smaller Industries). The charges for the larger users would be determined on a case-by-case basis under a permit program.

PERMIT PROGRAM

The District's Wastewater Control Ordinance(7) effective January 1, 1973, established a mandatory permit program. One criteria for a mandatory permit depends on the types of pollutants discharged and is applicable to industries discharging "incompatible"(5) pollutants. The second criteria is the size of the discharge. The criteria is applicable to the food processing industry and is based on economic considerations. This criteria was chosen from an evaluation of the probable variation in an industry's wastewater strength parameters and the size of the discharge. Mandatory permits based on the size of the discharge are issued permits to all large industries.

discharging more than 1,100,000 gallons in any month (37,000 gallons/day). This volume represents an average sewage bill of $150/month. For this size bill, a self-monitoring program is economically justifiable. These permits are then issued for the purpose of establishing equitable rates. Charges for permittees are based on a wastewater strength established in the permit and the unit rates for the wastewater quality parameters (See Table II, Unit Rates Within Special District No. 1). These strength values are compared with past District sampling before approval of the permit and are subsequently verified through a self-monitoring program. (Appendix II, Self-Monitoring Report).

For the first permit of a customer, the charges are computed using an estimated annual average wastewater strength. These estimates are made at the industry's discretion and are usually based on a flow composite sample taken over a normal working day or a normal working week.

These estimates are reviewed and if acceptable, become the basis for billing. Their applicability are verified through a self-monitoring program undertaken by the customer and through a District sampling program.

Monitoring Program

The District, having determined at what size sewer bill it would be economic to individually establish the strength, then investigate the criteria for establishing a sampling frequency.

Because the purpose of the permit program is for the establishment of equitable charges, detailed consideration has been given to the frequency of sampling by the industry. Inequities in the cost recovery system are essentially the difference between the amount of sewage service charge paid on the estimated wastewater strength and the amount that would be paid if the charge was based on the actual wastewater strength.
Any sampling frequency must seek to strike a balance between the cost of the sampling program and the inequities in the sewage charges. Table V (Sampling Frequency for Industrial Discharges) shows the sampling frequency established for industries within Special District No. 1. The sampling frequency has been directly related to the size of the sewage service charge and the variation in flow rate. The emperical relationship between these two variables has been derived considering the size of industries within Special District and the present costs of sampling and testing. All samples are required to be flow-proportional samples taken over a normal working day. (For very large industries or industries where there is high flow rate, the samples are required to be composited in proportion to the flow at the time of sampling using an automatic sampler.)

The establishment of sampling frequency on Special District No. 1 differs in two ways from the common practices of most other municipalities. These sampling frequencies are either based on a fixed time interval (e.g. one per month, one per week) without consideration given to the size of the discharger or in the more developed programs, such as of New York and Los Angeles County Sanitation District, are based on rate of flow. Special District No. 1, in recognizing that the prime purpose for a self-monitoring program in the food processing industry is for establishing equitable rates and charges has included the projected sewer service charges as a factor in determining sampling frequency. The sampling frequency is related to the industry's maximum sewer service charges. Where the industry is truly seasonal, variations in sampling frequency are established to fit the seasonal operation. Table VI (Comparison of Sampling Frequencies), compares the sampling frequency used by Special District No. 1 with that recommended by the New York State Department of Public Health(6) and that used by the Los Angeles County Sanitation Districts. Two unit charges have been assumed for industries within Special District No. 1 to facilitate comparison of sampling frequencies.

With each sample collected as part of the self-monitoring program, a test is required on each parameter which is the basis of the sewage service charges. At present, this includes those parameters listed in Table II (Unit Rates Within Special District No. 1). On completion of the secondary treatment construction, a charge on filtered chemical oxygen demand is anticipated. Chemical oxygen demand is considered more useful when attempting to establish charges on non-organic wastes and organic wastes that contain substances toxic to biological tests. The use of filtered chemical oxygen demand will be an attempt not to charge for the same substances or constituents twice.

These parameters, namely suspended solids and filtered chemical oxygen demand will be considered "compatible" with the treatment process and consequently no pretreatment for these parameters will be required. Industries within the food processing division will be able to discharge these wastes without pretreatment, provided the wastes are adequately screened and that oil and grease(4) concentrations of vegetables origin do not interfere with the conveyance or treatment processes.

Pretreatment will be required of wastes that are "incompatible" or are not amenable to adequate treatment by biological systems. These wastes may contain either constituents that pass through, or may interfere with the treatment capability of the biological system. These incompatible pollutants, many of which have been specifically listed in the Wastewater Control Ordinance(7) will be tested on each sample for those industries where a violation could occur. The actual testing frequency in relation to the number of samples is based on a consideration of the average and maximum wastewater strengths of the "incompatible pollutants".(5)

Administration and Operating Costs of the Program

The method of computing rates based on the quality and quantity of wastewater strength have already been discussed. For small industries where self-monitoring would be costly, the rates are established on an industry average. Provision is made for small industries who want to monitor and test their waste and for permittee industries to tailormake rates by use of the permit program. To date, under the permit program, charges have ranged from 9¢ to 83¢/ Ccf.

With the self-monitoring program that is undertaken by the industry, the District also undertakes a sampling program. These costs are recovered directly from the permittee by a charge against his self-monitoring report and a charge against each test required. These charges are presently $5.00 per sample and $1.50 per test required under the terms and conditions of the permit. These charges are based on sample checks averaging once for every four samples taken by the permittee.

To recover the costs of administering the program, the District levies a permit fee. For users who have their sewage service charge based on a strength determination or on an estimate of the wastewater volume, the charge is $100/permit. For users who require both flow and strength determination, the charge is $175. All permits must be renewed annually.

At present, the unit rates recorded in Table II (Unit Rates Within Special District No. 1) are based on the revenue requirements of the District. These revenue requirements are made up of annual capital expenses(which include bond repayments) and operating and maintenance costs. Any changes in these costs or in the amount of volume or quality parameter being discharged to the system can easily be evaluated and if necessary a new unit rate adopted. These new rates would then become the basis for the user category charges and the permit charges.

Industrial Cost Recovery

At the completion of construction of municipal treatment plants that now receive federal funds, each agency must undertake to collect from industrial users their share of the federal grant money(2).

For Special District No. 1 approximately 2,000 users will fall into the category of having to contribute revenue to meet this provision of the law. Using the quality and quantity procedure described previously, these incremental revenues can be allocated to each parameter. A separate parameter rate for the industrial user can be developed that will include their share of the Federal Grant. These industrial unit rates become the basis for charging industries in the various user categories and in the permit program.

The real question, however, is can any equitable rate system be developed within the provision of the law? Any discussion of this matter must finally depend on one's own prejudice of equity and would be incomplete without considering the flow of money in the economy and taxing policies. Obviously, these questions are too grandiose for this discussion but it is worth while to examine three possible options.

1. Agency Charges Industry Additional Amounts to Meet Federal Payback Provision -- The municipal agency recovers its annual capital requirements and then obtains, through a charge to industry, their share of the federal grant.

2. Agency Charges All Users 50% of the Depreciation on the Federal Grant and Industrial Users 100% of the Depreciation on the Federal Grant -- Municipal agency recovers its annual capital requirement in 3 parts: Bond money and interest requirements are computed.

Fifty percent of the Federal Grant is recovered from all users or a larger amount if necessary to cover the annual capital and replacement expenditures of the agency; an additional amount is computed for industry to cover their share of the Federal grant.

3. Both Industry and Non-Industry Contribute Revenue in Proportion to Their Wastewater Load -- The same revenue is collected from all users but is at least 75% of the depreciation on the grant funded facilities in order that industry contributes their full share of the federal grant. (This approach is mandated in California except that the California Water Resources Control Board has specified a minimum of 100% of the depreciation over a service life not to exceed 30 years.)

From Table VII (Comparison of Revenue From Industry Under Various Receipt Formulae) the advantages and disadvantages of these three cases are easily discerned.

Case I

This is probably the simplest to develop in that a satisfactory existing method of calculating rates would remain unchanged with additional amounts to meet the Industrial Cost Recovery Provision collected from industry as a separate item.

Case II

The amounts of revenue remaining for the municipalities' use after returning 50% of the industries's share of the federal grant contains amounts from industry and non-industry in proportion to the wastewater load.

Case III

Both industry and non-industry contribute in proportion to their load on the treatment plant. However, the monies remaining for use by the municipality is 13.5% industry money compared with 20% industry load on the treatment plant.

In all three cases, after meeting the Industrial Cost Recovery requirements the municipality is receiving more money than its annual revenue needs. Under Federal Law, 80% of the retained amount must be used for expansion and reconstruction of the facility. For a few agencies, the annual revenue requirements would exceed the depreciated capital over the 30 years. One point that this table clearly makes in its most general form is the impossibility of being able to collect money in proportion to load and have money in the municipalities' fund for plant replacement and improvements in proportion to load.

CONCLUSION

A municipal permit program can be a powerful tool not only for the traditional enforcement aspects of municipal industrial waste programs but as a means of equitably recovering charges from users. The charges associated with sampling the larger industries have been made directly against the self-monitoring program of the permittee. In establishing the frequency of the self-monitoring program, consideration has been given to the size of the discharge, the variation in discharge, as well as the amount of constituents in the waste stream.

Unless the municipal check-up program indicates, the required tests in the food processing industry are for compatible pollutants only.

Of great importance is the flexibility possible in establishing charges on an individual user basis through a permit program. This flexibility is of utmost importance as agencies face the problem of establishing charges and accounting for revenues associated with the Industrial Cost Recovery provision of the Federal Water Pollution Control Act Amendments. These amounts for industries can be included on a special rate structure or as part of a special permit charge.

The Industrial Cost Recovery provision in its present form, may be possible to administer as detailed in this paper, but lacks a logical explanation, especially under a concept of equity which the Act sets out to provide. Consequently, this provision of the Act should be repealed and replaced by a condition that the public wastewater agency have a program of self-sufficiency and that it have an approved revenue program that proves the agency is collecting rates equitably.

REFERENCES

1. PL 92-500, "Federal Water Pollution Control Act Amendments," October 18, 1972.

2. "Industrial Cost Recovery," CFR Title 40, Chapter 1, Sub-Chapter B, Part 35.

3. Executive Office of the President: Office of Management and Budget, Standard Industrial Classification Manual, U. S. Government Printing Office, 1972

4. Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WPCF, 13th Edition, 1971.

5. "Pretreatment Standards," CFR, Title 40, Chapter 1, Sub-Chapter D, Part 128.18.

6. Industrial Waste Discharges, New York State Department of Public Health, 1972.

7. "Wastewater Control Ordinance," Ordinance No. 270, East Bay Municipal Utility District, Special District No. 1.

TABLE I

FOOD PROCESSING INDUSTRIES WITHIN SPECIAL DISTRICT NO. 1

S.I.C.	DESCRIPTION	NO. OF INDUSTRIES	NO. OF MAJOR CONTRIBUTING INDUSTRIES
201	Meat Products Processing	16	1
2011	Slaughterhouses	1	0
2020	Dairy Products	17	4
2030	Canned & Preserved Fruits and Vegetables	7	6
2040	Grain Mill Products	3	1
2050	Bakery Products	14	3
2051	Bakeries (Bread only)	11	0
2060	Sugar Processing	14	0
2086	Beverages	12	2
2090	Miscellaneous Food	19	9
TOTAL		114	26

TABLE II

UNIT RATES WITHIN SPECIAL DISTRICT NO. 1*

CHARGE BASIS	RATE
Volume	6.4¢/100 cubic feet (Ccf)
Suspended Solids	2.7¢/pound
Chlorine Demand	8.2¢/pound (wastewater strength in excess of 30 mg/l chlorine demand)
Oil and Grease	1.7¢/pound (wastewater strength in excess of 40 mg/l oil and grease)

* At the time of adoption of rates on quality and quantity only primary treatment service was provided.

TABLE III

STRENGTH VALUES FOR FOOD PROCESSING INDUSTRY*

INDUSTRY DESCRIPTION	NO. OF SAMPLES	WASTE CHARACTERISTICS in mg/l		
		SUSPENDED SOLIDS	BIOCHEMICAL OXYGEN DEMAND	CHEMICAL OXYGEN DEMAND (Filtered)
Meat Products Processing	15	846	848	2,251
Slaughterhouses	22	1,367	1,420	1,150
Dairy Products	23	445	1,127	3,536
Canned & Preserved Fruits and Vegetables	33	306	537	1,309
Grain Mill Products	18	1,406	978	721
Bakery Products	17	620	688	3,457
Bakeries (Bread only---Sanitary Wastewater Only)	30	200	200	200
Sugar Processing	8	274	395	999
Beverages	26	140	319	383
Misc. Food	16	563	2,961	4,354

* Samples taken from industries within Special District No. 1.

TABLE IV

CHARGES FOR SMALLER INDUSTRIES IN SPECIAL DISTRICT NO. 1
BASED ON AVERAGE WASTE STRENGTH CHARACTERISTICS

USER CATEGORIES (Based on SIC)	INDUSTRY DESCRIPTION	TOTAL CHARGE ¢/Ccf
7218	Industrial Laundries	40
3110	Leather Tanning	30
2011	Slaughterhouses	30
5812	Eating Places	25
2010	Meat Processing	25
3410	Drums & Barrels	25
2850	Paint Manufacturing	25
2040	Grain Mills	25
2050	Bakeries	20
2020	Dairy Products Processing	15
2070	Fats and Oils	15
2090	Misc. Food Manufacturing	15
2600	Pulp & Paper Products Manuf.	15
7210	Commercial Laundries	15
2030	Canning & Packing	15
----	ALL OTHER USER CATEGORIES	10

TABLE V

SAMPLING FREQUENCY FOR INDUSTRY DISCHARGES

SAMPLE FREQUENCY ONCE EVERY	LARGEST BI-MONTHLY BILL $/month
6 months	0 - 100
4 months	100 - 250
3 months	250 - 500
2 months	500 - 1,000
6 weeks	1,000 - 2,500
4 weeks	2,500 - 5,000
3 weeks	5,000 - 10,000
2 weeks	10,000 - 25,000
10 days	25,000 - 50,000
7 days	>50,000

TABLE VI

COMPARISON OF RECOMMENDED SAMPLING FREQUENCIES*

WASTEWATER DISCHARGE RATE OF FLOW	NEW YORK	COUNTY OF L.A.	SPECIAL DISTRICT NO. 1 ASSUME 10¢ per Ccf	SPECIAL DISTRICT NO. 1 ASSUME 40¢ per Ccf
0.05 MGD	1	0 to 1/3	1/6 to 1/4	1/6 to 1/2
0.05 - 1 MGD	2	1/3 to 4	1/4 to 1	1/2 to 2
1 - 5 MGD	3	4	1 to 2	2 to 3
5.0 MGD	4	4	2 to 4	3 to 4

* Number of samples per month.

TABLE VII

(Capital Only)

COMPARISON OF REVENUE FROM INDUSTRY UNDER VARIOUS
RECEIPT FORMULAE OF INDUSTRY REVENUE AVAILABLE TO AGENCY

ANNUAL REVENUE NEEDS	$1.00	(50% is required for Bond Repayment, 50% is required for improvements and replacements.)
INDUSTRY LOADING	20%	
ANNUAL DEPRECIATION ON NEW PLANT	$2.00	
FEDERAL SHARE AT 75%	$1.50	
INDUSTRY'S SHARE AT 20%	$ .30	

CASE	TOTAL REVENUE COLLECTED	REVENUE FOR USE BY AGENCY	REVENUE COL-LECTED FROM INDUSTRY	REVENUE COL-LECTED FROM NON-INDUSTRY	% INDUSTRY REVENUE FOR USE BY AGENCY
1*	$1.30	$1.15	$ .50	$ .80	30.4
2**	$1.40	$1.25	$ .40	$1.00	20.0
3***	$2.00	$1.85	$ .40	$1.60	13.5

* Case 1 - Agency charges industry necessary additional amounts to meet Federal Pay-back Provision.

** Case 2 - Agency charges all users 50% of the Federal Grant to insure that it has money from industry and non-industry in proportion to wastewater loading.

*** Case 3 - Both Industry and Non-Industry contribute revenue in proportion to their wastewater load. (For a more complete description of Cases 1, 2, and 3, see text.)

Gentlemen:

Attached are the discharger self-monitoring reports for the next calendar quarter. *The elements and constituents to be tested are as specified in* the "Monitoring Schedule", Part G7 of your Wastewater Discharge Permit.

Please composite a sample of your wastewater effluent over a normal working day. The "Discharger Period" specified in Part B2 of your Wastewater Discharge Permit should be used as the period over which the sampling is performed. The sampling intervals for grab or automatic samples taken at periodic time intervals must not exceed two hours. The volume discharged between samples for automatic samplers paced to flow must not exceed 5% of the average daily flow. Samples taken at fixed time intervals must vary in volume consistent with the flow rate at the time of sampling. If the sampling is performed after discharge of equal fixed volumes, the samples may be composited directly.

The composite sample obtained must be tested without delay by a laboratory certified by the State Department of Public Health or a laboratory approved by EBMUD. Keep the sample under refrigeration until the specified tests are run and retain one quart for inspection by EBMUD for thirty (30) days following submission of the discharger self-monitoring reports.

Each discharger self-monitoring report must be signed by the person whose name is entered in Part A5 of the Wastewater Discharge Permit or his designated representative.

The Discharger self-monitoring report forms for the following calendar quarter period will be forwarded to you at the end of this sequence.

Very truly yours,

R. T. WILLIAMS, SR. SANITARY ENGINEER
Technical Services Division, WPCD

RTW:dm

Attachment

EAST BAY MUNICIPAL UTILITY DISTRICT
WATER POLLUTION CONTROL DEPARTMENT

DISCHARGER SELF-MONITORING REPORT
REPORT NO.

DISCHARGER

ACCOUNT NO.
LOCATION
SIDE SEWER NO.

OBTAIN A COMPOSITE SAMPLE OF YOUR WASTEWATER DISCHARGE FROM ONE NORMAL WORKING DAY DURING THE WEEK OF 01/21.

SUBMIT WITHIN 2 WEEKS LABORATORY TEST RESULTS FOR THE FOLLOWING ELEMENTS OF WASTEWATER STRENGTH.

LEAD, MG/L	PB	RESULT ..
PH	PH	RESULT ..
ZINC, MG/L	ZN	RESULT ..
CHROMIUM, MG/L	CR	RESULT ..
TOTAL SUSPENDED SOLIDS MG/L	TSS	RESULT ..
CHLORINE DEMAND, 15 MIN MG/L	CL2D	RESULT ..
OIL AND GREASE, TOTAL MG/L	O&GT	RESULT ..

ESTIMATE OF TOTAL DAILY DISCHARGE.......GALLONS

DATE SAMPLE TAKEN ../../.. ....
MO/DY/YR SIGNATURE

Wastewater Discharge Permit
Part A - Application / Permit

SECTION 1 APPLICATION

EBMUD USE
Date Application Received ______
Permit No A9A ______
Acct Nos A9B ______

Return the completed application by ______
Further Instructions See reverse side

A1 Applicant Business Name ______
A2 Address of premise discharging wastewater
A Street ______
City ______
A3 Business Address
A Street ______
City ______ Zip ______
B Mailing ______
City ______ State ______ C Zip ______
A4 Chief Executive Officer
A Name ______ B Title ______
C Mailing Address ______ D City ______ State ______ Zip ______
A5 Person to be contacted about this application
A Name ______ B Title ______ C Phone ______
A6 Person to be contacted in case of emergency
Name ______ Title ______
Day Phone ______ Night Phone ______
A7 Type of Application (if both mark both boxes)
A ☐ Wastewater Flow Estimation (Complete Part E)
B ☐ Wastewater Strength Determination (Complete Parts B C D E and F)
Check Part(s) Completed B C D E F __
A8 **CERTIFICATION** I certify that the information above and on the indicated Parts is true and correct to the best of my knowledge

SIGNATURE ______ DATE ______

PRINT NAME ______ TITLE ______

SECTION 2 PERMIT (To be completed by EBMUD)

AUTHORIZATION The above named applicant is hereby authorized to discharge wastewater to the community sewer subject to said Applicant's compliance with the EBMUD Wastewater Control Ordinance Part G of this Application/Permit and the following terms and conditions

1 Payment of the following fees and charges when billed by the District
a Annual Permit Fee $ ______
b Monthly Monitoring Program Charges (sampling and testing) $ ______
c Sewage Disposal Service Charge

2 Compliance with the permit conditions as specified in Part G Specifically you are required to

3 The Applicant shall report to EBMUD Water Pollution Control Department any changes (permanent or temporary) to the premise or operations that significantly change the quality or volume of the wastewater discharge or deviate from the terms and conditions under which this Permit is granted

4 EFFECTIVE DATE ______ 5 EXPIRATION DATE ______

______ DATED ______ MANAGER WATER POLLUTION CONTROL DEPT

SD 30 • 7/73

INSTRUCTIONS FOR COMPLETING PART A

SECTION 1 APPLICATION

Type or print the information requested

A1 **Applicant Business Name** – Enter the name or title of your business, preferably the same name as shown on your EBMUD water bill

A2 **Address of Premise Discharging Wastewater** – Enter the full street address of the building or premise which is producing the wastewater pertinent to this Application

A3 **Business Address** – Enter the business street address and the full mailing address

A4 **Chief Executive Officer** – Enter the name, title and full mailing address of the Applicant's Chief Executive Officer in the home office (This is often not the same address as given in A3)

A5 **Person to be contacted about this Application** – Give the name of the person who is thoroughly familiar with the facts reported on these forms and who can be contacted by the staff of EBMUD

A6 **Person to be contacted in case of an Emergency** – Give the name, title and telephone number(s) of the responsible person who can be contacted in case of an emergency (e g spilling of a prohibited substance)

A7 **Type of Application** –

A Wastewater Flow Estimation – Mark this box if

20% or more of the water received at this premise from all sources is NOT discharged to the Community Sewer AND you have requested that your sewage disposal charges be based on volume estimation of your wastewater

B Wastewater Strength Determination – Mark this box if

1) The primary business activity at this premise is required to have a Permit under the EBMUD Wastewater Control Ordinance, or

2) You have requested that your sewage disposal charges be based on a strength determination of your wastewater

Check Part(s) Completed – Indicate which Part(s) of this Application are completed and attach them to your Application

A8 **Certification** – The Application must be signed and dated by an officer, employee, or other agent of the business who has legal authority to bind the Applicant business Also print or type the name and title of the person signing the Application

Return the Application and required Part(s) to East Bay Municipal Utility District, Water Pollution Control Department, P O Box 24055, Oakland, CA 94623 by the date indicated at the top of the Application

SECTION 2 PERMIT

DO NOT COMPLETE THIS PART IT WILL BE COMPLETED BY EBMUD AND THE ORIGINAL RETURNED TO YOU

Wastewater Discharge Permit
Part B - Business Description

Purpose – The Business Description is primarily used to determine the substances which may enter into the wastewater discharge from the Business Activity The production quantities are necessary for State and Federal Reports and for intra-industry comparisons

EBMUD USE:
Permit No. ______

B1 **Business Activity** – (Complete a separate Part B for each major business activity occuring on the premise)
ACTIVITY ______ SIC ☐☐☐☐
(a) **Product:**

TYPE OF PRODUCTS (Brand Name)	QUANTITIES					
	PAST CALENDAR YEAR			ESTIMATED THIS CALENDAR YEAR		
	Amount		Units	Amount		Units
	Avg.	Max.		Avg.	Max.	

(b) **Description** – Describe the wastewater generating operations Indicate variations in production and operations during the year (Use additional sheets as necessary)

(c) **Substances Discharged** – Give common and technical names of each major raw material and product that may be discharged to the sewer Briefly describe the physical and chemical properties of each substance and product

NAME	DESCRIPTION

B2 **Discharge Period**
(a) Discharge occurs daily from ______ to ______
(b) Circle the days of the week that the discharge occurs S M T W T F S

B3 **Variation of Operation**
Indicate whether the business activity is
Continuous throughout the year, or
Seasonal – Circle the months of the year during which discharge occurs
J F M A M J J A S O N D

Comments ______

B4 **Other Liquid Wastes** – List the type and volume of liquid waste removed from the premises by means other than community sewers

DESCRIPTION	VOLUME (gals/mo)	REMOVED BY (Name & Address)

INSTRUCTIONS – SEE ON BACK

INSTRUCTIONS FOR COMPLETING PART B

General Instructions – Type or print the information A separate Part B is to be completed for each major business activity Examples of major business activities are paint manufacturing, metal plating, food canning, etc

B1. **Business Activity** – Describe the principal activity on the premise For the purpose of completing this Part, an activity is a major business class of manufacture (see Examples above) Enter the Standard Industrial Classification (SIC) Code Number, as found in the 1972 Edition of the Standard Industrial Classification Manual prepared by the Executive Office of the President, Office of Management and Budget, which is available from the Government Printing Office at Washington, D C., or at San Francisco, California – DO NOT USE PREVIOUS EDITION OF THE MANUAL Copies are also available for examination at most public libraries and at the EBMUD Water Pollution Control Plant.

(a) **Product** – List the types of products, giving the common or brand name and the proper or scientific name Enter from your records the average and maximum amounts produced for this activity for the previous calendar year, and the estimated production for this calendar year Attach additional pages if necessary

(b) **Description** – Describe the wastewater generating process occurring on the premises, including any seasonal variation in wastewater discharge volumes, plant operations, raw materials, and chemicals used in process and/or production

EXAMPLE At this location we manufacture paints, by a dispersion process in which pigments (magnesium silicates, iron oxides, titanium dioxide and organic pigments) are incorporated into a liquid media consisting of binders (alkyd, phenolic vinyl, acrylate and polyether) and thinners (acetate, aliphatic and/or aromatic hydrocarbons as well as water) All raw materials are purchased from an outside supplier Production is uniform throughout the year. Wastewater is generated for discharge to the community sewer from the washing of the mixing vats Consequently, all raw materials and products can find their way into the community sewers

(c) **Substance Discharged** – Give common (brand names) and technical names (chemical, scientific or proper names) of each raw material and product that may be discharged to the sewer Briefly describe the physical, (e g. color) and chemical, (e.g reacts with water) properties of each substance

Example

NAME	DESCRIPTION
Titanitol (Titanium dioxide)	White inert powder used as a pigment

B2 **Discharge Period**

(a) Enter the hours of the day during which waste from this Business Activity will be discharged to the sewer, e g from 0800 to 1700 hours (not 6 a m. to 5 p m)

(b) Circle the days of the week that the wastewater discharge from this activity occurs

B3. **Variation in Operation**

Indicate whether the business activity is continuous throughout the year or if it is seasonal If the activity is seasonal, circle the months of the year during which discharge occurs Make any comments you feel are required to describe the variation in operation of your business activity

B4 **Other Liquid Wastes** – List the type and volume of liquid wastes removed from the premises other than by the community sewer Under description, indicate the types of materials (scientific and common names) in the waste Also, in the column headed "REMOVED BY," write the name and address of the company who hauls this material If you do your own removal and disposal, indicate by writing your "Business Name "

Wastewater Discharge Permit
Part C - Schematic Flow Diagram

Purpose – The **Schematic Flow Diagram** shows the flow pattern of products through the facility and the various sources of wastewater This information will enable EBMUD to assess the quality, volume and peak flows of the discharge	**EBMUD USE** Permit No _____

Schematic Flow Diagram – For each major activity in which wastewater is generated, draw a diagram of the flow of materials and water from start to completed product, showing all unit processes generating wastewater Number each unit process having wastewater discharges to the community sewer Use these numbers when showing this unit process in the building layout in Part D

INSTRUCTIONS – SEE ON BACK

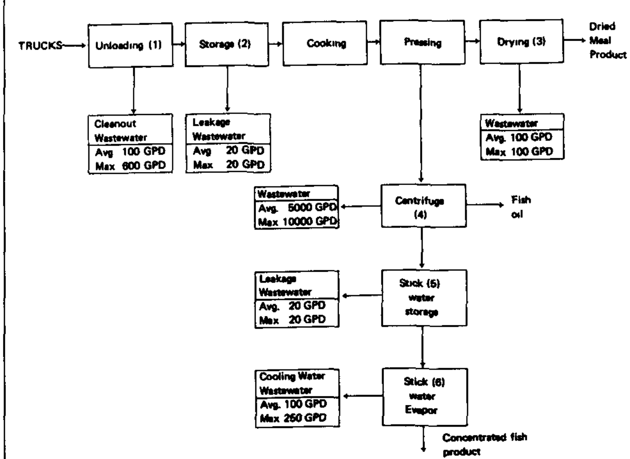
INSTRUCTIONS FOR COMPLETING PART C

General Instructions – Type or print the information A separate Part C should be completed for each major business activity described in Part B

A line drawing (schematic flow diagram) of each major business activity described in Part B is to be completed in the space below or drawn in on an attached sheet of paper (all sheets should be letter size) Number each process which generates wastewater using the same numbering as in the building layout or plant site plan shown in Part D An example of the drawing required is shown below in Figure 1

To determine your average daily volume and maximum daily volume of wastewater flow you may have to read water meters, sewer meters, or make estimates of volumes that are not directly measurable

FIGURE 1
ACTIVITY Fish Processing



Description: Flow diagram of fish meal and fish oil processing operations.

Wastewater Discharge Permit
Part D - Building Layout

Purpose – The **Building Layout** shows the wastewater generating operations which contribute to each side sewer This building layout will also enable EBMUD and the applicant to select suitable sampling locations for determining and verifying wastewater strength	**EBMUD USE.** Permit No _____

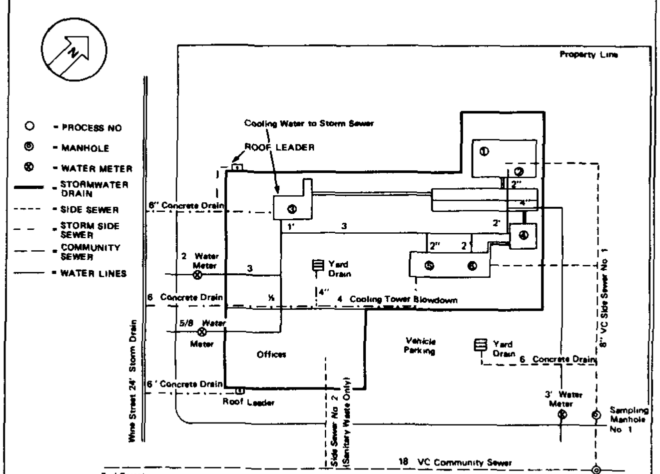
Building Layout – Draw to scale the location of each building on the premises Show location of all water meters, storm drains numbered unit processes (from Part C), community sewers and each side sewer connected to the community sewers Number each side sewer and show possible sampling locations

INSTRUCTIONS FOR COMPLETING PART D

General Instructions – Type or print the information

Building Layout – A building layout or plant site plan of the premise is required to complete Part D (Building Plans approved by E B M U D, may be substituted for Part D) An arrow showing north as well as the map scale must be shown The location of each existing and proposed sampling manhole and side sewer must be clearly identified as well as all sanitary and wastewater drainage plumbing. Number each unit process discharging wastewater to the community sewer Use the same numbering system shown in Part C (Schematic Flow Diagram) An example of the drawing required is shown below in Figure 2

FIGURE 2
Plan of John's Fish Co
(Scale 1" = 100')



Wastewater Discharge Permit

Part E - Water Source & Use

EBMUD

Purpose – The **Water Source and Use** information will enable EBMUD to determine the Volumes and Sources of wastewater discharged to the community sewer	**EBMUD USE** Permit No ______

E1 **Water Use and Disposition** – Estimate the average quantity of water received and wastewater discharged daily

NOTE Show on separate sheet the method and calculations used to determine the quantities shown on the table

	SUPPLY FROM			DISCHARGED TO		
	EBMUD	Other (1)		Comm Sewer	Other (2)	
WATER USED FOR	gal/day	gal/day	Source	gal/day	gal/day	Disch To
Sanitary						
Processes						
Boiler						
Cooling						
Washing						
Irrigation						
Other (3)						
TOTAL						

Notes.

(1) Enter the quantity and the appropriate code letter indicating the source
a well b creek, c estuary d bay e stormwater, f reclaimed water

(2) Enter the quantity and the appropriate code letter indicating the discharge point
a well, b creek, c estuary, d bay e stormdrain, f rail, truck, barge, g. evaporation, h product

(3) Describe ______________________________

E2 **Number of Employees**

	OFFICE		PRODUCTION (number of employees per shift)					
			DAY SHIFT		SWINGSHIFT		NIGHTSHIFT	
	No	Hours	No.	Hours	No	Hours	No	Hours
WEEKDAY		to		to		to		to
SATURDAY		to		to		to		to
SUNDAY		to		to		to		to

E3 **Source of Wastewater Discharged**

WATER METER NUMBER	PERCENT (%) DISCHARGED TO				TOTAL % DISCHARGED TO ALL SIDE SEWERS
	SIDE SEWER No 1	SIDE SEWER No 2	SIDE SEWER No 3	SIDE SEWER No 4	

INSTRUCTION – SEE ON BACK

INSTRUCTIONS FOR COMPLETING PART E

General Instructions Type or print the information Part E is to be completed by all dischargers who require a permit (Wastewater Strength and Flow Estimations)

E1 **Water Use and Disposition** – Estimate the water received and wastewater discharged in gallons per day for the preceding year For the water that is received from other than EBMUD services or discharged to other than community sanitary sewers, enter the appropriate letter in the column headed "Source" or "Discharge To "

The total supply from EBMUD should be checked using recent water bills to verify the estimates

E2 **Number of Employees** – Enter the average number of office and production employees at the premises daily during the preceding year If there is more than one shift per day, enter the average number of employees per shift and the duration

E3 **Source of Wastewater Discharged** – Item E3 shows the percentage of source water on each water meter used for computing the sewage disposal service charge

Step 1 Enter the number of each meter (EBMUD and private) serving the premise

Step 2 For each meter enter the percentage of water discharged to each side sewer If you have more than one side sewer, show on a separate page the method and calculations used to determine the proportioning to the side sewers

Step 3 Enter the total percentage discharged to all side sewers for each water meter by adding the figures in each side sewer column

EBMUD

Wastewater Discharge Permit

Part F - Side Sewer Discharge

Purpose – The **Side Sewer Discharge** information will identify for EBMUD the variation in flow rate and the type of constituents and characteristics of the discharge for each side sewer

EBMUD USE
Permit No ______
Sampling Location ______

F1 **Side Sewer No** ______________ (From Part D)

F2 **Wastewater Flow Rate**

PEAK HOURLY		MAX DAILY		ANNUAL DAILY AVG		IF OPERATIONS ARE SEASONAL AVERAGE DAILY (GALLONS/DAY)			
gallons/minute		gallons/day		gallons/day		seasonal min		seasonal max	
A		B		C		D		E	

F3 **If Batch Discharge, Indicate**

a Number of batch discharges ____________ per month
b Time of batch discharges ____ ____ , ____ (Days of Week) ,at ____ , ____ , ____ (Hours of Day) ,
c Average quantity per batch ____________ gallons
d Flow Rate ____________ gallons/minute

F4 ***Wastewater Constituents*** – *Indicate* if any of the following constituents, characteristics or substances is or can be present (X) in your wastewater discharge **as a result of your operations**

CODE	CONSTITUENTS	K	CODE	CONSTITUENTS	K	CODE	CONSTITUENTS	K
ALGC	Algicides*		FORMA	Formaldehyde		RAD	Radioactivity*	
AL	Aluminum		HC	Hydrocarbons*		SE	Selenium	
NH3N	Ammonia		I-	Iodide		AG	Silver	
SB	Antimony		FE	Iron		NA	Sodium	
AS	Arsenic		PB	Lead		SOLV	Solvents*	
BA	Barium		MG	Magnesium		SO4=	Sulfate	
BE	Beryllium		MN	Manganese		S=T	Sulfide	
B	Boron		HG	Mercury		SO3=	Sulfite	
BR-	Bromide		MO	Molybdenum		MBAS	Surfactants MBAS	
CD	Cadmium		NI	Nickel		TEMP	Temperature Increase (+)	
CA	Calcium		O&G M	Oil & Grease (Min Orig)		TEMP	Temperature Decrease (-)	
CL2	Chlorine		O&G T	Oil & Grease (Total)		TI	Titanium	
CL-	*Chloride*		PESTC	*Pesticides**		SN	Tin	
CR	Chromium		PH	pH Increase (+)		V	Vanadium	
CO	Cobalt		PH	pH Decrease (-)		TVA	Volatile Acids	
CU	Copper		PHENL	Phenols		ZN	Zinc	
CN-	Cyanide		P	Phosphorus				
F-	Fluoride		K	Potassium				

*Identify the Chemical Compounds or Elements

Comments

INSTRUCTIONS FOR COMPLETING PART F

General Instructions – Type or print the information Part F is to be completed by all businesses who require Wastewater Strength Determination Use a separate sheet for **each side sewer** that discharges wastewater to a community sewer (NOTE A side sewer is a sewer conveying the wastewater of a discharger from a building or structure to a community sewer)

F1 **Side Sewer No** – Enter the side sewer number for which this sheet of Part F has been completed Use the same number as shown on PART D

F2 **Wastewater Flow Rate** – Estimate the peak hourly discharge rates from the premise (i e the quantity which might be discharged during any one hour) The maximum daily discharge rate is the greatest flow which might be discharged in any one work day The annual daily average is the flow for an average workday taken over one year of operation A season is defined as a period of one month or longer Hourly and daily water supply meter readings may be used provided the filling and discharge of storage tanks, process vats, etc are taken into consideration

F3 **Batch Discharge** – A batch discharge is one which results from the draining of storage tanks or process tanks intermittent boiler blowdown, etc , to the side sewer

a Enter the number of batch discharges per month during the operating season of maximum flow

b Enter the days of the week the discharge occurs and the times of the day the discharge usually occurs

c Enter the average gallons discharged during each batch discharge operation

d *Enter the rate of flow in the side sewer from the batch discharges*

(i e Rate of flow from the batch discharge = $\frac{\text{Number of gallons in batch discharge}}{\text{duration for a single discharge}}$)

F4 **Wastewater Constituents** – Indicate, by checking the appropriate box, if your wastewater discharge contains any of the indicated constituents, characteristics, or substances as a result of the raw materials, processes or products used Identify the algicides, hydrocarbons, pesticides, solvents and radioactivity discharged if any, in the wastewater

F5 **Wastewater Strength Estimates** – Enter the average and maximum concentration of each of the indicated elements of wastewater strength for this side sewer The average strength should approximate the flow composited strength during the year

(Flow composited strength = $\frac{\text{Total milligrams of substance discharged for year}}{\textit{Total annual volume of water discharged in liters}}$)

The "Maximum Strength ' is the maximum concentration that would be measured in any grab sample taken at any time during the year from this side sewer If these values are acceptable to EBMUD they will become the basis for sewage disposal charges

The "Chlorine Demand" of a wastewater is the amount of chlorine required to produce a free chlorine residual of 0 1 mg/l after a contact time of 15 minutes as measured by the Iodometric Method on a sample at a temperature of 20°C *in conformance with the Standard Method*

F6 **Pollution Abatement Practices**

a **Wastewater Pretreatment**

Check the type of treatment if any given the wastewater from this side sewer before it is discharged to the community sewer

Description The treatment facility should be described in sufficient detail to enable an estimation of the facility s effectiveness This will require a description of the physical characteristics and size of the facility (Use additional sheets as necessary)

b **Planned Wastewater Treatment Improvements**

Describe any additional treatment or changes in wastewater disposal methods planned or under construction

F7 **Stormwater Area** – Enter an estimate of the total area (in square feet) which collects and discharges stormwater to the side sewer (include roof and ground level areas)

EBMUD

PART F – Side Sewer Discharge (Cont'd)

F5 **Wastewater Strength Estimates** – Enter the average annual and maximum wastewater strength for this side sewer for each of the following elements of wastewater strength for the period covered by the Permit

ANY SIGNIFICANT DEVIATION FROM THESE VALUES CAN RESULT IN TERMINATION OF THE PERMIT

ELEMENTS OF WASTEWATER STRENGTH	UNIT	CODE	AVERAGE	MAXIMUM
Suspended Solids	mg/l	TSS		
Total Chemical Oxygen Demand	mg/l	CODT		
Filtered Chem Oxygen Demand	mg/l	CODF		
Oil and Grease	mg/l	O&GT		
Chlorine Demand (See Instructions)	mg/l	CL2D		

If data from a commercial laboratory was used to determine the values, please give the name and address of the laboratory

Name ______________________ Address ______________________

F6 **Pollution Abatement Practices**

a **Wastewater Pretreatment** – Check the type of treatment if any given wastewater from this side sewer **before** it is *discharged to the community sewer*

☐ none ☐ holding tank ☐ grease trap, ☐ oil and water separator, ☐ grinding ☐ sedimentation ☐ pH adjustment
☐ biological treatment ☐ screening ☐ chlorination or ☐ other

Description

Describe the loading rates, design capacity, physical size, etc of each pretreatment facility checked above

b **Planned Wastewater Pretreatment Improvements** – Describe any changes in treatment or disposal methods planned or under construction for the wastewater carried by this side sewer

F7 **Stormwater Area**

Total Area in square feet exposed to storm water and draining to this side sewer __________ sq ft

INSTRUCTIONS – SEE ON BACK

Page 2 of 2

Wastewater Discharge Permit
Part G - Permit Conditions

EBMUD

G1 Applicant Name (Same as Item 1 on Application) ______ Permit No ______

G2 BCC – Enter the Business Classification Code Assigned to this business by EBMUD ☐☐☐☐

G3 SIC – Enter the Standard Industrial Classification Codes for each major activity described in Part B

1 ☐☐☐☐ Part B, Page ______ 2 ☐☐☐☐ Part B, Page ______

SECTION 1 CALCULATION OF SEWAGE DISPOSAL SERVICE CHARGES

Purpose This Section establishes a single charge for each water meter based on the strength and volume of the wastewater in each side sewer

G4 **Sewage Disposal Service Charge Determination for Each Side Sewer**

		SIDE SEWER NO 1		SIDE SEWER NO 2		SIDE SEWER NO 3		SIDE SEWER NO 4	
SUSPENDED SOLIDS	mg/l								
	lbs/Ccf								
	¢/Ccf								
CHLORINE DEMAND	mg/l(a)								
	lbs/Ccf								
	¢/Ccf								
OIL & GREASE	mg/l(b)								
	lbs/Ccf								
	¢/Ccf								
VOLUME	¢/Ccf								
TOTAL CHARGE	¢/Ccf								

(a) Excess over 30 mg/l (b) Excess over 40 mg/l

G5 **Determination of the Total Charge to be applied to each Water Meter**

WATER METER NUMBER	SIDE SEWER NO 1 (1) Total Charge ¢/Ccf	(2) % Disch.	(3) Column (1)x(2) ¢/Ccf	SIDE SEWER NO 2 (1) Total Charge ¢/Ccf	(2) % Disch	(3) Column (1)x(2) ¢/Ccf	SIDE SEWER NO 3 (1) Total Charge ¢/Ccf	(2) % Disch	(3) Column (1)x(2) ¢/Ccf	SIDE SEWER NO 4 (1) Total Charge ¢/Ccf	(2) % Disch	(3) Column (1)x(2) ¢/Ccf	TOTAL CHARGE FOR EACH WATER METER ¢/Ccf

G6 **Sewage Disposal Service Charge Determination for Each Meter**

A ACCOUNT NUMBER	B METER NUMBER	UNIT OF MEAS	C CONVERSION FACTOR	D FIXED VOLUME (Ccf) (1)	E TOTAL % DISCHARGED	F TOTAL CHARGE Ccf (2)

(1) Show on an attached sheet the method of estimating the amount of wastewater discharged from the premises

(2) Show on an attached sheet the method of computing the Sewage Disposal Service Charge

INSTRUCTIONS FOR COMPLETING PART G

General Instructions Type or print the information Part G will be completed by EBMUD

G1 **Applicant Name** – Enter the legal name or title of the business as shown on the Permit Application

G2 **BCC No** – Enter the four (4) digit Business Classification Code Number assigned by EBMUD

G3 **SIC No** – Enter the Standard Industrial Classification Code Number from the 1972 Edition of the Standard Industrial Classification Manual prepared by the Executive Office of the President, Office of Management and Budget Copies are available from the Government Printing Office at Washington, D C , or at San Francisco, California Copies are also available for examination at most public libraries and the Water Pollution Control Plant of EBMUD **DO NOT USE PREVIOUS EDITIONS OF THE MANUAL!**

G4 **Sewage Disposal Service Charge Determination for Each Side Sewer**

This matrix enables the sewage disposal service to be determined for each 100 cubic feet (Ccf) of water used from each water meter

Step 1 Enter the projected average annual wastewater strength for suspended solids, chlorine demand in excess of 30 mg/l, and oil and grease in excess of 40 mg/l

Step 2 Convert the answer from Step 1 (mg/l) to pounds per hundred cubic feet (lbs/Ccf) of wastewater by multiplying the mg/l by $62\,4 \times 10^{-4}$

Step 3 Calculate the charge for each element by multiplying the lbs/Ccf by the Unit Charge shown in the District s latest Schedule of Rates and Charges

Step 4 Determine the Total Charge by adding the individual ¢/Ccf

G5 **Determination of the Total Charge Applied to each Water Meter** – The total charge computed for each water meter will be applied against the volume of water shown on the meter reading (Deductions will be made in item G6 for volumes or percentages not discharged to the side sewer)

Step 1 Enter in Column (1) the unit charge for each side sewer as computed in item G4 "Total Charge "

Step 2. Using the total percentage discharged (see item E3) compute the percentage discharged to each side sewer Enter these percentages in the respective Column (2) "% Disch "

Step 3 For each water meter and each side sewer in turn, calculate the product of the "Unit Charge' and the "Percentage Discharged " Enter the resulted in the column headed ' Column (1)x(2) "

Step 4 For each water meter add the "Column (1)x(2)" to give the total charge to be applied to each water meter Enter the result in the column headed "Total Charge for each Water Meter "

G6 **Sewage Disposal Service Charge Determination for Each Meter**

A **Account No** – List all account numbers pertaining to this Permit with the "Key Account" first The "Key Account" number is an account number used for the permit identification (Permit Number)

B **Meter No** – For each account number list the water meter numbers assigned to that account The letter p" after the meter number indicates a private meter

Unit of Measurement – Enter the unit of measurement (e g cubic feet, gallons, 1000 gallons, etc)

C **Conversion Factor** – If the unit of measurement is other than gallons or cubic feet, enter a factor which will convert the meter reading to Ccf (e g , a factor for converting time on a time elapse meter to Ccf)

D **Fixed Volume** – If a fixed volume is charged to a meter or to an account enter the volume in Ccf The volume may be positive or negative If negative, the value is to be preceded by a negative sign (-)

E **Total Percentage (%) Discharged** – Enter the percentage of the water registered by each meter that is discharged to the community sewer This factor only applies to the amount appearing on each meter reading The percentage does not apply to the volume appearing under the column headed "Fixed Amount " If the figure is preceded by a negative sign the amount computed will be deducted from the sewage bill

F **Total Charge per Ccf** – Enter the total charge for each water meter previously determined in item G5

G7 **Monitoring Schedule** – Enter each element required to be monitored by the Permittee Enter the average and maximum concentration for each of these elements In the column headed "TEST FREQUENCY", enter the test frequency in weeks for each element or constituent Testing is to commence from the effective date of the Permit (see G11)

G8 **Monitoring Program Charges**

A Compute the sampling and testing charge based on the annual number of samples and tests required by EBMUD

B Permit Fee – $175 for accounts requiring both flow and strength determinations $100 for accounts requiring either flow or strength determinations

G9 **Laboratory Testing.** – EBMUD may approve laboratories not approved by the State Department of Public Health when the Applicant desires to perform EBMUD required tests in his laboratory Indicate whether a laboratory approved by the Department of Public Health of the State of California or EBMUD will be used for the testing

G10 **Time Schedule** – EBMUD will enter the actions required to remedy the ordinance violations or compliance schedules

EBMUD

PART G – Permit Conditions (Cont'd)

SECTION 2 MONITORING AND COMPLIANCE CONDITIONS

Purpose This Section establishes suitable monitoring and compliance programs

[illegible] **Monitoring Schedule**

ELEMENT OR CONSTITUENT (CODE)	UNIT	SIDE SEWER NO. 1 Avg	Max	Freq	SIDE SEWER NO 2 Avg	Max	Freq	SIDE SEWER NO 3 Avg	Max	Freq	SIDE SEWER NO 4 Avg	Max	Freq

[illegible]. A. Monitoring Program Charges

TOTAL SAMPLES PER YEAR A ☐ @ $5 00 each = ____/yr – 12 = $ ____/month

TOTAL TESTS PER YEAR B ☐ @ $1 50 each = ____/yr – 12 = $ ____/month

B. Permit Fee ☐ $175 ☐ $100

[illegible]. Laboratory Testing – Indicate the laboratory to be used by Permittee

A. ☐ Laboratory approved by the State Department of Public Health

B. ☐ Laboratory approved by EBMUD

G10. Time Schedule – Time schedules for compliance with the Ordinance limitations and prohibitions construction of pretreatment facilities sampling and monitoring facilities, and other orders by the Manager

ITEM NO	TIME SCHEDULE Month	Day	Year	– EVENT –

G11. Effective Date of this Permit ☐☐ MONTH ☐☐ DAY ☐☐ YEAR

G12. Expiration Date of this Permit ☐☐ MONTH ☐☐ DAY ☐☐ YEAR

INSTRUCTIONS – SEE ON BACK

USE OF ROTATING BIOLOGICAL CONTACTOR ON MEAT INDUSTRY WASTEWATERS

by

Don F. Kincannon*, Jimmie A. Chittenden**, and Enos L. Stover*

INTRODUCTION

Available land is a key consideration when planning wastewater treatment facilities for the meat processing industry. Some plants are so located that land is available for anaerobic ponds and additional aerobic treatment. Whereas, other plants are so located that it is difficult to find space for any type of wastewater treatment. This is especially true of processing plants that are located inside the city limits and discharge their wastewaters into the city sanitary sewer. In many communities these plants are being required to pretreat their wastewaters before discharging into the sanitary sewer. In many cases these same meat processing plants incorporate very little if any recovery operations, thus producing a wastewater that is very difficult to treat.

This paper will report on an experimental study that was conducted in order to determine whether or not a rotating biological contactor could successfully treat the wastewaters from a meat processing plant that did not incorporate any in-plant recovery operations.

Chittenden and Wells (1) have previously reported on treating meat processing wastes by following an anaerobic lagoon with a rotating biological contactor. This paper will also report on additional work that has been completed with this treatment process.

RBC TREATING RAW WASTES

Treatment Plant Description

The experimental study on a raw meat processing waste was conducted in the Bioenvironmental Laboratories at Oklahoma State University. The wastewater was obtained from a meat processing plant located in Perkins, Oklahoma, which is ten miles south of Oklahoma State University. No in-plant recovery operations such as blood recovery or grease recovery is practiced. The RBC was initially set up at the meat processing plant, however, numerous operational problems occurred. It was then decided to move the RBC into the laboratory and transport the wastewater.

The rotating biological contactor*** employed for this study was a four-foot long unit. It consisted of six compartments or stages with five polystyrene discs in each stage. The total surface area of polystyrene

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*School of Civil Engineering, Oklahoma State University.
**Iowa Beef Processors, Inc., Dakota City, Nebraska.
***Autotrol Corp., Milwaukee, Wisconsin.

medium available for microbial growth was 177.5 square feet. This was contained in a volume of 11.8 cubic feet giving a specific surface area of 15 ft^2/ft^3. A 1/10 horsepower electric motor rotated the discs at eleven revolutions per minute. The discharge line from the final stage of the unit was located such that the liquid volume in the unit was ten gallons. It was learned after all experiments were completed that an adaptor is normally installed in the discharge opening so that the unit would have a liquid volume of thirty gallons. Thus the detention time employed in this study was less than normally employed with this particular RBC. A flow rate of 0.5 gpd/ft^2 was utilized in all experiments of this study. With the ten gallon volume used this provided a liquid detention time of two hours and 40 minutes.

A slim growth was developed on the discs by first operating the unit as a batch operation. Then gallons of meat processing wastewater was placed in the RBC with a sewage seed from the Stillwater, Oklahoma, municipal sewage treatment plant. After the slime growth started to develop the unit was then operated as a continuous flow process. During the length of the study the unit was operated part-time as a batch process in order to save on the quantity of meat processing wastewater that had to be transported. In all cases the unit was operated as a continuous flow unit for a sufficient period of time before samples were taken. That is, the unit was allowed to reach steady state conditions before sampling began. In some cases the meat processing wastewater was diluted with tap water in order to provide the desired initial ΔCOD.

The term ΔCOD is defined as the difference between the influent COD and the nonbiodegradable COD. Thus, ΔCOD measures only the biodegradable organics present in the wastewater and is therefore comparable to the ultimate BOD.

Results

The ΔCOD remaining at each stage for a typical experiment is shown in Figure 1. It can be seen that samples were collected and analyzed at regular intervals for at least a seven or eight hour period. The average removal for this time period is used in presenting the rest of the results. It can be seen in Figure 1 that at least 50% of the ΔCOD removed occurred in the first stage.

Figure 2 shows the percent ΔCOD removed by stages for experiments conducted at three different organic loadings. The RBC was capable of removing 74 percent of the ΔCOD when the initial ΔCOD was 1410 mg/l. However, the removal efficiency was greatly reduced when the initial ΔCOD was increased. When the initial ΔCOD was 4510 mg/l the removal efficiency was only 18 percent.

The actual ΔCOD's remaining for these experiments are shown in Figure 3. In all cases the effluent ΔCOD was much too high for discharge into a receiving stream. However, for an initial ΔCOD of 1410 mg/l the effluent ΔCOD was 370 mg/l. This reduction would make this wastewater much more acceptable for discharge into a sanitary sewer. The removal characteristics of the RBC when the initial ΔCOD was 1410 mg/l is also shown in Table I.

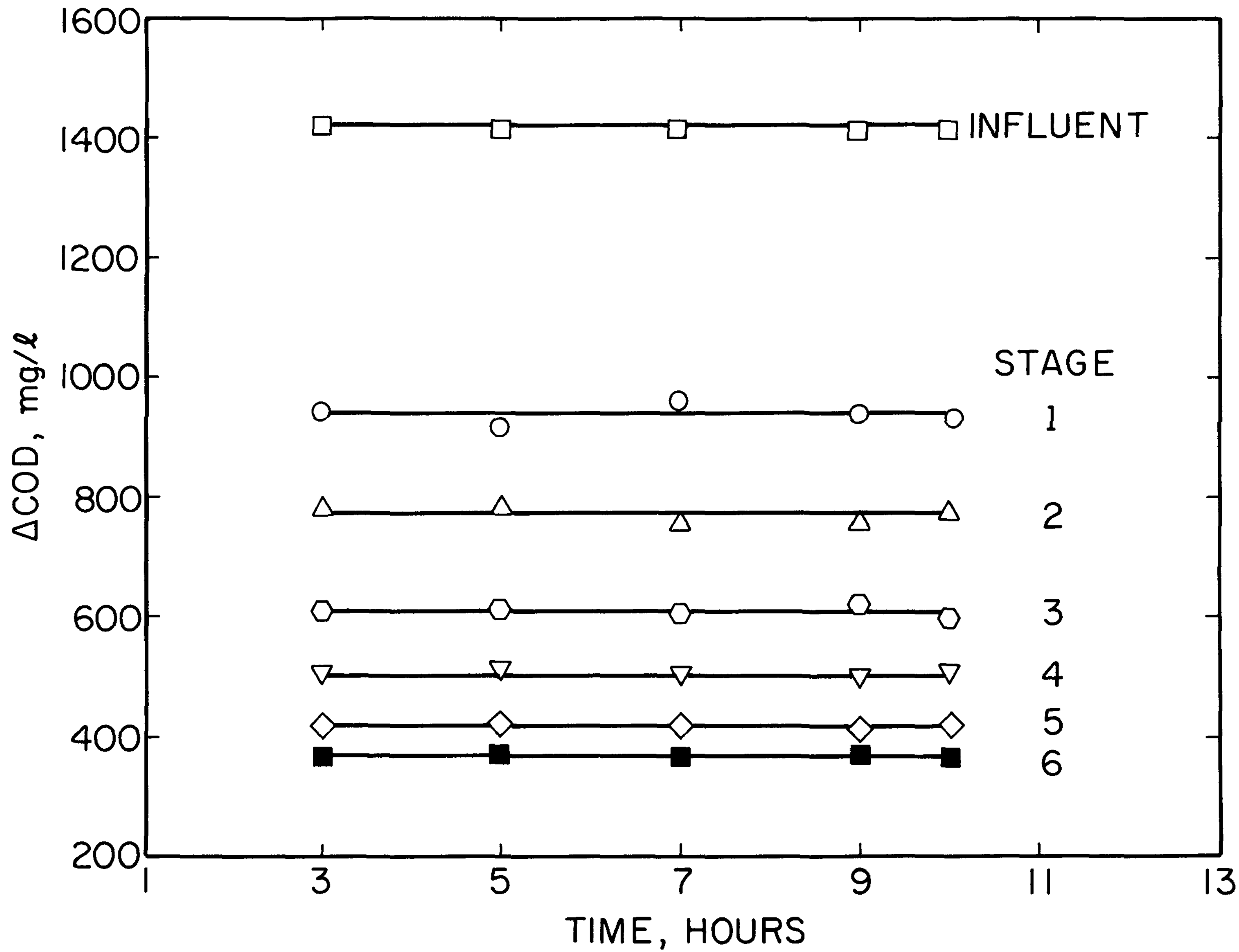

Figure 1. ΔCOD REMOVAL BY STAGES.

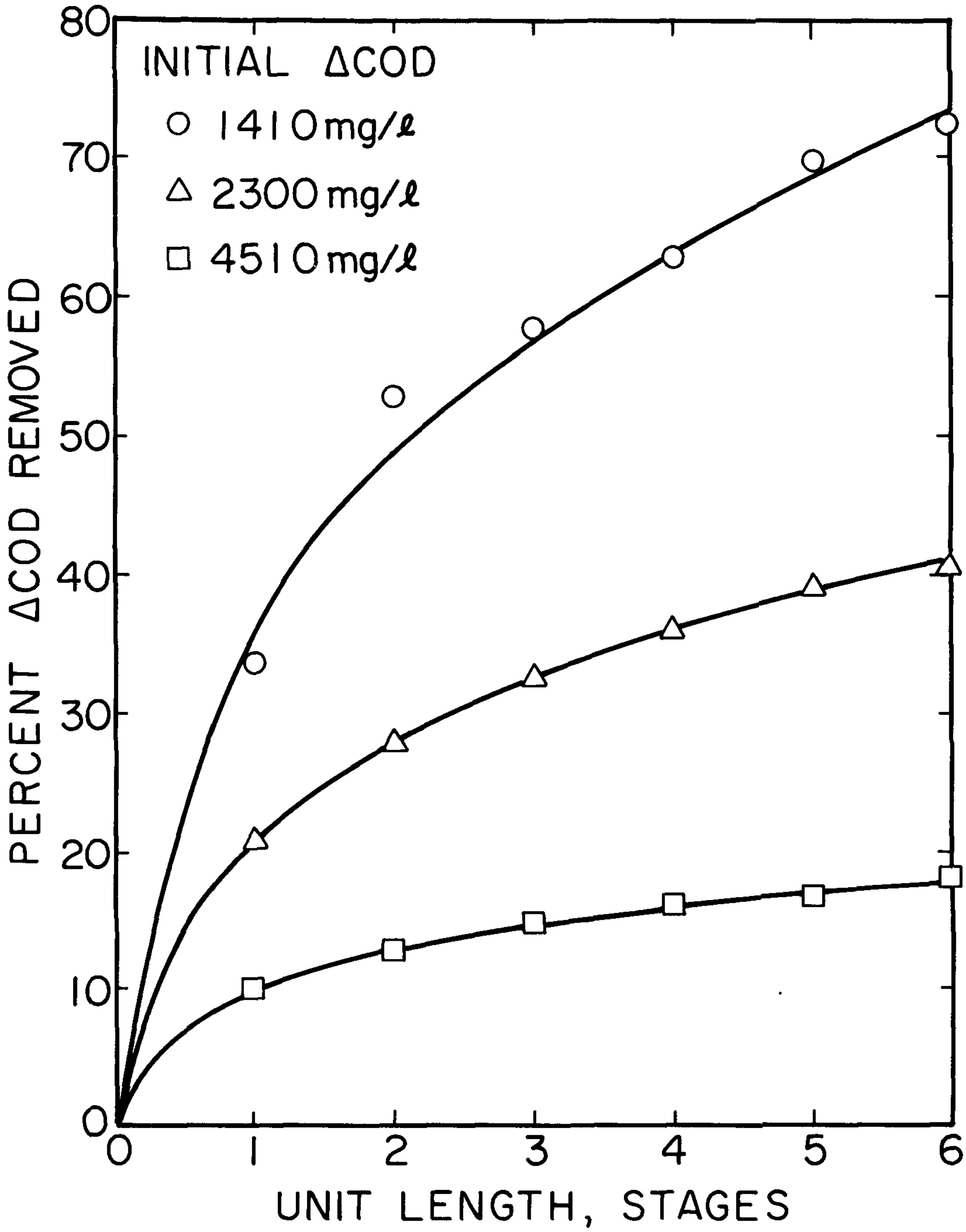

Figure 2. PERCENT ΔCOD REMOVAL PER STAGE.

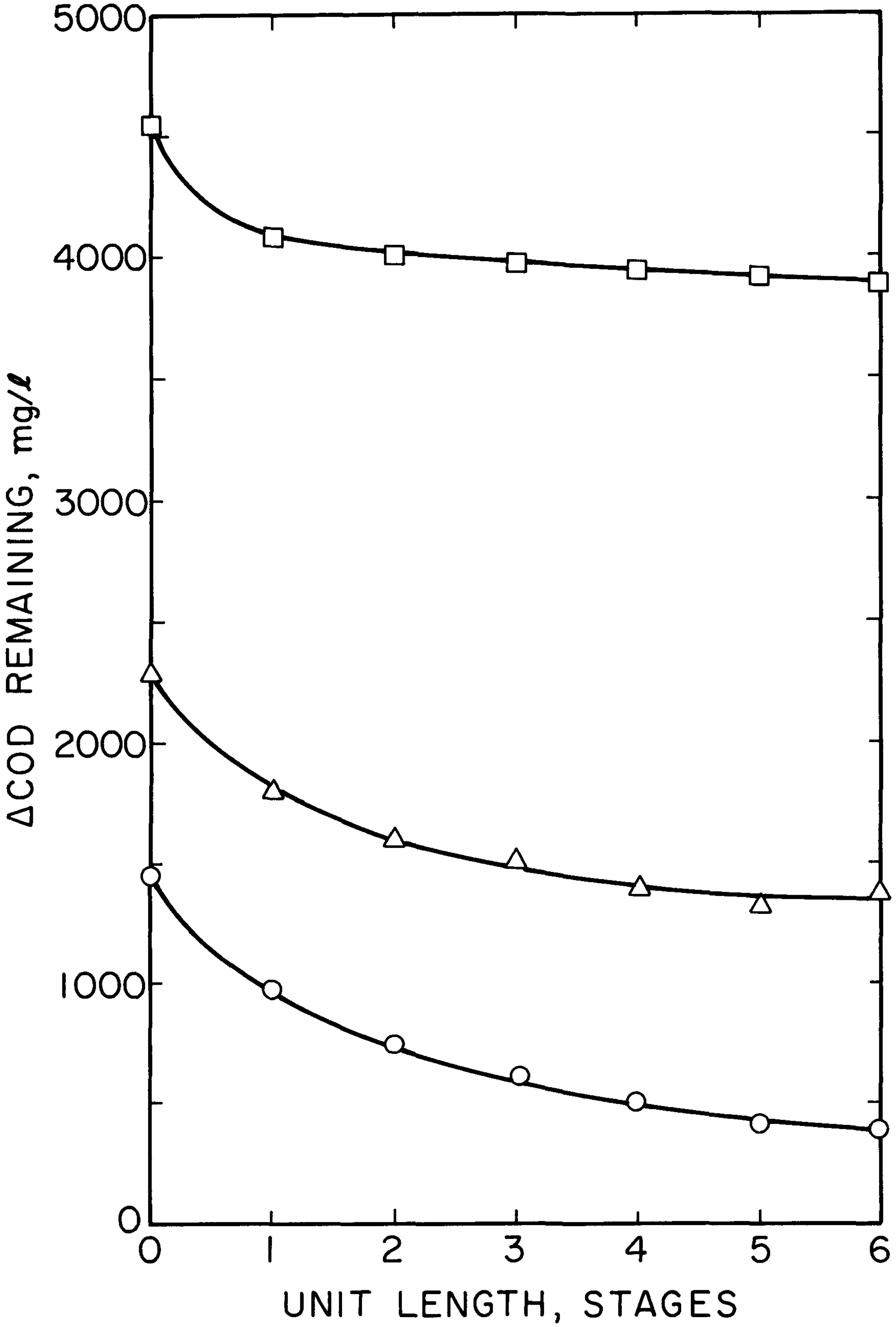

Figure 3. ΔCOD REMAINING PER STAGE.

Table I. Summary of RBC Operation at Low Organic Loading

Stage	ΔCOD, mg/l	% ΔCOD removed per stage	Total ΔCOD removed	Substrate Removal Rate (k)
Influent	1410			
1	935	34	34	k_1 = 0.180
2	770	18	54	
3	610	21	57	
4	505	17	64	k_2 = 0.073
5	420	17	70	
6	370	12	74	

It was found in all experiments that the ΔCOD was removed in two phases. The first phase usually being the first stage and the second phase being the remaining stages. In a few cases the first phase would extend into the second stage.

A summary of ΔCOD removed per stage for three experiments is shown in Table II. It is interesting to note that no matter what the initial ΔCOD was the same mg/l of ΔCOD were removed by corresponding stages. The first stage consistently removed at least 50 percent of the total ΔCOD that was removed.

Table II. ΔCOD Removed Per Stage

Influent ΔCOD	mg/l ΔCOD Removed Per Stage					
Stage	1	2	3	4	5	6
1410	475	165	160	105	85	50
2280	480	120	140	90	70	50
4510	430	100	70	30	40	80

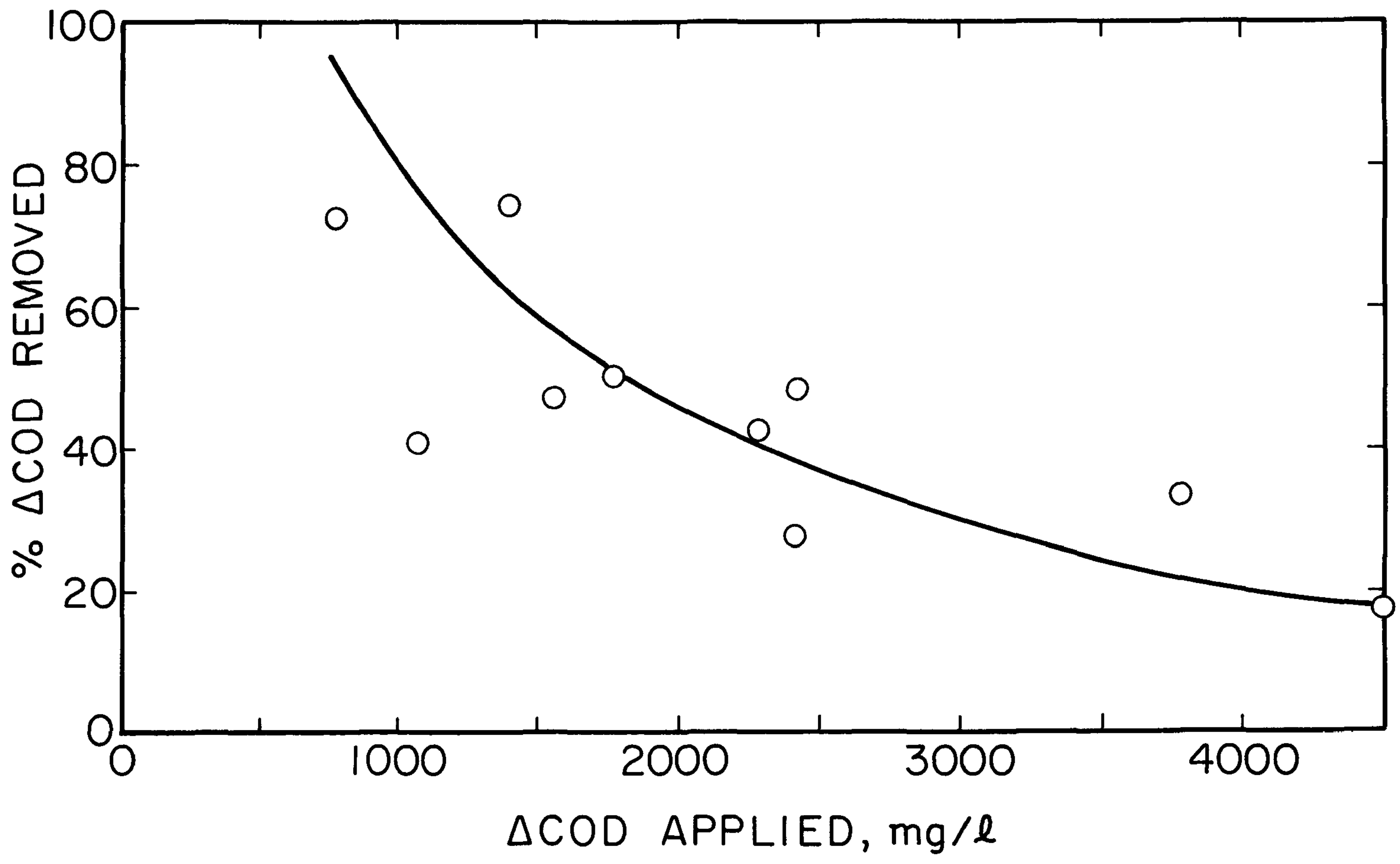

Figure 4. PERCENT ΔCOD REMOVED VS. ΔCOD APPLIED.

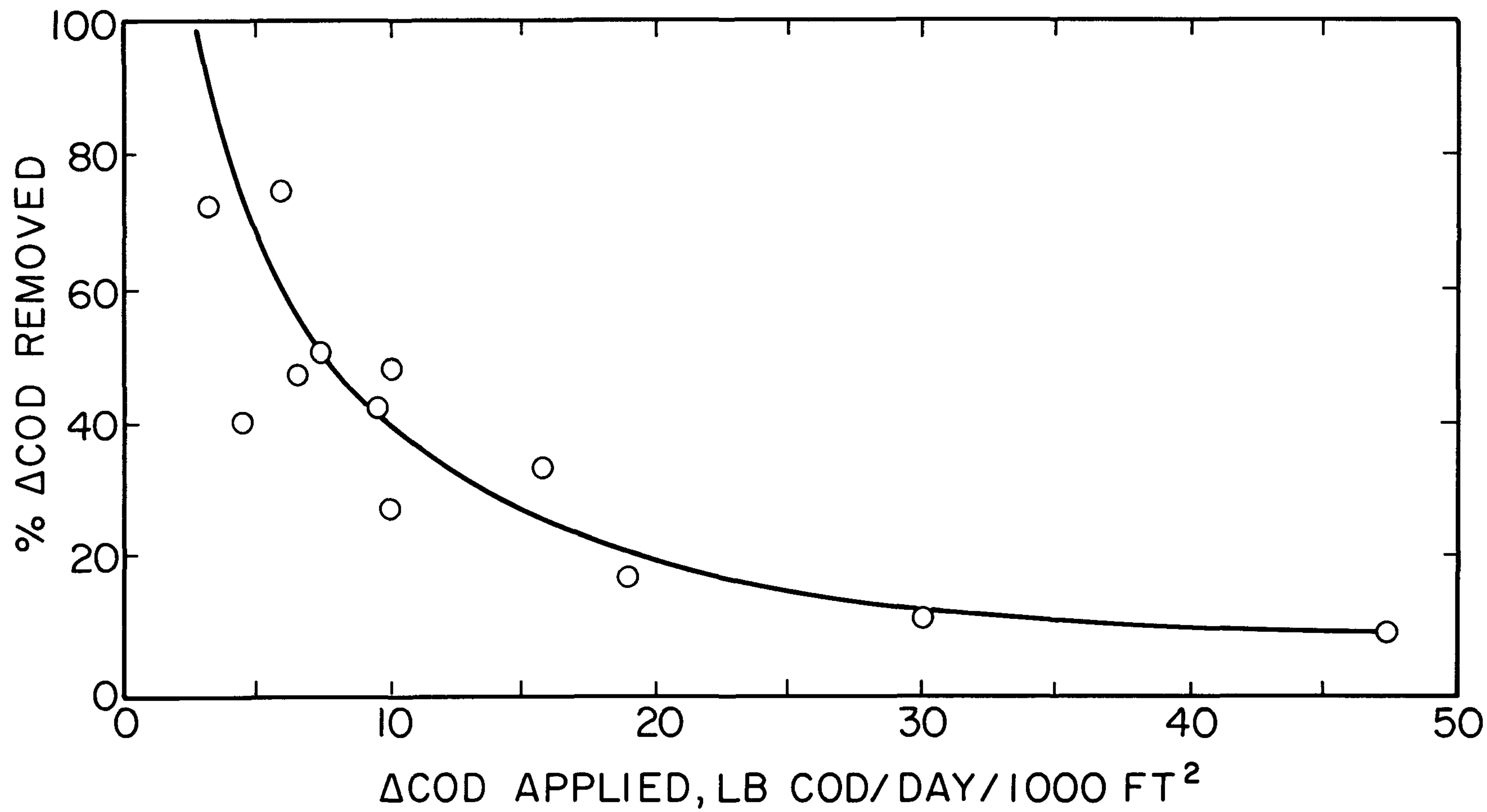

Figure 5. PERCENT ΔCOD REMOVED VS. TOTAL ΔCOD APPLIED.

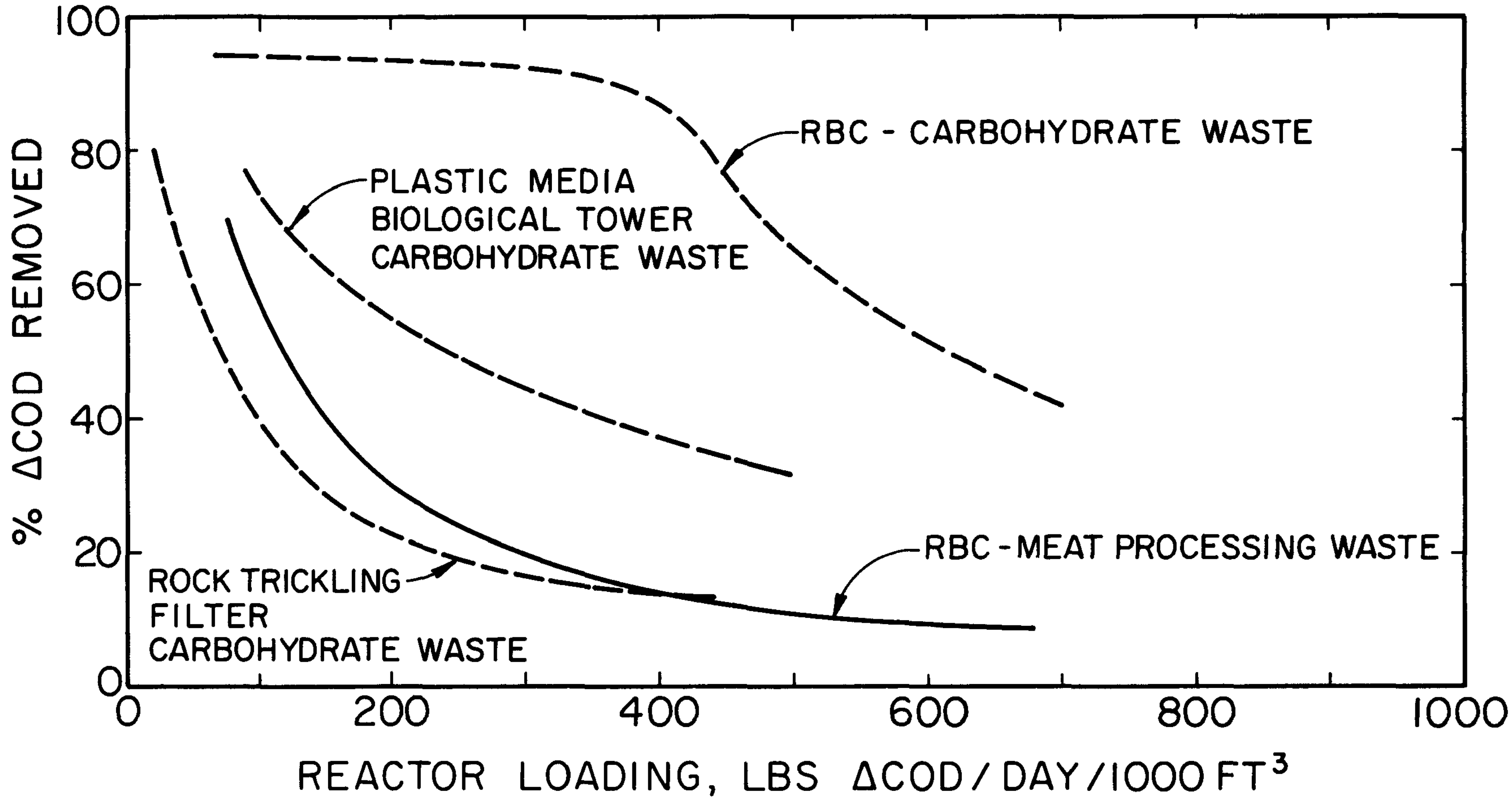

Figure 6. COMPARISON OF VARIOUS TREATMENT PROCESSES.

A summary of the percent ΔCOD removed for all initial ΔCOD values is shown in Figure 4. It can be seen that as the influent ΔCOD increased the removal efficiency decreased. The ΔCOD loading in mg/l does not take into account the hydraulic loading. One way of considering both the organic loading and the hydraulic loading is to consider the organic loading in pounds per day. Also the variation in different sizes of RBC's can be accounted for if the loading is calculated as lb $\Delta COD/day/1000ft^2$. The percent ΔCOD removal for various total loadings is shown in Figure 5. Again the percent ΔCOD removed decreases as the total organic loading is increased. It can also be seen that a 70 percent efficiency was obtained at a loading of 5 lbs ΔCOD per day per 1000 ft^2 of RBC area.

A summary of work completed on a carbohydrate wastewater is shown in Figure 6. The results of that study are compared with the results obtained from the meat processing wastewater study. When the RBC was used to treat the carbohydrate wastewater a high removal efficiency was achieved for a rather high increase in organic loading. However, when this same wastewater was treated with either a plastic media biological tower or a rock trickling filter the efficiency immediately started decreasing as the organic loading was increased. It is interesting to note that when treating the meat processing wastewater the RBC acted more like the biological tower or trickling filter. That is, the efficiency began to drop as soon as the organic loading was increased.

There was one very great difference in the RBC when treating the carbohydrate wastewater and when treating the meat processing wastewater. The suspended solids in the liquid in the unit were quite high with the carbohydrate wastewater, varying from 500 - 6000 mg/l. However, the suspended solids concentration with the meat processing wastewater was quite low, varying from 100 - 200 mg/l. Thus with the carbohydrate wastewater the RBC was acting both as an activated sludge and as a fixed-bed reactor. However, with the meat processing wastewater the RBC was acting only as a fixed-bed reactor.

RBC FOLLOWING AN ANAEROBIC LAGOON

Treatment Plant Description

The pilot plant study on a meat processing wastewater after undergoing treatment in an anaerobic lagoon was conducted by the Iowa Beef Processors, Inc. at their plant in West Point, Nebraska.

The RBC* employed for this study was a four stage unit utilizing the "Extended Area Disc". The total surface area available for microbial growth was 250 square feet. There were 9 discs per stage for a total of 36 discs. The discs were rotated at 13 revolutions per minute. The liquid volume of the unit was 37 gallons. During this study the hydraulic loading varied from 0.57 gpd/ft^2 to 2.16 gpd/ft^2. This allowed the detention time to vary from 1.64 hours to 6.17 hours.

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*Autotrol Corp., Milwaukee, Wisconsin.

Results

The BOD remaining at each stage for 3 different days of operation is shown in Figure 7. Again it can be seen that the majority of the BOD removed is removed in the first stage and very little BOD is removed in the last three stages. These results are very similar to those obtained on the raw meat processing wastewater.

The pounds of BOD removed per day per 1000 ft^2 of RBC surface area for corresponding BOD loadings are shown in Figure 8. A straight line can be drawn through the data points and the slope of this line represents the efficiency of the RBC unit that can be expected at the loadings studied. The results of this study show that a 71 percent efficiency was achieved during this study.

The effluent BOD that was obtained for various BOD loadings is shown in Figure 9. It can be seen that as the BOD loading increased the effluent BOD also increased. It is also evident that a low BOD loading is required before achieving an effluent that is acceptable for discharge to a stream. In this study a BOD loading of 0.9 lbs/day/1000 ft^2 or less was required to achieve an effluent BOD of 20 mg/l or less. This is a very low loading rate.

DISCUSSION

In these experiments a very interesting phenomenon was observed. The majority of the ΔCOD or BOD was removed in the first stage and very little was removed in the remaining stages. This is shown in Figure 3 and Table II for the raw waste. In Table II it can be seen that approximately 470 mg/l of ΔCOD was removed in the first stage. The maximum amount removed in any other stage was 165 mg/l. Figure 7 shows that the same thing occurred with the settled anaerobic lagoon wastewater. This is a strange response especially when it is remembered that a very sufficient amount of ΔCOD or BOD still remains after the first stage. No explanation for this phenomenon is offered.

During these experiments it was also observed that the RBC was an excellent evaporator. In fact, it does such an excellent job of evaporating that this must be taken into account when operating the RBC system. Either a continuous wastewater flow must be supplied to the reactor or recycle must be incorporated into the operational plan. Certainly this must be considered in light of the operational hours of meat processing plants.

These experiments have shown that the RBC can effectively treat both raw meat processing wastewaters and meat processing wastewaters following treatment by an anaerobic lagoon. However, the organic loadings must be quite low below acceptable effluents are obtained. This may make the RBC quite expensive. No economic comparison with other treatment processes has been made. Therefore, no conclusions can be made about whether or not the RBC is an economical process for meat processing wastes.

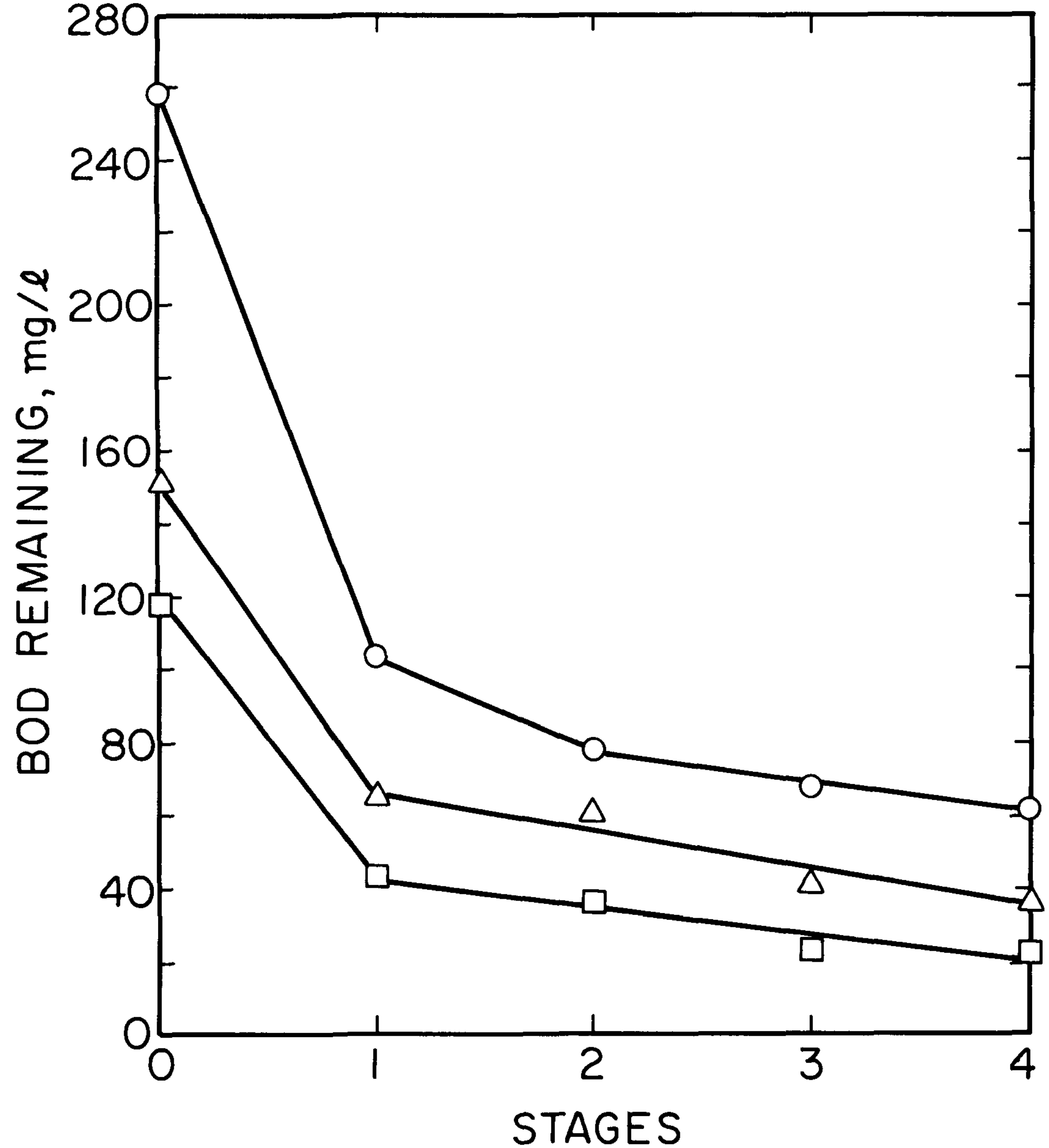

Figure 7. BOD REMAINING PER STAGE OF RBC.

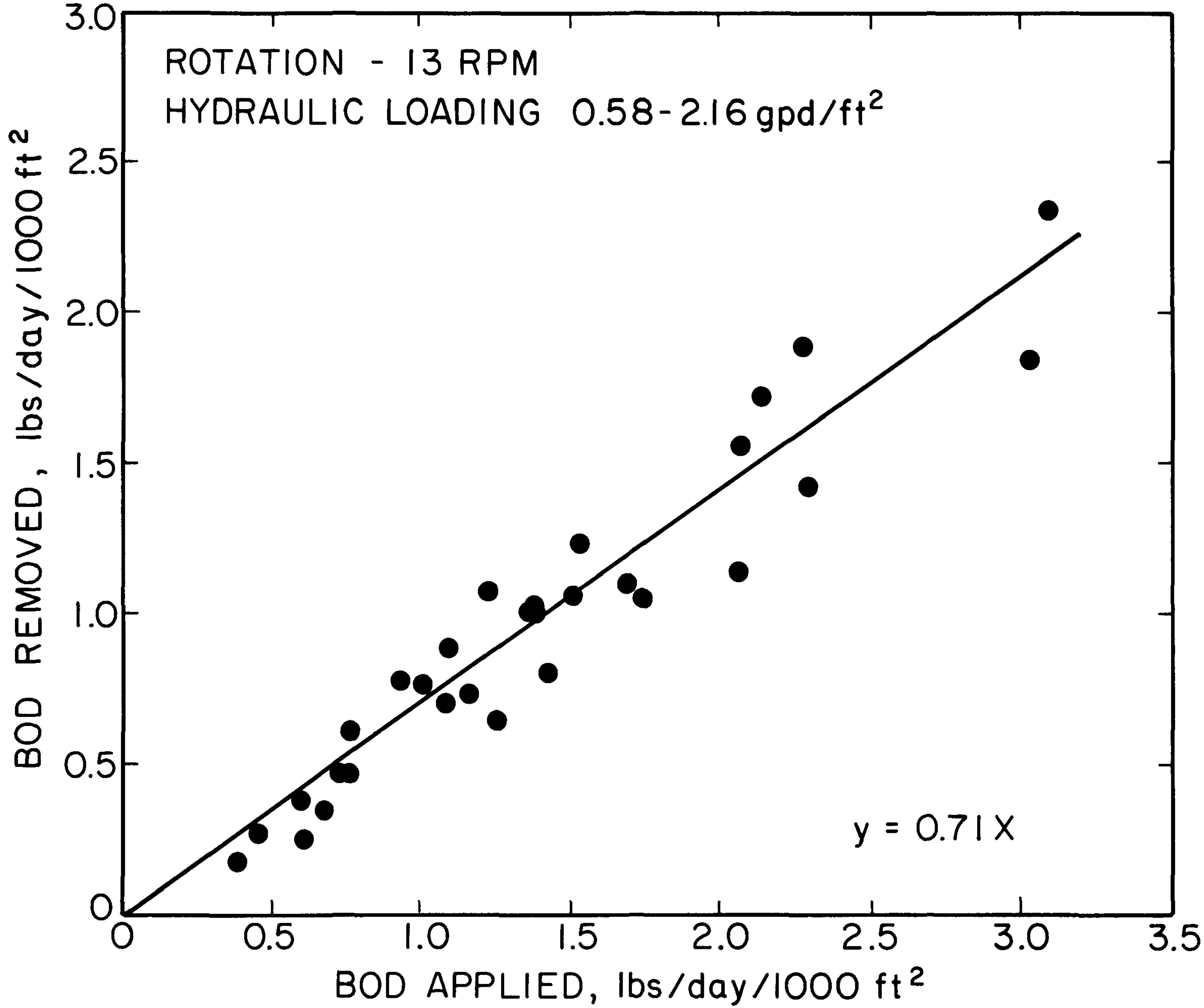

Figure 8. BOD REMOVED VS. BOD APPLIED.

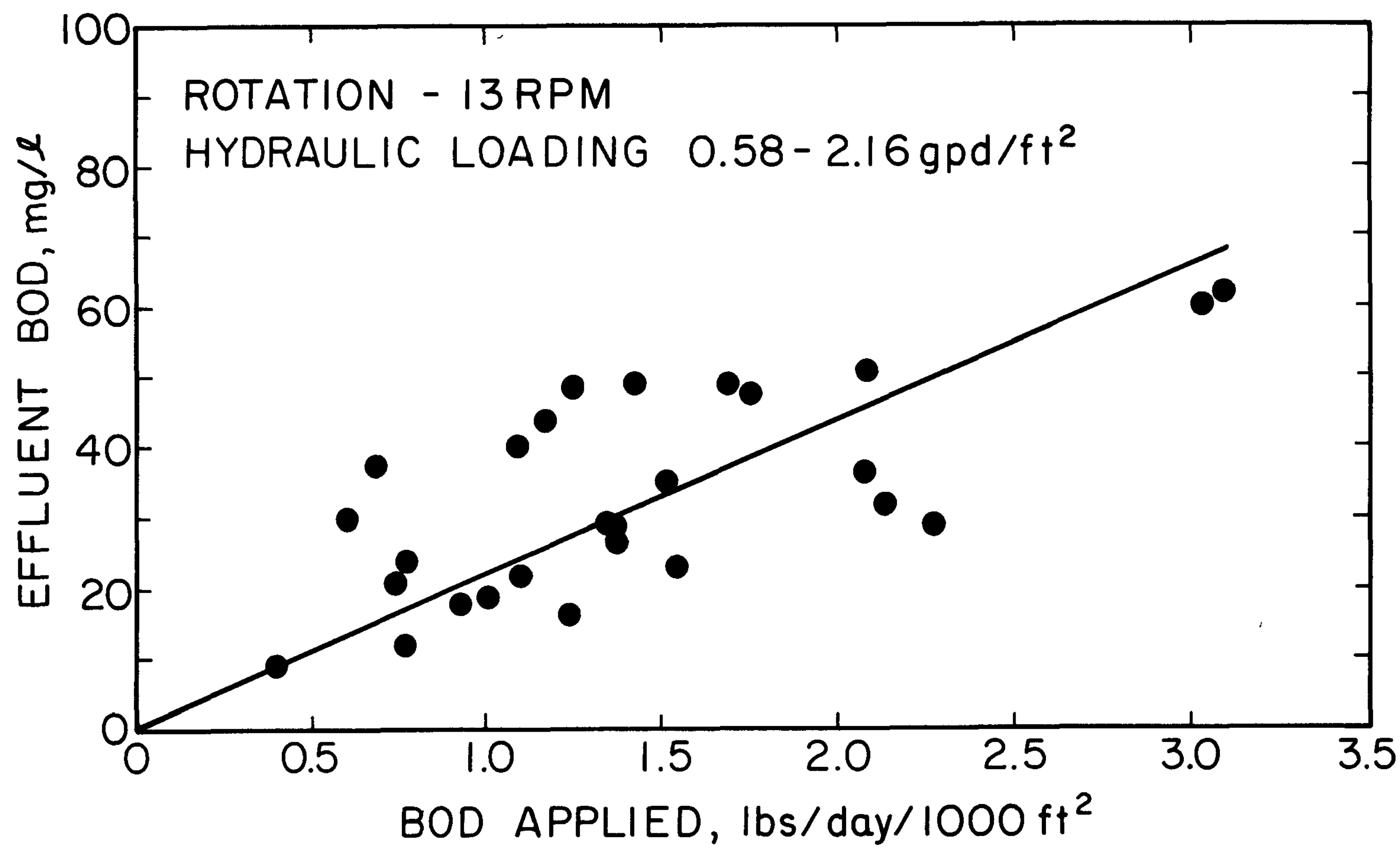

Figure 9. EFFLUENT BOD AS A FUNCTION OF BOD APPLIED.

1. CHITTENDEN, JIMMIE A. and WELLS, W. JAMES, JR. Rotating Biological Contactors Following Anaerobic Lagoons. J. Water Pollution Control Federation, Vol. 43, pp. 746-754, May 1971.

INDUSTRIAL WASTEWATER REUSE

by

James D. Clise *

INTRODUCTION

For the past three years the Environmental Health Administration of Maryland's Department of Health and Mental Hygiene has been involved in a study at one of Maryland's poultry processing plants.

The objective of the study was to demonstrate the feasibility - both technical and economic - of reclaiming poultry plant wastewater for reuse as potable water. Our efforts to this point have been successful in demonstrating technical and economic feasibility of reclaiming poultry processing wastewater to levels of compliance with drinking water standards. The question remaining is - what possible dangers could accompany reuse of this water which would not be evident in normal drinking water evaluations, or what standards should apply to reclaimed water to assure its safety.

Sterling Processing Corporation, a company engaged in the slaughtering, eviscerating, and processing of poultry, is located in Oakland, Maryland. Plant facilities were constructed in 1956-57, with an original capacity of 3,000 birds an hour, equipped to process broilers, fowl, turkeys, and kosher killed turkeys. Present plant capacity is 6,000 birds an hour with operations restricted to the processing of broilers, averaging 167,000 lbs. live weight killed (lwk) per day. The plant has never had an adequate - reliable water supply.

The community water supply serving the town of Oakland is of inadequate capacity to provide water to the poultry plant. Groundwater resources in the area are limited and of unsatisfactory quality. Sterling Processing Corporation constructed two wells in 1956, and has since acquired a third well which was abandoned by Oakland when the town obtained a surface water supply. In 1965, a water treatment facility was constructed at the poultry plant and is currently in use for the removal of iron and control of bacteriological quality.

Prior to the beginning of this project, Sterling Processing Corporation initiated a series of water conservation measures. Initially, an employee awareness program was conducted. Written directions were issued and daily inspections were made to identify opportunities for employees to assist in the reduction of wasted water. The entire piping system was inspected and all leaks eliminated. Where possible, the use of hoses was eliminated and all essential hoses were equipped with automatic shut-off valves. A valve was installed on each supply line serving the processing plant to allow for regulation of flow. A portable high pressure cleaning system was installed and cleanup personnel were provided with brooms to assist in the removal of solids from the floors. Refrigeration compressor water was recycled to the raw water section of the water treatment plant. Pumps were provided to allow the recycling of chill vat water for reuse in the scalder. Valves were provided on the water lines leading to the water treatment plant filters to more closely control filter rates and eliminate water pressure variations within the

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distribution system. These efforts reduced water consumption from 11 gallons (41.64 liters) per bird to an average of 6.8 gallons (25.74 liters), but did not solve the problem of insufficient water. This continuous need for water, plus the good quality of effluent being discharged to the river made this plant susceptible to the idea of water reuse.

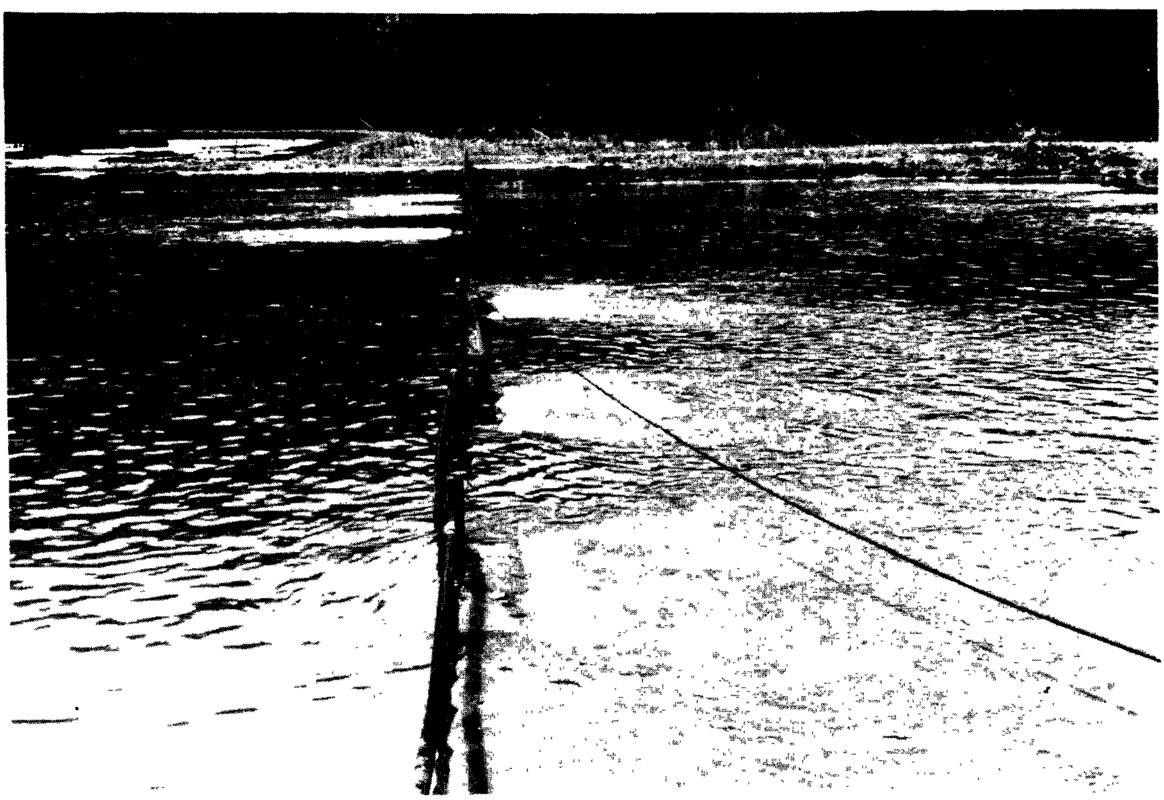
The study provided an opportunity for a thorough evaluation of the Sterling wastewater treatment system.

DISCUSSION

Poultry processing wastes are treated and disposed of by rotary screening for removal of feathers and viscera which are sold for protein reclamation, with wastewater treated in two mechanically aerated lagoons in series, followed by chlorination and discharge to the Little Youghiogheny River. Present wastewater treatment facilities were constructed in 1965-66, replacing an anaerobic lagoon which discharged into the Oakland sewer system.

The wastewater treatment system consists of two lagoons totalling 2.75 acres in area. Each lagoon is 140' wide. The primary unit is 590' long and the secondary lagoon is 230' long. Each pond is six feet deep. Primary lagoon capacity is approximately 3.75 million gallons and secondary capacity is 1.5 million gallons providing holding capacity for 12 working days' flow.

The primary lagoon is equipped with 64 Link Belt circulators, a grease skimmer, and an effluent wier trough discharging into the second lagoon.



Aerated Lagoon Showing Water Circulation

Entering at the bottom of the circulators, wastewater is discharged at the surface in one direction, creating a counter-clockwise surface flow.

Air is supplied to the circulators by three positive displacement blowers, each powered by a 20 hp. motor. The system provides 3,360 cfm of air at 2.8 psig. Air is distributed to the circulators through a header pipe encircling the two lagoons.

The secondary lagoon is equipped with 40 Link Belt circulators, a grease skimmer, and a combination settling unit and chlorine contact chamber with an overflow wier trough and discharge line to the river.

Secondary Lagoon Showing Chlorine Contact Chamber

Incoming raw wastewater has a BOD_5 averaging 540 mg/l, amounting to a loading approximating 480 lbs/acre/day with a 93% reduction in the lagoon system. Raw wastewater suspended solids average 831 mg/l equalling a loading of 750 lbs/acre/day with an 88% reduction in the system.

Wastewater treatment facilities were designed and installed by Griffith Engineering of Falls Church, Virginia.

Preliminary grab sample evaulations of wastewater lagoon effluent indicated the wastewater treatment facility reduced the BOD value to an average of 15 mg/l, and reduced suspended solids to 58 mg/l.

WASTEWATER LAGOON EFFLUENT CHARACTERISTICS
USED AS BASIS FOR DESIGN

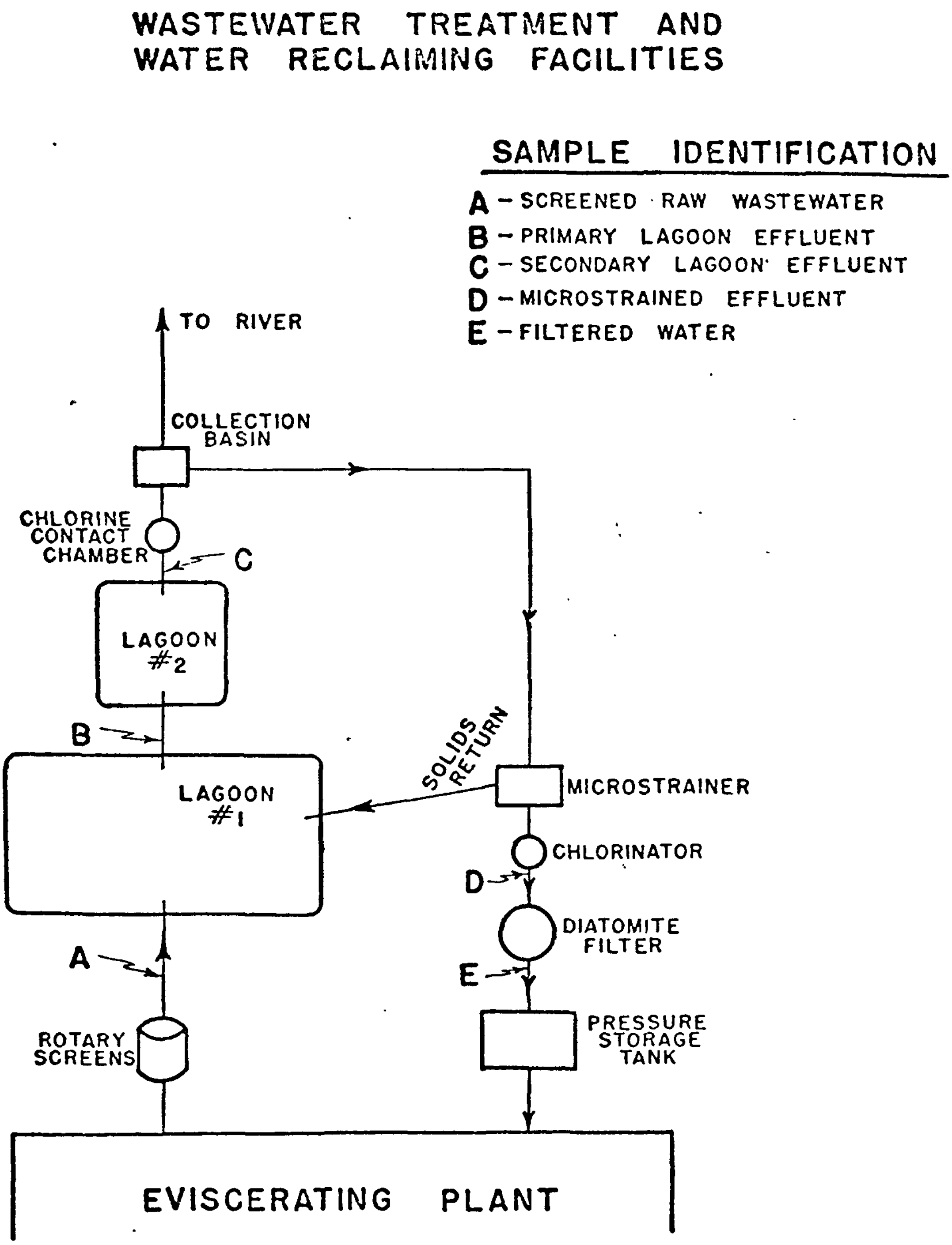
mg/l

Grease	7.8
Phosphate as P	1.3
Iron as Fe	0.3
Chloride as Cl	88
Nitrogen as Free Ammonia	8.8
Albuminoid Ammonia	1.0
Nitrites	0.005
Nitrates	3.0
Alkalinity as Calcium Carbonate	148
Hardness as Calcium Carbonate	178
Turbidity	30
Color	80
BOD_5	15
Chemical Oxygen Demand (COD)	140
Total Solids	426
Dissolved Oxygen	2.9
Suspended Solids	58
Volatile Solids	400
pH	7.0

Wastewater lagoon effluent characteristics, as determined during the study, exceeded the basic design criterion from 52% to 77% as shown, resulting in overloading of equipment and the subsequent alteration of project design.

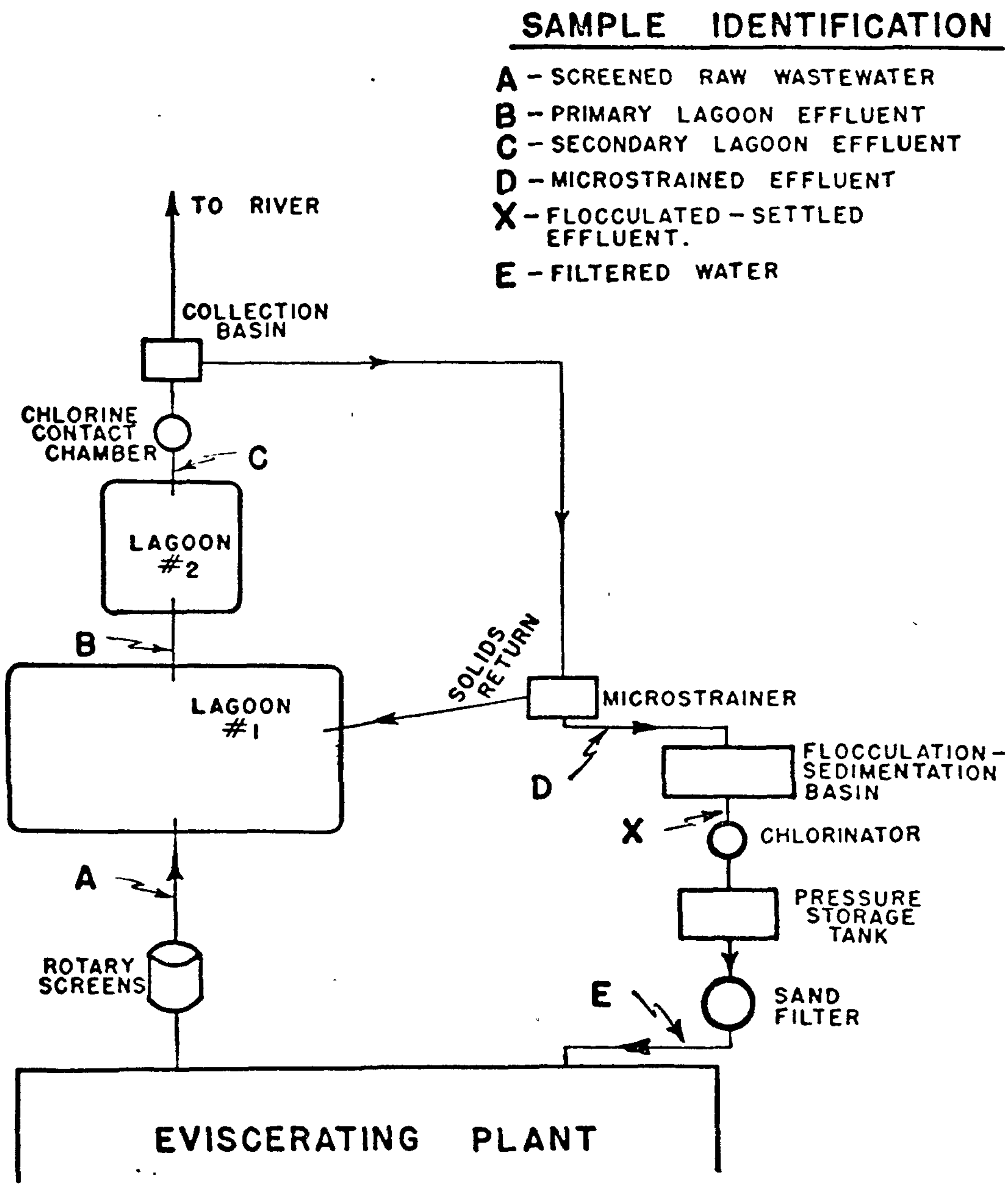
WASTEWATER LAGOON EFFLUENT QUALITY VARIATION FROM VALUES USED FOR
DESIGN OF ADVANCED TREATMENT UNIT

	Design Value mg/l	12 Month Mean mg/l	12 Month Median mg/l	Percent Samples Exceeding Design Value
BOD_5	14.8	31	25	52.3%
Suspended Solids	58	106	109	70.0%
Grease	7.8	24	19	76.7%



Original Design

WASTEWATER TREATMENT AND WATER RECLAIMING FACILITIES



Revised Design

Advanced Treatment Design

Basic design of the water treatment facility consists of a control building; 35 micron microstrainer; diatomite filter containing 200 square feet of septum, rated at 1.6 gpm/sq ft; and 20,000 gallon pressure storage tank.

Supplemental equipment consists of a 3,000 gallon concrete pit used as a collection sump for lagoon effluent; sewage pump for the delivery of effluent to the microstrainer; high head pump for delivery of microstrained effluent to the diatomite filter (50 psi); chlorine recorder; and electrical control panel. All equipment is automatically controlled by the water height in the pressure storage tank. Each unit can be independently operated manually. All equipment is automatically controlled by the water height in the pressure storage tank. Each unit can be independently operated manually. All equipment is rated at approximately 300 gpm.

Equipment is housed in a 20' x 30' concrete block structure located between the poultry plant and wastewater treatment lagoons.

Six inch PVC pipe is used to carry effluent from the secondary wastewater treatment lagoon overflow sump to the control house. All piping within the control house is 6" steel with bolted flange connections.

Solids removed by microstraining of the wastewater lagoon effluent are returned to the primary wastewater lagoon by gravity flow from the microstrainer drum.

The operational phase was conducted in two segments. The first utilized facilities as originally designed consisting basically of a 30 micron microstrainer and diatomaceous filter. The second segment incorporated changes made in an effort to solve unanticipated treatment problems and utilized 70 micron screening, flocculation, sedimentation, and sand filtration.

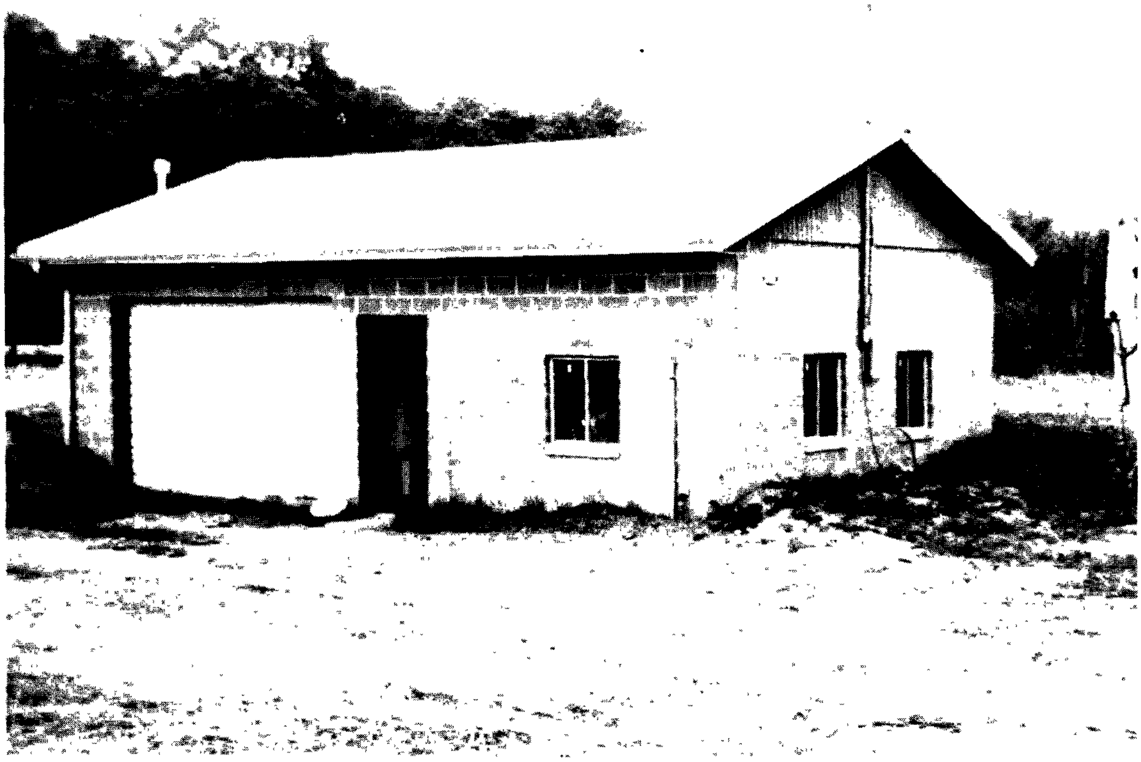
Operational Problems

The advanced water treatment involved in reclaiming poultry processing wastewater as you can imagine presents numerous unusual water treatment problems:

Microstrainer screens were continuously backwashed by cold water sprays for removal of algae and other suspended particulate matter. Due to the presence of grease, it was necessary to provide a source of hot water for occasional removal of adhering matter.

Seasonal variations in suspended solids content of the lagoon effluent resulted in erratic flows through the 30 micron microstrainer. This difficulty was particularly noticeable during the algae growing season from May through August of each year. Suspended solids content varied from 5 - 35 mg/l.

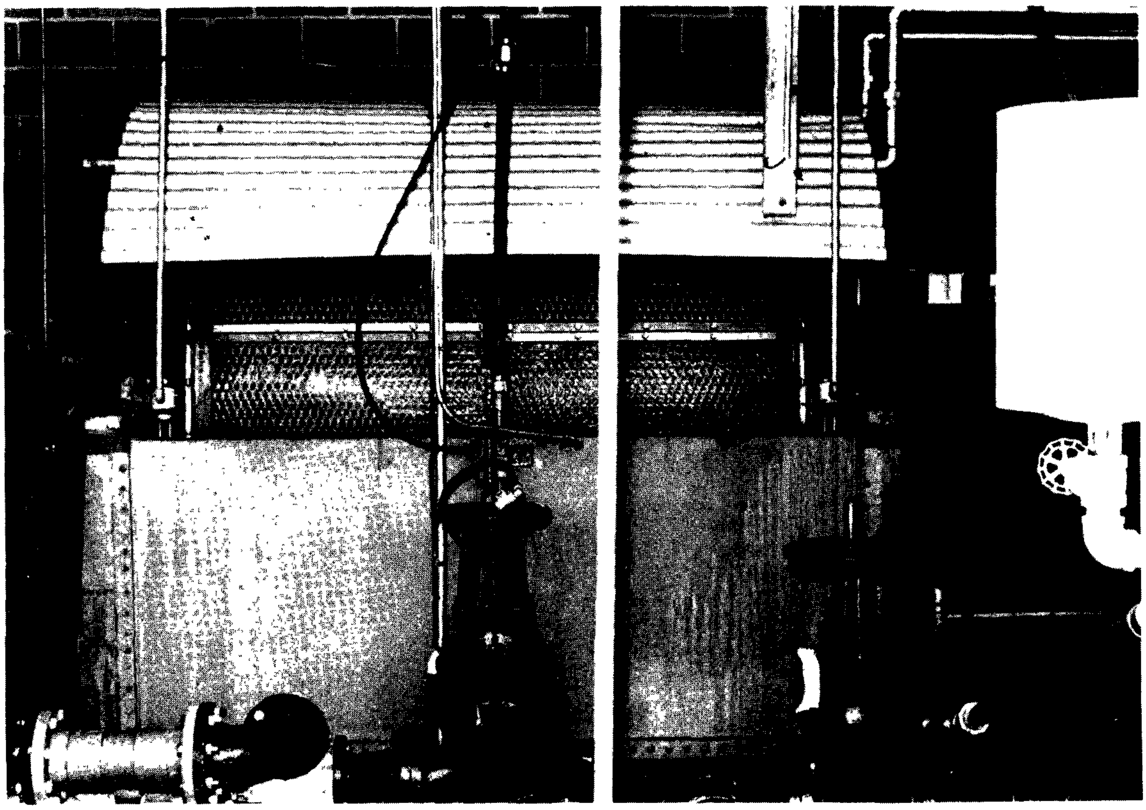
Cold water for the microstrainer sprays was initially obtained from the discharge side of the high head pump transporting microstrained water to the filter. Due to the introduction of high levels of chlorine immediately before the take off point, difficulties were encountered from trichloramine fumes. Spray water take off was moved to the storage tank fed distribution system with a resulting reduction in chlorine fumes within the control house.



Control House Housing Microstrainer and Chlorination Equipment

During the winter months, when ice formation on the lagoon surfaces interfered with the operation of grease skimmers, particles of grease and tissue fibers were present in the wastewater lagoon effluent passing into the filter plant. Increased servicing of the skimmers, on a daily basis as opposed to the initial practice of weekly skimming, resulted in a reduction of grease content in the lagoon effluent from 125 mg/l to 8 mg/l.

Daily skimmer servicing resulted in the reduction of clogging of the microfilter screens. Maximum consistent flow, however, through the 30 micron screens never exceeded 167 gpm. Ultimately the 30 micron screens were replaced with 70 micron screens. These larger screen openings allowed a continuous flow of 300 gpm through the microstrainers with only slight decrease in effluent quality.



Microstrainer - 300 Gallons Per Minute - 70 Micron Screens

Flocculation Chamber Showing Grading and Cold Water Protection

Chlorination

Laboratory studies utilizing "breakpoint" chlorination were undertaken in an effort to destroy grease. They indicated approximately 7.2 mg/l of chlorine was required to reduce 1 mg/l of grease to a stable compound. At this point in the study grease content in the wastewater lagoon effluent was approximately 15.5 mg/l, which would exert a chlorine demand of 112 mg/l. Two gas chlorinators were used, one at the secondary lagoon contact chamber and one between the microstrainer and the diatomaceous earth filter, each operating at 80 lbs/day for a total capacity of 160 lbs/day. This rate approximated 45 mg/l of chlorine, compared to the 112 mg/l required by the average concentration of grease, so "breakpoint" was not consistently reached.

The use of highly chlorinated water in the microstrainer sprays resulted in release of excessive chloramine fumes within the control house. The problem was reduced by supplying microstrainer sprays with water from the pressure tank. "Breakpoint" was more consistently reached following storage in the tank.

Attempts to satisfy chlorine demand resulted in formation of an opalescence in the filtered water. At times, when opalescence was not present in the filter effluent, it was noticed in the filtered reclaimed water following storage in the pressure storage tank. This opalescence was assumed to be the result of colloidal solids which coagulated at pH ranges below 4.6 resulting from excessive chlorine content, indicating the probability of colloidal protein being present in the wastewater lagoon effluent. Efforts to verify the presence of protein through the use of available laboratory capacilities, including the use of an infrared spectrophotometer, were inconclusive.

The probability of protein is supported, however, by the nitrate nitrogen present. Protein from animal sources normally contains approximately 16% nitrogen. Therefore the concentration of protein present can be 6.25 times the concentration of nitrogen. Nitrate nitrogen present in the wastewater lagoon effluent averaged 7.0 mg/l thoughout the study. Normal nitrate nitrogen concentration of Sterling's water supply, based on routine analyses conducted during the study, equals 2.3 mg/l. Subtracting this value from the nitrate nitrogen present in lagoon effluent and applying the factor of 6.25 indicates a possible protein content of 29.4 mg/l:

$$(7.0-2.3) \text{ mg/l} \times 6.25 = 29.4 \text{ mg/l protein}$$

Similar calculations based on total nitrogen present, as opposed to nitrate nitrogen, would indicate increased probability of the carryover of protein through the wastewater lagoon system.

Flocculation and Sedimentation

To eliminate problems of colloidal content, grease, and excessive solids, additional facilities were designed and constructed to provide for flocculation and sedimentation of wastewater effluent following microstraining and prior to filtration. The construction was completed and the unit placed in operation in the early spring of 1973, and was used during the remaining months of the project.

Laboratory examinations and jar tests were used to determine most efficient and effective coagulation materials. Floc formation was attained through addition of 5 grains per gallon (86 mg/l) of alum followed by the addition of an equal amount of lime.

Optimum levels of coagulants for formation of floc, as determined by daily jar tests, remained relatively constant throughout the study.

The diatomaceous earth filter proved to be totally inadequate for use with water of the quality being applied. In no instance was the design volume of 300 gpm attained.

Sand filter

During the second segment of the study the diatomaceous earth filter was bypassed and one of the sand filters in the Sterling water treatment unit was used.

Each of the two 15' diameter sand filters in the Sterling water treatment unit has sufficient capacity to filter the total demand flow for the poultry plant. The piping to one filter was altered to allow it to be used as a standby for the Sterling water treatment plant and also as the final filter for the project's advanced water treatment unit. The sand filter proved capable of filtering the applied water at a continuous rate of 300 gpm with weekly backwash.

Piping arrangement allowed water from the sedimentation basin clear well to be pumped to the Sterling sand filter. The filtered water could then be returned to the primary wastewater lagoon, bypassed directly to the river, or discharged into the raw water basin of Sterling's water treatment unit.

Reuse

The Sterling plant was closed for a period of six weeks due to a labor strike. This provided an opportunity to study problems and effects relating to the use of reclaimed water to augment the Sterling water supply.

During this period, the Sterling plant's water treatment unit was operated at capacity with the total volume discharged through the plant's drainage system into the primary wastewater lagoon. Lagoon effluent was treated in the advanced treatment unit utilizing sand filtration. Reclaimed water was introduced into the Sterling plant supply at the rate of 100 gpm, 200 gpm, and ultimately 300 gpm.

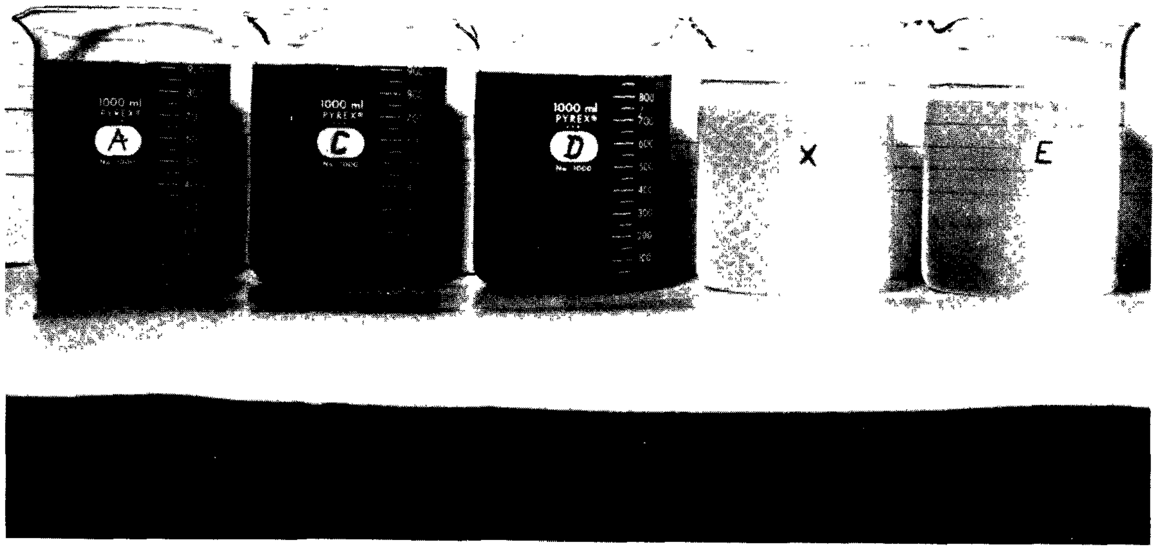
To resolve pressure variation difficulties inherent in the interconnection of two pressure systems, and further, to provide maximum treatment of reclaimed water, water from the advanced treatment unit was introduced into the raw water basin of the Sterling water treatment unit, and introduced into the poultry plant's distribution system through Sterling's pumping arrangement. Continuous monitoring of the integrated supply demonstrated the ability to maintain a free chlorine residual throughout the system and the maintenance of a turbidity level of less than 2 (JTU). The treatment facilities utilized during this operation are as follows:

Wastewater Treatment and Advanced Water Treatment Route of Flow

Screening
↓
Primary Lagoon with grease skimming
↓
Secondary Lagoon with grease skimming
↓
Settling
↓
Chlorination
↓
Microstraining
↓
Flocculation, sedimentation
↓
Chlorination ("breakpoint")
↓
Pressure storage
↓
Sand filtration
↓
Chlorination ("breakpoint")
↓
Flocculation, sedimentation
↓
Sand filtration
↓
Chlorination (free residual)

Sampling and Analytical Procedures

The study provided for chemical and physical examination of samples collected from each of five sampling points throughout the system. Samples were collected routinely of raw wastewater, primary and secondary lagoon effluent, microstrainer effluent, and filtered water. During the second operational segment, samples of settled water and comparison samples of filtered water from the diatomaceous earth and sand filters were also examined.



A = Raw Poultry Waste

C = Secondary Lagoon Effluent

D = Effluent From Microstrainer

X = Flocculated - Settled Water

E = Filtered Reclaimed Water

Samples of raw wastes and wastewater secondary lagoon effluent were composited over 24 hours and collected once each day. Grab samples were collected of the primary lagoon effluent and from each point in the advanced water treatment unit. Sampling procedures allowed for continuous evaluation of effectiveness of each phase of the wastewater lagoon treatment and advanced water treatment processes.

Quality Control Procedures

Routine chemical and bacteriological examinations were conducted in the Cumberland, Maryland, branch laboratory which operates under supervision of the Laboratories and Research Administration of the Maryland State Department of Health and Mental Hygiene. Specialized chemical, virology, and chromatograph examinations were conducted in the Administration's central laboratory in Baltimore, Maryland.

All examinations were made in accordance with the procedures established in the following:

> The Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. Published by American Public Health Association, and Water Pollution Control Association.
>
> EPA Methods for Chemical Analyses of Water and Wastes, 1971. Published by Environmental Protection Agency.
>
> Handbook for Analytical Quality Control in Water and Wastewater Laboratories, 1972. Published by Environmental Protection Agency.
>
> Pesticide Analytical Manual, Food and Drug Administration
>
> Polyelectrolyte Technique for Virus Detection as developed by Dr. Joseph L. Melnick (Baylor University).

Chemical - Physical Evaluation

Results of chemical and physical examinations of reclaimed water throughout both segments of the operational phase of the study show that, with the exception of turbidity, study facilities proved capable of consistently reaching standards established for drinking water for each characteristic studied. Facilities used during the second segment of the study's operational phase proved capable of producing a finished water with turbidities ranging from 1 to 3 units.

The limited period of study following completion of the settling basin did not allow thorough evaluation of advantages of coagulant aids. Increased efficiency of coagulation should result in more consistent turbidity control. Although chloride content of the finished water was consistently below the allowable limit of 500 mg/l, continuous recycling of this wastewater could result in chloride's buildup exceeding satisfactory levels.

Chemical-Physical Quality of Reclaimed Water

mg/l

	Drinking Water Standard-1962	N	$\bar{X}$	$\bar{O}$
Turbidity (JTU)	5	54	3.5	1
Color	15	90	5	7
Pesticides		16	0	
pH		207	6.6	1.4
Alkalinity		101	104	57
Hardness		22	131	24
Dissolved Solids	500	158	335	129
Chloride	250	162	117	53
Cyanide	0.2	8	0	-
Fluoride	1	23	0.21	0.13
Nitrate (NO_3)	45	89	31	8
Phosphate		47	10	2
Sulfate	250	23	13	5
Aluminum		17	0.03	0.04
Arsenic	0.05	26	0.01	0.01
Cadmium	0.01	8	<0.01	0
Calcium		26	46	12
$Chromium^6$	0.05	8	<0.01	0
Copper	1.0	26	0.06	0.01
Iron	0.3	27	0.27	0.19
Lead	0.05	8	0.01	0.01
Manganese	0.05	10	0.02	0.02
Mercury	0.005	8	0.003	0.003
Potassium		20	10.7	9.5
Selenium	0.01	8	<0.01	0
Silver	0.05	8	<0.01	0
Sodium	270	19	21	15

N = Number of Samples $\bar{X}$ = Mean Value $\bar{O}$ = Standard Deviation

Four points of chlorination are contained in the complete treatment processes:

1. <u>Chlorination of secondary lagoon effluent</u>. Rate of chlorination at this point is determined by level of disinfection necessary for the control of coliform in effluent discharged to the river. A minimum of 30 minutes' contact time is provided with the objective of 1 mg/l of free residual chlorine in discharged effluent. At the beginning of the study it was discovered that short circuiting of the contact chamber often resulted in the presence of free chlorine in discharged effluent without effective disinfection. The chlorine diffuser line was lengthened

to extend the entire length of the chlorine contact chamber. Normal rate of application in the chlorine contact chamber for bacteriological control has been established at 20 lbs/day.

2. Chlorination of settling basin effluent. Chlorine is added on the suction side of the pump which delivers settled water to the pressure storage tank prior to filtration. During the first operational segment of the study, water was filtered prior to discharge into the pressure tank. During the second segment, water was pumped into the pressure storage tank prior to delivery to the sand filter. This procedure provides for an additional 30 minute period of chlorine contact.

   Chlorine dosage at this point is determined by chlorine demand. Normal dosage rate is 20 lbs/day with the objective being the reaching of "breakpoint".

3. Pre-chlorination, Sterling water treatment raw water basin. Rate of chlorination is 5 lbs/day to control biological growth within the unit and to satisfy chlorine demand of raw water. Objective is to reach "breakpoint" and to carry a chlorine residual onto the sand filter surface.

4. Chlorination of filter effluent. Final chlorination is provided at the rate of 5 lbs/day, with chlorine introduced into water service main entering the processing plant. The objective is to assure a chlorine residual throughout the poultry plant distribution system.

Bacteriological Evaluation

Bacteriological samples were collected routinely from the overflow line from the wastewater lagoon chlorine contact chamber to determine the reliability of chlorination of lagoon effluent. A chlorine feed rate of 20 lbs/day (8 mg/l) was determined adequate to assure the discharge of effluent containing fewer than 240 fecal coliform/100 ml. At a chlorination rate of 20 lbs/day (8 mg/l), 90% of the samples collected over a two year period contained <3 fecal coliform/100 ml.

During the study period, 352 bacteriological samples of filtered water from the advanced water treatment system were collected and examined for coliform, fecal strep, and total plate counts. A chlorine application rate of 20 lbs/day (8 mg/l) prior to filtering resulted in consistent bacteriological counts of <3 coliform/100 ml; <1 fecal strep/100 ml; and a standard plate count of <100/ml. The chlorination rate of 60 - 80 lbs/day, necessary to reach "breakpoint" during the 66 minute retention period in the pressure storage tank prior to filtering, provides additional assurance of bacteriological safety of the water.

Virus Control

Examination procedures to assure the total absence of viable virus organisms in water are not presently available. U. S. P. H. S. Drinking Water Standards - 1962, indicate the inactivation of enteric viruses in water requires a minimum free chlorine residual of 0.3 mg/l for 30 minutes, or 9 mg/l of combined residual and

3 minutes. Chlorine was added in the wastewater lagoon contact chamber. Chlorination at this point was in sufficient amount to provide a combined residual following 30 minutes' retention. Additional chlorination, at the rate required to reach "breakpoint" during a minimum of 60 minutes' retention, was provided prior to filtration.

Maryland's Laboratories and Research Administration has the capability of identifying human enteric virus organisms in water. During the study 9 five gallon samples were composited at random from filtered reclaimed water and examined for human enteric virus organisms. All samples were negative. Continuous automatic monitoring and recording of free chlorine residual was provided.

Financial Considerations

Initial cost of the two wastewater treatment units was $84,000, excluding land value. Construction cost of the advanced water treatment unit, including control house, covered sedimentation basin, 1000 feet of pipe line and equipment, was $89,998.50, resulting in a combined construction cost of $173,998.50.

Annual cost of operating the wastewater treatment unit has been determined to be $22,658.75. Annual cost of the advanced water treatment unit is $19,476.77, for a combined annual cost of $42,135.52. This is equal to a total wastewater treatment and water reclaiming cost of $1.03/1000 lbs. LWK.

SUMMARY

It is technically and economically feasible to reclaim poultry processing wastewater to levels of compliance with drinking water standards.

Problems encountered in advanced treatment of this wastewater can be resolved through practical application of currently available equipment and technology.

The degree of recycling of poultry processing wastewater which can be utilized without problems remains to be seen. Evidence indicates the possibility of buildup of chlorides. Additional attention should be given to the possibility of virus survival and carryover of organics.

Future studies are being designed to evaluate these problems and to determine the significance of reusing reclaimed water within the poultry processing plant.

REMOVAL OF PROTEIN AND FAT FROM MEAT SLAUGHTERING AND PACKING WASTES USING LIGNOSULFONIC ACID

by

T. R. Foltz, Jr.*, K. M. Ries**, and J. W. Lee, Jr.***

INTRODUCTION

A physical-chemical process is described herein that is designed to remove the protein and fat from meat slaughtering and packing operations. The intent is to recover these wastes materials for their potential feed value, or alternate use, rather than regard them as pollutants to be treated in a waste water treatment plant.

The technical literature describes the nature of slaughtering or abattoir wastes and meat packing wastes as being high strength in terms of BOD_5, suspended solids, grease or fat, and nitrogen(1). The principal materials present are proteins and fat that are animal body fluids and tissue lost in the various operations necessary to produce edible products. As these wastes are commonly warm, have an almost neutral pH, contain nutrients and are readily biodegradeable, various systems of biological waste treatment have been successfully used to produce a final effluent low in BOD, suspended solids, and grease(2)(3)(4). Most previously designed biological waste water treatment systems were not designed to remove the nitrogen present, but discharge limitations on nitrogen are expected to be placed on most discharges in the future(5). Nitrogen removal represents a significant additional cost to the meat industry in addition to technical difficulties present in currently proposed nitrogen removal resolutions(1)(3).

A process designed for removal of protein matter from raw wastes has the potential of directly removing the nitrogen in its original state, thereby reducing the need to add-on additional waste treatment operations specifically for nitrogen control. A process using lignosulfonic acid (LSA)

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treatment of proteinaceous wastes has a potential for nitrogen removal plus potential recovery of waste water protein for recycling as an animal feed ingredient.

BACKGROUND

The physical-chemical combining of lignosulfonic acid and proteins in an aqueous system has been known for over 30 years(6)(7). Wallerstein(8) in 1944, described the recovery of proteins from dilute solutions using spent sulfite liquor at a pH of 2 to 4. The precipitating agent in the sulfite liquor was identified as lignosulfonic acid and a ratio of 2 parts lignin to 5 parts protein was observed to be optimal. Pearl(9) discussed the uses of lignin in a survey paper in 1957, and mentioned the reaction of lignosulfonic acid with proteins to form insoluble complexes and indicated this reaction was used to remove proteins from effluents of canneries or fish-processing plants.

In 1968, a U.S. Patent(10) was issued to Leif Jantzen of Oslo, Norway, assignor to Arthur C. Trask and Sons, Chicago, that described a method of purifying an aqueous protein-containing liquid by adding lignosulfonic acids to effect precipitation of combined protein-lignosulfonic acids and separating the precipitate.

In a paper by Tønseth & Berridge(11), lignosulfonic acid precipitation of proteins from various industrial waste waters, including slaughterhouse wastes was reviewed. Sulfite lye (spent sulfite liquor), was compared to lignosulfonic acid as precipitating agents on blood albumen solutions, showing the lignosulfonic acid to be superior. Ferric chloride was also compared, and performance was poorer than with lignosulfonic acid.

Pilot plant trials on poultry wastes were described by Rosen(12) using pilot plant equipment developed by Alwatech A/S, an Oslo, Norway based firm of water treatment engineers. BOD removals ranging from 60 to 95 percent were reported, and economic aspects were also discussed.

Jørgensen(13) in Denmark, in a series of laboratory scale tests compared protein precipitation with the following chemical agents:

Control (no agent used)
Sulfuric Acid
Aluminum Sulfate
Glucose Trisulfate
Sulfite Liquor

Lignin Sulfonic Acid (LSA)
Glucose Trisulfate plus Azoprotein

He observed that lignin sulfonic acid was more effective in protein removal than the other chemicals. The protein precipitation with glucose trisulfate plus azoprotein gave a lower residual BOD and the recovered protein had better feed value than with lignin sulfonic acid. Aluminum sulfate while less effective on nitrogen removal, was found effective for phosphate removal.

Hopwood and Rosen(14) reported further developments by Alwatech A/S, and described the "Alwatech process" wherein purified sodium lignosulfonate called "Alprecin" can be used at pH 3 to recover protein and fat from various industrial wastes. Pilot plant data was reviewed, from studies using Alwatech dissolved-air flotation equipment.

Since 1970 Alwatech A/S has marketed equipment and technology in Europe for recovery of proteins from waste water on an industrial scale. To date, several plant scale installations of Alwatech equipment have been completed and are in operation in Sweden and England. There are currently no plant scale installations in operation in the United States.

THEORY

The precipitation of soluble protein with soluble lignosulfonic acid in an acidic aqueous system is believed to be a nearly instantaneous reaction involving the negatively charged sulfonate groups on LSA molecules and positively charged amine groups present on the protein molecules. The complexing of these large molecules results in a gelatinous suspended material that can be removed by a suitable physical liquids-solids separation technique.

Protein molecules contain both positively charged amine groups and negatively charged carboxyl groups when the solution is at pH values near 7. Acidification of proteinaceous waste water to pH values below the isoelectric point will result in proteins carrying a net positive charge. Isoelectric values vary with different proteins, but acidification to 3.5 or below normally insures a pH below the isoelectric for most protein solutions.

Lignosulfonic acid when in solution has the sulfonate group essentially completely ionized, resulting in a net negative charge on the LSA molecule. With acidification, the strong acid group of the sulfonate continues to carry a negative charge even at pH values of 2 to 3. At extremely low pH values below 1, the sulfonate group begins losing its charge.

Table I summarizes the respective net charges on LSA and protein molecules at various pH ranges, noting the resulting precipitation potential.

Table I. Influence of pH on LSA-Protein Precipitation

pH Range	Protein	LSA	Precipitation
0-1	Positive Charge	Weak Negative Charge	Poor
2-3	Positive Charge	Negative Charge	Good
3.5-4.5	Isoelectric (no net charge)	Negative Charge	Poor
Above 4.5	Negative Charge	Negative Charge	None

This table reveals that the pH must be in range of 2 to 3 to obtain effective precipitation. Actual experimental evidence confirms that this is the optimal pH range for precipitation of the maximum amount of protein.

Because the precipitation involves balancing of opposite ionic charges, it follows that an optimal ratio exists between LSA and proteins in order to maximize protein removal with the least amount of LSA. Experimental evidence also confirms that treatment of proteinaceous wastes with LSA is quantitative, making LSA dose control important(15).

In precipitating and removing the LSA and protein complex, fat and fatty material (as determined by hexane soluble extraction) are also largely removed. In raw waste, fat is primarily particulate and emulsified matter with a free fatty acid content ranging from 5 to over 50 percent of the total fat content. Acidification of raw wastes eliminates the strong negative charge on the free acid carboxyl groups resulting in a loss of water solubility. Therefore, at protein precipitating pH values, most of the fat material tends to separate from the water and float to the surface. The presence of LSA would not be expected to enhance fat removal if protein matter was absent from the raw wastes.

With protein present and forming an insoluble material with LSA, the fat tends to be comingled with the protein-LSA material.

LIGNOSULFONIC ACID (LSA)

Lignosulfonic acid is a by-product from the sulfite wood pulping industry and is commercially available in a variety of forms and quality.

Spent sulfite liquor contains wood lignin that has been made soluble by the introduction of sulfonate groups in the lignin. Sulfonated lignins are large molecules made up of repeating units of polymerized coniferyl alcohol, together with lesser amounts of sinapyl and p-coumaryl alcohols. (Sinapyl alcohol contains two aromatic methoxyl groups while p-coumaryl alcohol has none.) Approximately half the coniferyl units are sulfonated, primarily on the aliphatic carbon attached to the aromatic ring(16). Figure 1 illustrates a typical segment of sulfonated lignin. The term "lignosulfonic acid," or LSA, is herein used to describe the sulfonated lignin matter as present in an aqueous system, which is ionized as shown in Figure 1.

The molecular weight of lignosulfonic acid is not a defined quantity as the commercially available materials are actually mixtures of various molecular weight lignins. Jantzen(17) described the desirability and method of separating lignosulfonates into two molecular weight fractions and defined them as follows:

Name of LSA Fraction	Average Molecular Weight
Alpha acid	14,620
Beta acid	5,180

In protein precipitation, the higher molecular weight fraction is more suitable than low molecular weight LSA(18).

Spent sulfite liquor is over 50 percent LSA on a dry weight basis, and is functionally capable of precipitating proteins. However, spent sulfite liquor contains carbohydrate matter that contributes soluble BOD to the protein solution being treated, and is an undesirable precipitant for this reason.

Desugared sulfonated lignins are commercially available from several mills that are better candidate precipitants for waste water protein than spent sulfite liquor. More highly purified lignosulfonic acid is the most suitable

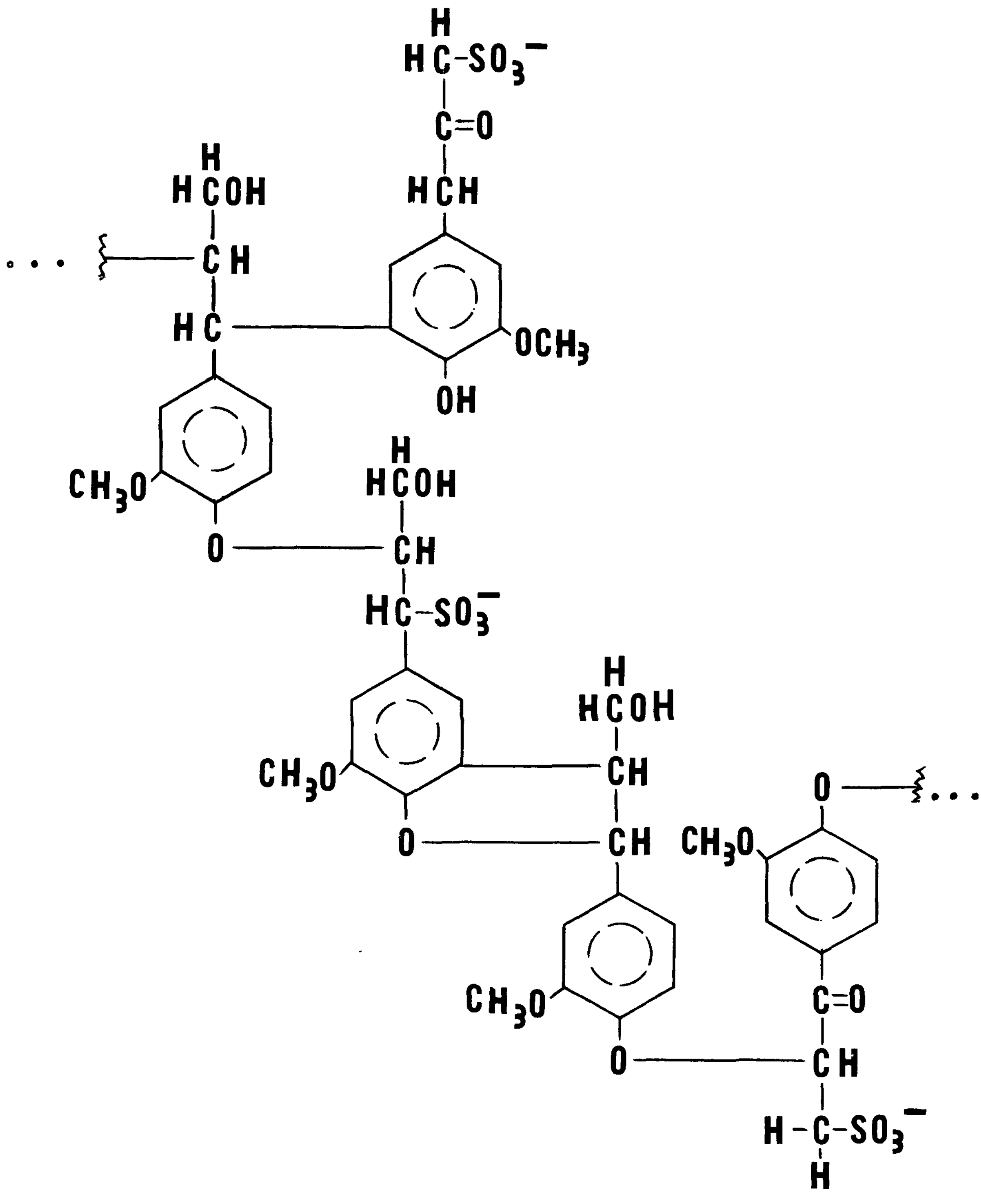

Figure 1. Typical Segment of Sulfonated Lignin Molecule

material to use as the precipitating chemical, especially products that have mainly high molecular weight LSA.

LSA products are available in the salt form such as sodium, calcium, or ammonium lignosulfonate. As the cation is not involved in precipitation, the choice of salt form is dictated by reasons other than precipitation performance. Ammonium lignosulfonate would be clearly unsuitable in applications where nitrogen removal was an objective.

LSA is available as a dry powder bagged in 50 lb. bags or as a bulk liquid at about 50 percent total solids.

It is important to note that LSA is not a standard chemical, but rather a complex mixture of sulfonated lignins plus minor wood extract impurities. Differences in the woods used, method of cooking, and subsequent handling will affect the properties of LSA.

In application LSA is used as a stock solution at about 10 percent total solids, which makes a blackish-brown liquid that is easily handled and pumped.

Lignin sulfonates are FDA approved for use in animal feed as described in the Code of Federal Regulation, 21CFR121.234.

PILOT PLANT TESTS - GREEN BAY

A brief pilot plant study was conducted at a beef abattoir in Green Bay, Wisconsin, to evaluate the LSA precipitation and removal of protein and fat under actual plant conditions. Arrangements were made through the Arthur C. Trask Corporation in Chicago to have Alwatech A/S of Oslo, Norway, deliver and operate a small pilot plant for a period of several weeks. The test program was designed to demonstrate the optimum pollutant removal capability of LSA and to characterize the protein matter separated.

The plant operations contributing waste waters consisted of typical beef kill floor operations, paunch manure screening, inedible dry rendering, blood drying, and hide curing. Sanitary wastes, livestock pen wastes, and refrigeration cooling water flows were handled separately and were not present in the raw plant wastes. The fresh raw wastes were pretreated by screening in a North Screen. A 20-gallon per minute side stream from the screen effluent was pumped to the pilot unit as the raw waste to be treated.

The pilot plant consisted of an influent pump, partial influent pressurization to 75 psig, chemical feed systems for sulfuric acid and LSA, and a circular dissolved-air flotation tank having a 60-minute theoretical detention time. Figure 2 illustrates a schematic of the pilot plant equipment. Air was provided by a small compressor to provide air for dissolving into the pressurized influent. Sludge scrapers were present for floating solids removal from the flotation cell. The flotation unit effluent was not neutralized and was considered the effluent from the pilot unit.

Sulfuric acid, technical grade, was metered as a 1 percent solution and powdered LSA was made up as a 10 percent feed solution for metering into the process. Figure 2 illustrates a schematic of the pilot equipment employed.

Beaker tests were first performed to establish anticipated pH and LSA dose ranges to be studied in the pilot operation.

Actual pilot plant runs for sampling were conducted after a minimum of one-half hour of continuous normal operation, with the flotation tank already filled with chemically treated raw waste water remaining from the previous run. The pilot runs lasted a minimum of four hours per run, and all sampling was on a composite basis.

Nine reported runs were conducted using a powder LSA called "Na-Peritan" which was supplied by Arthur C. Trask Corporation from sources in Norway. This product was a purified sodium salt of lignosulfonic acid that contained very little residual wood sugar and was a high molecular weight fraction of LSA. Table II summarizes the data from these nine runs.

Two other LSA products were also evaluated druing the pilot trials; an ammonium salt of LSA and a sodium salt of LSA, both experimental products from Scott Paper Company. Typical runs for these products produced roughly similar results except total nitrogen removal was poor for the ammonium LSA.

Acid addition and LSA dose were varied by the Alwatech operator to achieve good visual performance without regard to arriving at the economically minimum chemical requirement. While a precipitating pH of 3.4 was experimentally found to be suitable for effective precipitation, the average pH for all runs was 2.6, with one run as low as 2.0. Good precipitation was found at this pH range, but excess acid was used that would not be representative of full plant scale operation.

The LSA dose range tested was 244 to 537 mg/l, which represented a range of effective precipitation rather than a

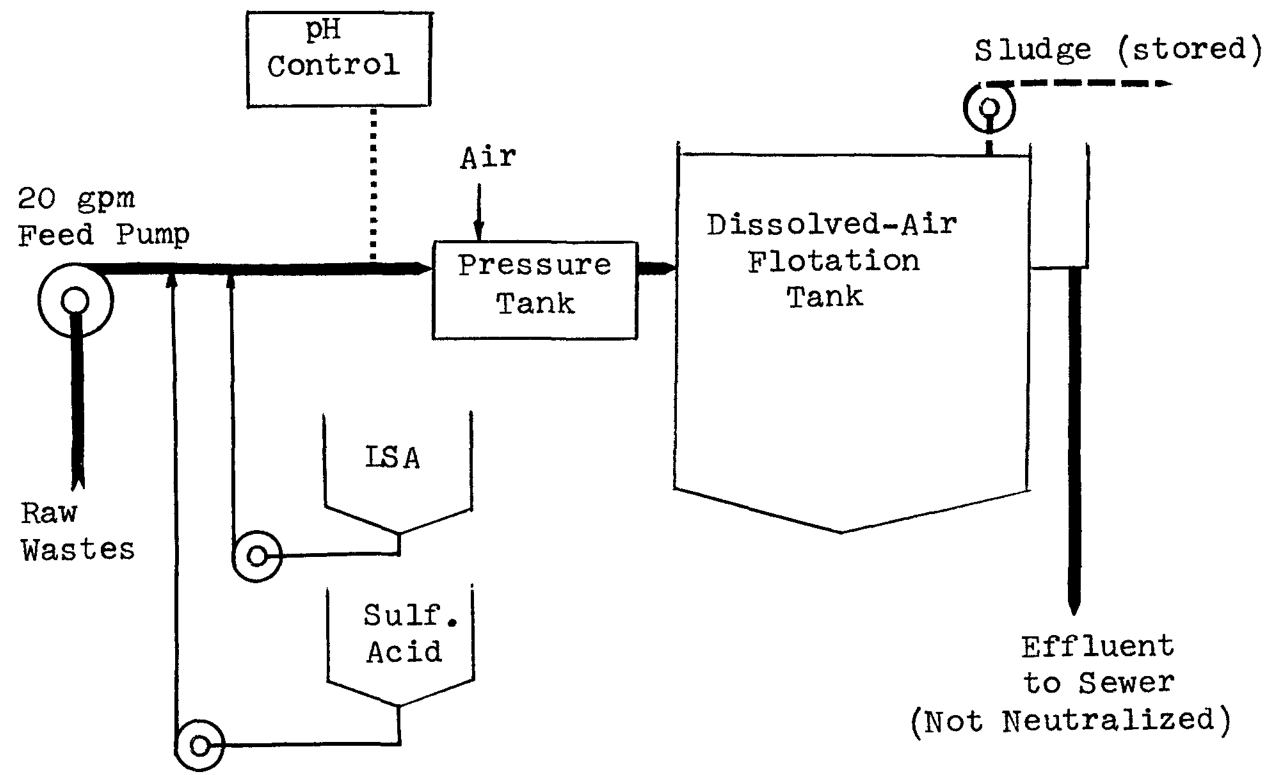

Figure 2. Schematic of Pilot Plant, Green Bay, Wisconsin

Table II: Summary Data, LSA Precipitation with Alwatech Pilot Plant Armour and Company Beef Abattoir, Green Bay, Wisconsin

Test No.	I	II	III	IV	VII	VIII	IX	X	XI	Average
LSA, mg/l	244	355	405	298	537	516	484	534	428	422
H_2SO_4, mg/l	-	506	750	1000	663	671	917	910	850	784
pH: inf	6.5	6.8	6.4	6.5	7.0	6.6	6.8	6.8	7.8	6.8
eff	2.9	3.0	2.3	2.1	2.7	2.6	2.4	2.4	3.4	2.6
BOD: inf. mg/l	1260	920	1700	960	1160	1040	1070	1160	2130	1258
eff. mg/l	180	180	90	170	267	223	178	156	360	208
% Rem.	85	82	94	82	77	78	83	86	83	84
TSS: inf. mg/l	760	1770	1470	1310	560	666	684	658	1220	960
eff. mg/l	71	82	35	39	33	24	20	28	23	41
% Rem.	91	95	98	97	94	96	97	96	98	96
FOG: inf. mg/l	254	526	744	473	296	749	252	243	370	435
eff. mg/l	19	17	9	6	35	38	18	21	30	22
% Rem.	93	97	99	99	88	95	93	91	92	95
TKN: inf. mg/l	448	220	126	182	105	138	175	175	129	188
eff. mg/l	46	24	21	24	22	18	21	18	21	24
% Rem.	90	89	83	87	79	87	88	90	84	87
Sludge Data:										
TS, %	5.8	7.2	8.0	9.2	7.5	5.5	5.0	5.1	6.9	6.7
Protein % of TS	76	66	36	8	28	36	40	42	44	42
Hex.Sol.% of TS	34	17	34	48	42	41	34	41	17	34

BOD denotes Biochemical Oxygen Demand, 5-day, 20°C, seeded
TSS denotes Total Suspended Solids
FOG denotes Fat, Oil, and Grease (hexane solubles)
TKN denotes Total Kjeldahl Nitrogen, as N

range of minimum dose to achieve adequate precipitation.

As Table II illustrates, effective pollutant removal was accomplished in terms of BOD, suspended solids, fat or grease, and total Kjeldahl nitrogen. The pilot plant outperformed the existing plant scale dissolved-air flotation unit in service at the abattoir as summarized in Figure 3. Samples of the recovered raw sludge were withdrawn and analyzed by the Armour and Company Food Research Laboratory in Oakbrook, Illinois. Table III summarizes the analytical values for the LSA sludge, and Table IV compares the amino acid profile of the LSA sludge as compared to soybean oil meal and casein. These analyses reflect raw sludge solids characteristics and are not necessarily representative of a final product as produced on a plant scale.

PLANT SCALE OPERATION - SUTTON BENGER

A one-day visit was made to observe the operation of a plant scale installation of Alwatech equipment at a poultry plant in England in November, 1972. This plant was designed for approximately 75,000 broilers per day, and was located at Sutton-Benger, near Chippenham, in Wiltshire, England.

Typical of broiler plants in the United States, this plant had rotating screens on each of the offal flow-away waste water and feather flow-away waste water sewers. This plant had an older industrial waste treatment facility consisting of primary clarification, trickling filters, final clarifiers and humus tanks prior to final river discharge.

The newer Alwatech equipment consisted of the following:

1. Balancing tank to receive screened raw wastes.
2. Precipitation and flotation system, designed for 400 gallons per minute flow.
3. Neutralization system.
4. High rate trickling filters with plastic media
5. Final clarifiers.

The Alwatech system provided primary waste water treatment and the effluent was then subsequently treated in the existing older secondary treatment plant final to river discharge.

After balancing the flow to dampen fluctuations in flow and waste water strength, the raw waste was initially dosed with approximately 140 mg/l of Alprecin (LSA). Once the dosage was set, this dose was held constant and no changes in LSA dose were needed from day-to-day or hour-to-hour. The flow

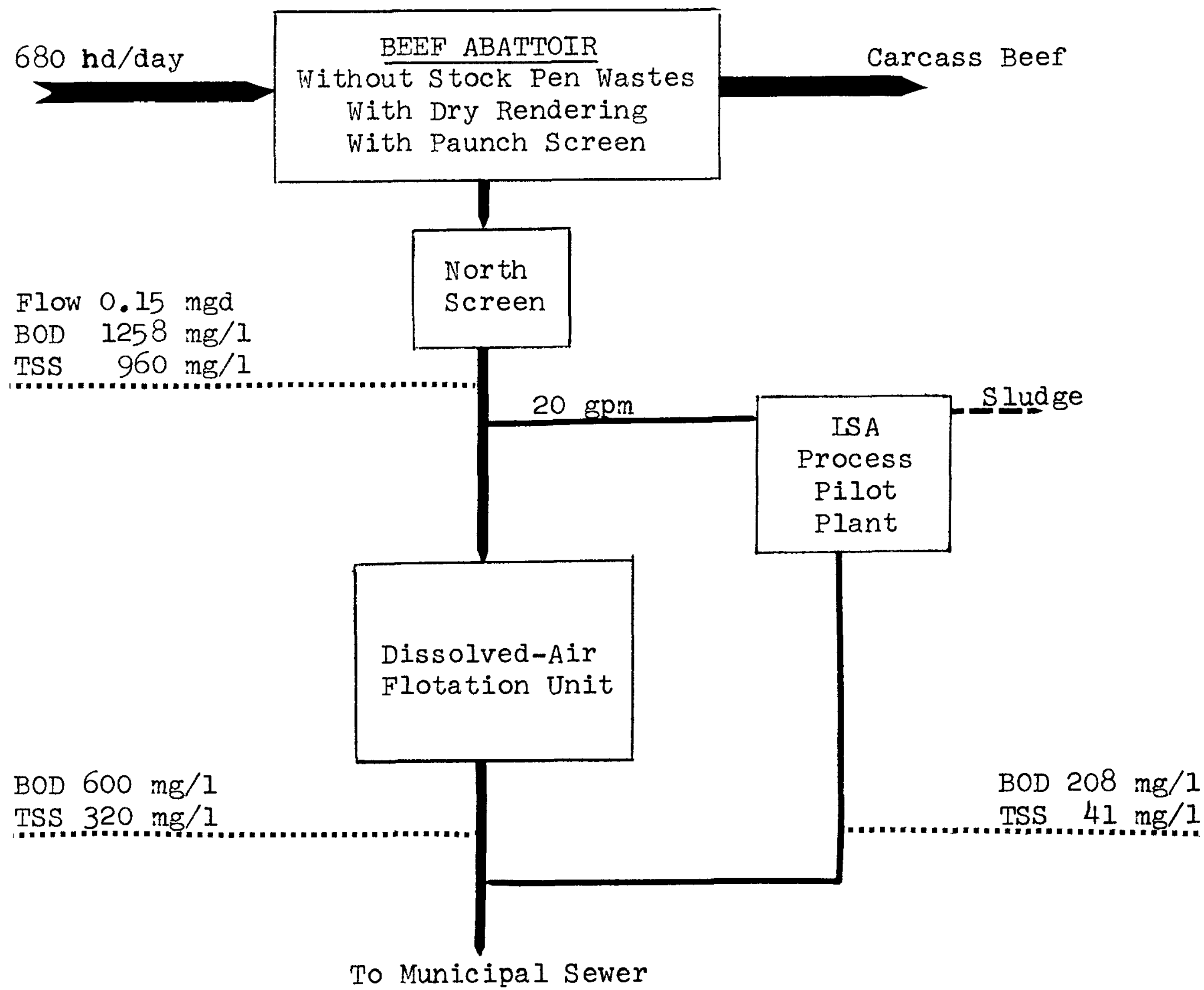

Figure 3. Pilot Plant Performance at Green Bay Compared to Existing Dissolved-Air Flotation.

Table III: Analysis of LSA Sludge from Pilot Plant Studies, Armour and Company, Green Bay, Wisconsin

Item	Percent of Dry Matter
Protein	40.2
Fat	24.08
Crude Fiber	4.29
Lignin Sulfonate	31.62
Total Solids	100.00
Total Nitrogen	6.43
Total Non-protein Nitrogen	0.503
Sodium	0.359
Potassium	0.042
Calcium	0.054
Magnesium	0.0083
Phosphorus	0.398
Sulfur	1.55
Iron	0.169
Copper	0.0025
Manganese	0.022
Zinc	0.0066

Vitamin A (including carotene) IU 5811

Table IV: Amino Acid Profiles for LSA Sludge (Green Bay Pilot Study), Soybean Oil Meal and Casein

Amino acids	LSA Sludge gm of amino acid per 16 gm of N	Soybean oil meal gm of amino acid per 16 gm of N	Casein gm of amino acid per 16 gm of N
Lysine	9.77	6.30	8.5
Threonine	5.75	3.70	4.2
Valine	8.05	5.23	6.5
Methionine	1.67	1.30	3.4
Isoleucine	4.19	5.45	5.8
Leucine	11.74	7.40	9.0
Phenylalanine	6.17	4.80	5.1
Tryptophan	1.32	1.30	1.4
Histidine	4.82	2.40	3.2
Arginine	5.49	7.00	3.6
Aspartic acid	12.49	11.40	6.7
Serine	5.42	4.70	6.7
Glutamic acid	14.70	19.30	22.5
Proline	5.16	4.70	12.3
Glycine	5.83	3.80	2.1
Alanine	8.23	4.30	3.2
Cystine	3.80	1.70	0.3
Tyrosine	4.61	3.05	5.4

was then split into three flows. Two equal main flows were regulated by flow controllers for delivery to each of two dissolved-air flotation units. The third flow, approximately 15 percent of the incoming total flow, was pressurized to 75 psig, saturated with air, and then split into two equal flows to deliver dissolved air to the two main influent streams.

Just prior to entry into the flotation unit, the waste water was mixed with the side stream of waste water with dissolved air, and a one percent solution of sulfuric acid was added to depress the mixture from pH 7 to pH 3. In one flotation cell, the raw waste pH was monitored, with the electrodes being cleaned by a timed ultrasonic generator. The pH was continuously recorded and a control function automatically actuated the sulfuric acid feed pumps to maintain a pH 3.0 ± 0.3. The normal sulfuric acid dose was 250 mg/l.

The flotation units were circular 18 ft. diameter fiberglass tanks with surface scrapers consisting of a vacuum suction system for sludge removal. The clarified effluent from the two flotation units were combined and delivered to a small mixing tank where hydrated lime was added at the rate of about 180 mg/l, and automatically pH controlled to 7.0 ± 0.5. The neutralized waste was then subjected to biological treatment in the subsequent trickling filter system.

Sludge from the two flotation cells was accumulated in an existing pit and hauled away for land disposal as a temporary measure. It was understood that studies were then underway to utilize the recovered sludge as an animal feed component.

The entire precipitation and flotation system plus chemical handling was housed in a building to reduce the influence of weather on plant operations.

Pilot plant data in establishing the design of Alwatech equipment revealed that on the raw wastes of 1,000 to 1,500 mg/l BOD, the removals observed were as follows:

BOD removal	73.8%	(64.3 to 80.5 range)
COD removal	76.3%	(70.6 to 86.8 range)
TSS removal	82.7%	(75.6 to 89.2 range)

No plant operating results were available for review at the time of visit, but visual performance in producing a clear effluent after flotation suggested the pilot plant data was duplicated in the actual plant scale operation.

The subsequent biological treatment of the precipitation and flotation effluent was reported successful in meeting the final effluent standards of 30 mg/l BOD and 40 mg/l Suspended Solids.

No difficulties in operation of the entire system were observed during the visit. Plant operator functions consisted of maintaining all equipment in good working order and insuring adequate chemicals are available to the chemical feed systems.

PLANT SCALE OPERATION - KALMAR

A brief visit was made to another installation of Alwatech equipment that used LSA treatment of meat industry wastes. As in the case of Sutton-Benger, the primary goal was BOD, grease, and suspended solids reduction, with the intent of recovering a by-product. Nitrogen removal was not a specific objective.

This facility was a complex packing plant in Kalmar, Sweden, that slaughtered beef, hogs, and a minor number of lambs, horses, and elk. A wide variety of sausages, smoked meats, and other processed meat products were produced. Canning operations included canned meat products and some canning of vegetables, with peas and carrots being processed at the time of visitation in November, 1972.

The waste water treatment system in operation consisted of the following:

1. Grease skimming basin converted into a balancing tank.
2. Rotary screen (1/8 inch diameter openings) pretreatment.
3. Precipitation and dissolved-air flotation system.
4. Neutralization system.

The final treated effluent was then discharged to the Kalmar municipal sewerage system for joint treatment with domestic wastes.

The precipitation and flotation processes were operating at a design flow of about 400 gallons per minute on each of three out of the five working days. On the remaining two working days, reduced operations produced a raw waste flow of about 265 gpm.

Screened waste was dosed with a constant dose of 220 mg/l Alprecin (LSA). As at the Sutton-Benger installation, manual control of the LSA dose rate was found effective in maintaining proper precipitation. The LSA was fed as a ten percent stock solution with the feed rate proportional to the total waste flow. Unusually high strength shock loads with BOD values well above 2,000 mg/l did require upward adjustment of the LSA dose, but this problem was considered infrequent, and one best controlled by improving inplant operations.

The LSA dosed screened waste was split into the 15 percent side stream for influent pressurization and air dissolving, while the major flow was equally split for delivery to the two 18 ft. diameter fiberglass flotation cells. Sulfuric acid addition and re-entry of the dissolved-air side stream took place just prior to entry into the flotation tanks. The pH was monitored, recorded, and controlled at pH 3.0 by automatic adjustment of the sulfuric acid feed pumps. Sulfuric acid dose was typically about 350 mg/l. The flotation effluent flowed by gravity to a neutralization tank for adjustment of pH to 7.0. A lime slurry was pumped to the neutralization tank and was manually set for about 180 mg/l hydrated lime. With manual adjustment of neutralization, the recorded final pH fluctuated between pH 6 and 8.

Sludge accumulating in the flotation tank was scraped into four radial troughs at the sludge surface, using a timed motorized scraper making two sweeps in three minutes followed by three minutes off-time. The sludge normally was about ten percent total solids and was pumped to a storage tank.

At this plant, edible blood was being recovered and used in processing. Residual collected blood was mixed with the LSA sludge in the sludge storage tank and the mixture was heated to about 50°C. The heated sludge and blood mixture was then subjected to live steam to coagulate the protein matter. This mixture was then dewatered by a solid bowl centrifuge which produced a granular solid of about 40-50 percent dry matter. The centrate was recycled back to the raw waste balancing tank. The recovered solid was then added to the main plant continuous inedible rendering system for final drying and recovery with inedible tallow and cracklings.

Table V summarizes BOD_7 removal based on influent samples prior to the raw waste screen and effluent samples at the flotation unit discharge.

At the time of visitation, this plant had very little representative data on the nitrogen removal achieved in the precipitation and flotation equipment. Alwatech engineers conducted a brief study to provide the data as summarized in Table VI(18).

Table V: BOD Removal at Kalmar(18)

	Influent BOD_7, mg/l	Effluent BOD_7, mg/l	Percent Removed
	1200	360	70.0
	1500	300	80.0
	1360	330	75.8
	1440	370	74.3
	1290	220	83.0
	1100	150	86.0
	1700	300	82.0
	1600	320	80.0
	2100	340	83.8
	1950	380	80.5
	1500	380	74.6
	1700	270	84.0
	1750	340	80.6
Avg.	1553	312	79.9

Table VI: BOD and Nitrogen Removal at Kalmar(18)

Test Number		1	2	3	4	5	6	7	Avg.
BOD:	Inf. mg/l	1290	1100	1700	1600	2100	1950	1750	1622
	Eff. mg/l	220	150	300	320	340	380	340	300
	% Rem.	83	86	82	80	84	81	81	82
TKN:	Inf. mg/l	91	77	119	112	147	136	122	114
	Eff. mg/l	24	18	32	33	38	40	35	32
	% Rem.	77	77	73	71	74	71	71	73
TS:	Inf. mg/l	3088	2855	2564	3607	3138	4129	3216	3117
	Eff. mg/l	3174	2569	2605	3173	3140	4012	3094	2981

Notes: Influent excluded rumen cleaning and gut-cleaning waters, samples just prior to flotation. Effluent downstream of neutralization.

CONCLUSIONS

1. Lignosulfonic acid treatment of meat industry waste waters under acidic conditions, followed by dissolved-air flotation is capable of removing significant quantities of BOD, suspended solids, grease, and nitrogen from raw wastes, as demonstrated in pilot plant and plant scale installations.

2. LSA treatment appears suitable as a pretreatment step to final biological treatment. It is therefore a candidate process for both meat industry plants using municipal sewerage systems and in cases where the industry must treat its own waste water.

3. Removal of protein and fat with LSA offers the potential of a recovered by-product that may have value as a component in animal feed. This would eliminate a problem of ultimate disposal of the materials removed.

4. The physical-chemical nature of the process makes it convenient to rapidly start-up the process when needed, and to stop processing when desired.

5. The process requires very little land area, and if housed, will operate indpendent of weather effects.

6. The process appears best applied to very fresh raw waste of high protein content and where inedible rendering operations can be used to handle the recovered dewatered sludge. Waste waters having a low buffering capacity are advantageous as acid and neutralization chemical requirements are reduced.

7. Various LSA products are commercially available from several suppliers that are suitable for protein precipitation.

References

1. ERICKSON, E. E., PILNEY, J. P., and REID, R. J. Development Document for Effluent Limitation Guidelines and Standards of Performance for the Meat Packing Industry. Prepared for the U. S. Environmental Protection Agency under Contract No. 68-01-0593: (1973).

2. STEFFEN, A. J. Treatment of Packing Wastes-Practices and Trends. Ontario Industrial Waste Conference: 27 (1966).

3. BELL-GALYARDT-WELLS. Upgrading Meat Packing Facilities to Reduce Pollution-Waste Treatment Systems. Environmental Protection Agency Technology Transfer Program, Job No. 730105: (1973).

4. McKINNEY, R. E., editor. 2nd International Symposium for Waste Treatment Lagoons. Distributed by University of Kansas, Lawrence, Kansas: (1970).

5. WITHEROW, J. L. Waste Treatment Systems for the Small Packer. The National Provisioner: 8 (Sept. 1973).

6. GUSTAVSON, K. H. Svensk Papperstidn 44: 193 (1942).

7. WILSON, J. A. and PORTH, I. H. J. Am. Leather Chemists Assoc. 38: 20 (1943).

8. WALLERSTEIN, J. S., FARBER, E., MAENGWYN-DAVIES, G. D., and SCHADE, A. L. Recovery of Proteins from Wheat Mashes with Sulfite Waste Liquors. Industrial and Engineering Chemistry 36: 772 (1944).

9. PEARL, I. A. Present Status of Chemical Utilization of Lignin. Forest Products Journal 7: 427 (Dec. 1957).

10. JANTZEN, L. Protein-Rich Feed Material and Method of Making. U. S. Patent No. 3,390,999: (July 2, 1968).

11. TØNSETH, E. I. and BERRIDGE, H. B. Removal of Proteins from Industrial Waste Waters. Effluent and Water Treatment Journal: (March 1968).

12. ROSEN, G. D. Profit from Effluent. Poultry Industry: (April, 1971).

13. JØRGENSEN, S. E. Precipitation of Proteins in Waste Water. Vatten 1: 58 (1971).

14. HOPWOOD, A. P. and ROSEN, G. D. Proteins and Fat Recovery from Effluents. Process Biochemistry: 15 (March 1972).

15. CLAGGETT, F. G. and WONG, J. Salmon Canning Waste-Water Clarification, Part II. Circular No. 42, Fisheries Research Board of Canada: (Feb. 1969).

16. BALL, F. J. Chemistry of Lignin and its Applications. Presented at APPA-TAPPI Research Conference: (Oct. 1965).

17. JANTZEN, L. Method of Separating Lignosulfonic Acids. U.S. Patent No. 2,838,483: (June 10, 1958).

18. TØNSETH, E. I. Personal Communication (1972).

DESIGN CONSIDERATIONS FOR TREATMENT OF MEATPACKING PLANT WASTEWATER BY LAND APPLICATION**

by

Anthony Tarquin*, Howard Applegate*, Frank Rizzo*, and Larry Jones*

INTRODUCTION

The increasing demands being placed on municipalities and industries to remove residual carbon, nitrogen, and phosphorus from wastewater discharges has stimulated interest in the land application method of wastewater treatment. The purpose of this paper is to present some initial observations from pilot studies on the suitability of treatment of meatpacking plant wastewater by land application. Land application of wastewater produces high quality effluents from high BOD wastes with relatively low investment and operating costs. The trend toward standards which allow discharge of wastewaters with only low concentrations of carbon and little or no nitrogen and phosphorus has had a particularly hard impact on those industries which generate wastewaters that have high concentrations of these materials. Thus, when an industry produces a wastewater with a BOD of 1000 mg/ℓ, good secondary biological treatment with even 95 percent overall efficiency would still result in a discharge with a BOD of 50 mg/ℓ. Additionally, most of the nitrogen and phosphorus that was present in the untreated wastewater would remain in the effluent. High quality effluents could be achieved with tertiary methods, but the cost of wastewater treatment would be increased considerably. The meatpacking industry is one of the industries that generates wastewater with extremely high concentrations of carbon, nitrogen, and phosphorus.

BACKGROUND

The research described in this paper is a three-year pilot-demonstration project that began June 1, 1972 at the Peyton meatpacking plant located in El Paso, Texas. The first two years of the project will involve pilot

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**This project is supported by funds from the Environmental Protection Agency under Grant No. 801028 and John Morrell Co., Chicago, Ill., and the University of Texas at El Paso.

testing of four separate wastewater application areas treating a total of about 40,000 gpd. Full scale demonstration is planned in the third year of the project.

The system has been in operation for approximately eight months spanning part of the cool winter season and the hot summer months. Rainfall in the El Paso area is scanty, averaging about seven in. per year, with most of the rainfall coming in the summer months through brief but heavy thundershowers.

MEATPACKING PLANT WASTEWATER CHARACTERISTICS

Meatpacking plant wastewater contains most of the pollutants found in domestic wastewaters, except that their concentrations are five to ten times higher. For the most part, meatpacking plant wastes are amenable to treatment by all conventional secondary biological methods. When high concentrations of grease are present, however, problems with sludge settling can be encountered with the activated sludge process.

At the Peyton packing plant the effluent flows into a rectangular sedimentation - skimming tank (catch basin) which has a detention time of 30 min. at peak flow. The efficiency of the tank for BOD, COD, and grease removal has averaged about 66 percent. Nitrogen, phosphorus, and total solids removals have been considerably less. Table 1 shows the average results of some of the analyses performed on the effluent from the catch basin.

Table 1 - Catch Basin Effluent

Analysis	Avg. Conc.,mg/ℓ	Range,mg/ℓ
Grease	1400	285 - 8160
BOD	1340	200 - 115,000
COD	4180	307 - 160,000
P	17	3 - 35
Kjeldahl-N	124	27 - 1200
Total Solids	4200	950 - 13,980

The rather large range for most of the parameters is a manifestation of a daily killing and clean-up cycle. As expected, the strongest wastes are observed during the killing operations and early clean-up hours. The wastewater volume varies similarly, with the maximum flow occurring during killing hours, tapering off to a very small flow after midnight.

Design Considerations

Many factors must be taken into consideration in the design of a soil treatment system for wastewater treatment, including the geology of the area, type of soil, permeability of the soil, wastewater characteristics, and soil cover.

The wastewater treatment area at the Peyton packing plant is flat land composed of 12-24 in. of sandy clay loam underlain by fine sand. The characteristics of the wastewater dictated that only small volumes could be applied at any one application if odors due to an aerobic conditions were to be avoided. Therefore, a sprinkler infiltration type system was designed and constructed. This is in contrast to soils having low vertical infiltration rates that would be more adaptable to a flooding basin infiltration system (1) or to spray runoff treatment (2,3). If a flooding basin system is used, however, a rapid flooding rate would be required in order to equalize the hydraulic loading on the soil. When a sprinkler irrigation system is required, the minimum nozzle size should be 3/8 in. dia., with 1/2 in. dia. or greater preferable. The larger nozzle sizes minimize clogging due to manure and bone fragments that are sometimes present in the wastewater.

Regardless of which type of system is used (infiltration or runoff) some type of soil cover is preferable. Ideally, the most suitable soil cover for a meatpacking plant wastewater would possess the following characteristics: High moisture tolerance, high salt tolerance, resistance to high sodium concentrations, high nutrient uptake, and long growing season. In the south and southwestern part of the United States, grasses that do well under these conditions are Bermuda (common or NK-37), tall wheat, tall fescue, and blue panicum. Leafy plants are not as desirable as grasses because of leaf damage from the high total dissolved solids concentration. In addition, the high total dissolved solids concentration usually makes it advantageous to irrigate with low total dissolved solids (TDS) water until the seeds have germinated and the grasses have grown at least one inch tall.

RESULTS

The results obtained in relatively short term operation are very encouraging from the standpoint of treatment efficiency. At hydraulic loadings of up to 4 in./week, COD removals have consistently exceeded 90 percent in the first three in. of soil with greater than 99 percent removal through four feet. Table 2 summarizes results obtained at the four-foot sampler depth at a wastewater application rate of about four in./week.

Table 2 - Short-term Treatment Results

Parameter	Average Removal, %	Range of Removal,%
COD	99	92 - 100
Grease	100	100
Nitrogen	50	30 - 95
TDS	25 - 50 increase due to evaporation	

The grease present in the original wastewater is separated very quickly after application of the wastewater to the soil. Although the organic concentration of the soil in the treatment areas has increased, there has been no measurable build-up of grease up to this time. Studies are currently underway to determine the rate of grease decomposition and the decomposition products.

Nitrogen removal has varied considerably, depending on the frequency of application. Generally, better nitrogen removals have been obtained with flooding rather than through several small applications/week. The nitrogen is present in the treated samples in nitrate form only, indicating a high degree of nitrification. Higher organic loads could therefore be tolerated, causing lower dissolved oxygen concentrations in the soil water and possible nitrogen loss through denitrification.

The TDS concentration of the wastewater increased considerably on passage through the soil. The low humidity in combination with high summer temperatures results in concentration of the dissolved solids through evaporation. The only detrimental effect observed thus far due to the high TDS concentration of the soil water has been depressed germination of various grasses.

The removal of phosphorus by the soil system was initially very high, i.e., greater than 99 percent. At the present time, however, very little phosphorus is being removed in the spray areas that have been in operation the longest. It appears that the initial available absorption sites have been filled and a slower chemical reaction is now removing small amounts of phosphorus (4). This was expected, however, since the topsoil at the Peyton plant is a maximum of 24 in. thick and contains over 56 percent sand and only 10 percent clay.

Discussion

There are several potential problems associated with land application of meatpacking plant wastewater. One of the most serious is the possibility of the presence of pathogenic bacteria in the wastewater. Brucellosis, Salmonella, and Shigella bacteria have been isolated from the effluent of the catch basin. Brucella organisms can survive for long periods of time in the soil and are capable of infecting both man and animals. A more thorough investigation is now under way at the Peyton site, but the problem warrants serious consideration in the handling of all meatpacking plant wastes.

The problem of pathogenic bacteria present in the wastewater is compounded by the drifting of aerosols formed during application of the wastewater. Under even slight wind conditions (5-10 MPH), aerosols can be observed to drift up to 500 feet. Under the same conditions, a bacterial spore could conceivably drift for miles.

The presence of manure and bone fragments in the wastewater necessitates using rather large nozzles. Since large nozzles require higher pressures for equal distribution when using impact type sprinklers, the problem of drifting is almost unavoidable. An alternative to impact sprinklers is a moving distributor which operates a low pressure using large nozzles. The suitability of this type of system is now under investigation at the Peyton site.

The high TDS concentration in most meatpacking plant wastewaters is caused by sodium chloride. As a result, most packing plant wastewaters have a very unfavorable sodium absorption ratio. This would cause serious problems with infiltration in clay-containing soils unless amendments were added. Sandy type soils are generally not affected by unfavorable sodium adsorption ratios and therefore are generally best suited for accepting meatpacking plant wastes as they leave the plant.

Finally, the high concentration of nitrogen present in most meatpacking plant wastewaters presents a potential problem of ground water pollution. The experience gained with soil treatment systems so far indicates that close control of the treatment system is required in order to remove greater than 50 percent of the nitrogen. Even then, the high concentration originally present could cause significant amounts of nitrogen to reach the ground water table.

CONCLUSIONS

Based on the results from relatively short-term operation, the following conclusions can be made with reasonable certainty:

(1) Virtually all of the organic carbon can be removed from meatpacking plant wastewater by a properly operated soil treatment system.

(2) While high concentrations of grease seem to pose no problem in short term land application of meatpacking plant wastewater, the long term effects of grease on the wastewater infiltration rate bears watching.

(3) In order to achieve high nitrogen removals, the system must be designed to allow close control of the hydraulic and process loads, and

(4) Special consideration should be given to the following potential problems:

(a) possible presence of pathogenic bacteria in the wastewater.

(b) aerosol drifting due to high pressure sprinkler application.

(c) a very unfavorable sodium absorption ratio, and

(d) ground water pollution from high concentrations of nitrates.

1. BOUWER, HERMAN, RICE, R.C., and ESCARCIGA, E.E. Renovating secondary sewage by ground water recharge with infiltration basin. Office of Research and Monitoring, EPA, Project no. 16060DRV,(1972).

2. LAW, JAMES and THOMAS, R.E. Nutrient removal from cannery wastes by spray irrigation of grassland. U.S. Dept. Interior, Water Pollution Control Research Series: 16080 (11/69).

3. WITHEROW, JACK Waste treatment evaluation. The National Provisioner, 169:40 (1973).

4. CHEN, Y.S.R., BUTLER, JAMES, and STUMM, WERNER. Kinetic study of phosphate reaction with aluminum oxide and kaolinite. Environmental Science and Technology, 7: 4 (1973).

CLEANING AND LYE PEELING OF TOMATOES
USING ROTATING RUBBER DISCS

by

R. P. Graham

PRELIMINARY INVESTIGATIONS

At the Western Regional Research Center (WRRC) of the Agricultural Research Service, USDA, we have studied various methods of peeling caustic treated vegetables and fruits to reduce the amount of peeling waste which normally enters plant effluent waters. As a result of these studies we have developed a rubber disc machine to be used for peel removal in place of conventional hydraulic washing. Studies on the use of rubber disc machines for cling peach peeling have shown substantial reduction in water pollution and consumption. Although studied primarily for peeling peaches the rubber disc machines have since found additional uses.

The commercial use of rotating rubber disc machines for peeling caustic-treated fruit was undertaken in a number of plants during the 1972 season, about half of them operating on tomatoes. Operation on tomatoes proved to be quite different from that on other fruit, such as peaches. For example, peach skins virtually disintegrate upon lye treatment and are easily removed, but tomato skins remain as large pieces or in some cases stay completely intact and are thus difficult to remove. Observations of tomato peeling during the 1972 season indicated that some accessory equipment might be helpful by initiating rupture of the skin before the rubber disc peeling operations. Also during the 1972 season, preliminary work was done at WRRC on cleaning tomatoes, using the same configuration of rubber discs used in peeling work.

The following people and organizations cooperated in the study: Western Regional Research Center, Berkeley, CA - R. P. Graham, M. R. Hart, J. M. Krochta, G. S. Williams, W. C. Rockwell, A. I. Morgan, Jr.; National Canners Association, Berkeley, CA - W. W. Rose, N. L. Yacoub, H. J. Maagdenberg, W. A. Mercer; Hunt-Wesson Foods, Hayward, CA - E. F. Haarberg; Canners League of California, Sacramento, CA - J. W. Bell.

Tomatoes coming into a plant have up to 2 percent soil present as clods, up to 0.2 percent soil as smear on the tomato surfaces, and tomato juice from broken fruit. Cleaning of tomatoes is a multiple-step operation. Tomatoes are initially dumped into water to avoid further damage. The dump water also serves to eliminate the soil clods and accumulated juices, and to wet and initiate removal of smear soil and juices. This smear is difficult to remove. Conventionally, energy for removal is provided by flumes and water sprays which follow a dump tank. The 1972 work at WRRC showed the potential for supplying the energy for smear soil removal with rotating rubber discs, using a much smaller amount of water.

Subsequently, discussions held with research personnel from the National Canners Association (NCA) resulted in the decision to set up an integrated pilot plant at a cannery to study rubber disc cleaning and peeling of tomatoes.

The NCA made arrangements with Hunt Wesson Co. to permit installation of a 2 to 5 ton-per-hour plant at their "A" street cannery in Hayward, California. This location was ideal because tomatoes used in the cleaning and peeling studies could be returned to a flume leading to the cannery's product line.

The WRRC built the pilot plant equipment and supplied the operating personnel. The Berkeley laboratory of the NCA did the sampling and analysis. Some financial assistance was provided by the Canners League of California under arrangements made by the NCA. Tomatoes and the utilities were furnished by Hunt Wesson Co. and their personnel were most helpful and cooperative throughout the study.

TOMATO PILOT PLANT

Description of Plant

The plant was set up as shown in Fig. 1. Detailed descriptions of the equipment will be presented later in a complete report. Cannery tomatoes were received in 1000 pound tote bins. The plant began with a platform scale where tote bins were weighed to determine the amount of tomatoes being processed. This was followed by a bin dumper where tomatoes were dumped into water to cushion their fall, wet them, and remove clod soil and accumulated juices. Dumping was controlled so that all of the tomatoes were wetted for approximately the same time before removing them from the dump tank. This time varied from 1-2 minutes. An elevator then carried the tomatoes to a rubber disc machine where smear soil and other contaminants were removed. Broken and undersized tomatoes were then sorted out as they passed over a live roller conveyor. Sorted tomatoes were elevated to a ferris wheel caustic dipper where they were lye treated. Leaving the caustic dipper, the tomatoes rolled over a slitter where numerous small cuts were made in their skin. The tomatoes were then peeled by a rubber disc machine.

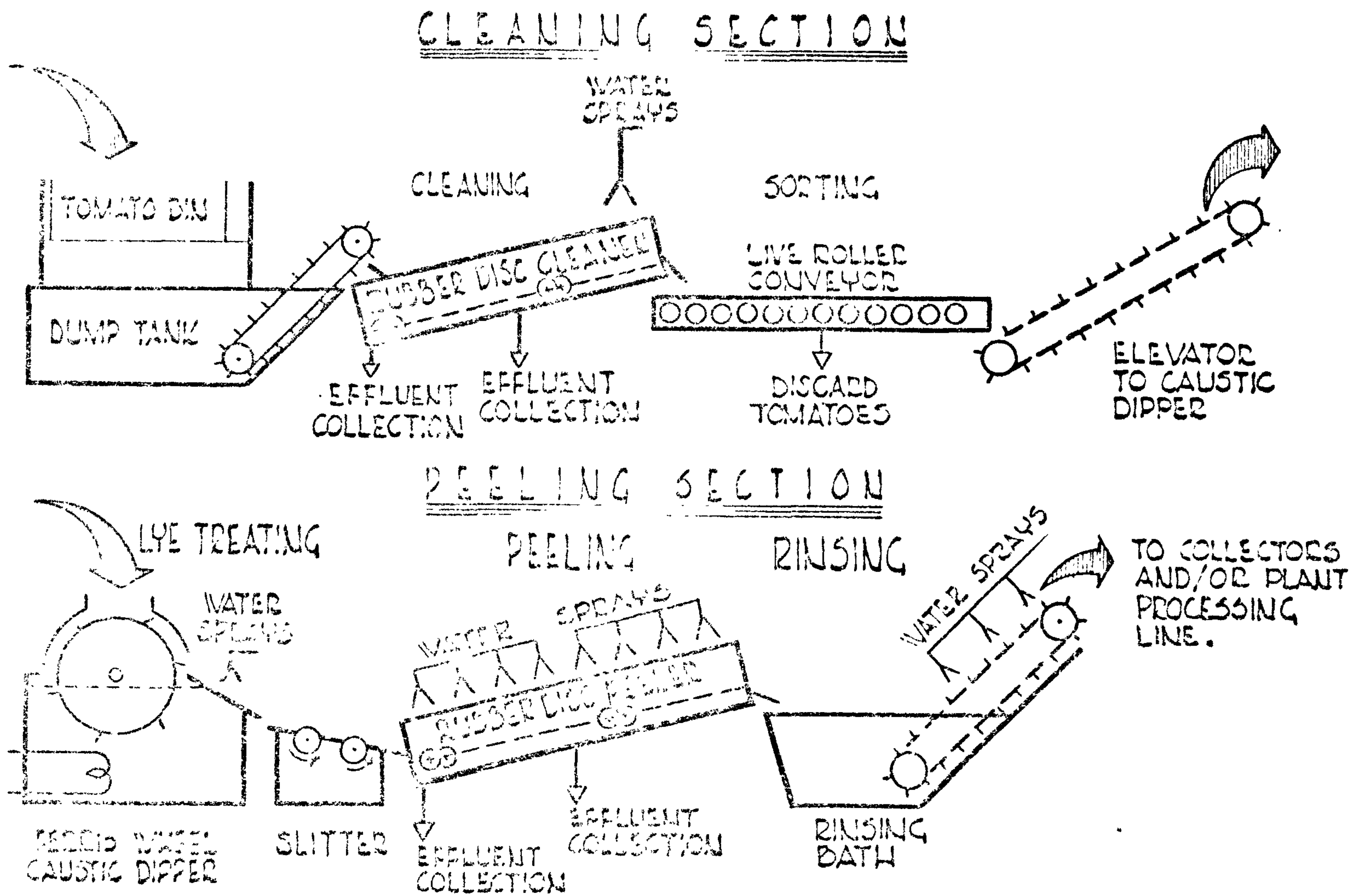

FIG. 1 SCHEMATIC OF PILOT SCALE PROCESSING LINE

The final piece of equipment was a rinsing bath, after which the peeled tomatoes were weighed and sent to the plant product line.

The two rubber disc machines were essentially duplicates. Both were 12 inches wide by 10 feet long and built so that the slope of the machines and the speed of the discs could be varied. The action of the 4 1/2 inch rotating discs in cleaning or peeling is to wipe the tomato with the sides of the disc and throw waste material into collectors. Each machine contained two 5-feet-long collectors dividing the machine into halves. The waste from each half, containing both liquid and solids, was collected separately for measurement. The discs in the cleaning section were usually run at 400 rpm with the slope of the machine set at 16 inches rise in 10 feet. The discs in the peeling section were run at a speed of 300-400 rpm with a rise of 14 inches in 10 feet. Under these conditions the usual residence time for tomatoes in the rubber disc cleaner was 15-25 seconds, and in the rubber disc peeler, 20-30 seconds.

When the entire line was operated, capacity was limited to from 2 to 2.5 tons per hour by the peeling section. In separate cleaning tests, where the peeling section was by-passed, the feed rate was as high as 5 tons per hour. During operating runs all of the tomato components and liquid effluents were weighed to provide material balances.

The plant was operated over the entire season to study all maturities of tomatoes. Both VF-198 pear and VF-145 round tomato varieties were successfully processed. The total amount run was 45 tons in 1,000-pound batches. Complete data on the operation of the plant is being published in a booklet through the efforts of the National Canners Association and the Canners League of California and will be available for distribution.

Cleaning

The cleaning unit was provided with several sets of nozzles to permit the use of foam, detergent water, or plain water. Our tests indicated that tomatoes wetted in the dump tank and then run on the disc machine could be adequately cleaned with water alone. However, it is entirely possible that tomatoes harvested under more adverse circumstances could benefit from the use of a detergent. These tests showed that the application of as little as 5 gallons of water per ton of tomatoes applied just short of the discharge of the cleaner could reduce the smear soil to 7 ppm and could reduce the bacteria and mesospore count by about 95 per cent. In addition, the spinning discs removed 40-70 per cent of stems still attached to the tomatoes.

The function of the dump tank must be emphasized, as in addition to cushioning the dumping it removed most of the soil clods and juice from broken tomatoes. A reduction in the soil clods brought into the plant plus a possible means to drain away juice from broken tomatoes, and the use of the disc cleaner could permit more recirculation of the dump water and thereby substantially reduce the amount of water used per ton of tomatoes. (We hope to do further work next season towards the elimination of the soil clods on the field harvesters so that they will not be hauled into the plant.)

Lye Peeling Section

Whole canned tomatoes are a very important product. Of the approximately five million tons of tomatoes harvested annually in California, 10 to 15 per cent are lye peeled and canned as whole tomatoes. The peeling operation consumes very large amounts of water and generally requires a considerable amount of hand labor for sorting.

The machine was operated to provide fairly complete peeling. Peeling evaluation is described in the complete report and consisted of examining samples of tomatoes for completeness of peel removal. Most runs had over 80 per cent of the tomatoes completely peeled and over 95 per cent at least partially peeled. Peeling loss ranged from 15 to 20 per cent and was equivalent to present cannery operation.

In spite of the 30-second treatment of the tomatoes in 18 per cent caustic at 220°F, the tomato skin still had considerable tensile strength. The skin was fairly well loosened from the tomato but was difficult to remove. One of the unique features of this lye peeling plant was the slitter used to assist in the peeling operation. The slitter consists of two rows of rotating 3-inch-diameter knives spaced 1/2 inch apart. The knives protrude through an adjustable table which was used to vary exposure of the knives from 0-0.1 inch. The 0.1 inch exposure gave the best results. As the tomatoes rolled down the incline from the ferris wheel lye dipper, they received several slits about 0.1 inch deep and 0.25 inches long. Peeling was definitely improved as compared with tests where the slitting discs were retracted. However, for future plant work a third or fourth row of knives might prove advantageous.

Twelve low-pressure nozzles sprayed water on the tomato bed at a rate of about 60-80 gallons per ton. Good peeling at 2 to 2.5 tons per hour was obtained when the bed was fully covered. If the water sprays were reduced the capacity of the machine was substantially reduced.

The water and the skins from the peeler were run over a 1/8 inch-hole perforated screen where the skin was separated from the alkaline puree. The puree had a solids content of 2 to 3 per cent and when neutralized to pH 4.5 and concentrated gave a product that was essentially free from contamination. Microscopic examination showed the material to consist of over 50 per cent whole tomato cells. Some canners may find it advantageous to recover the cell material by settling and centrifuging in order to reduce the effluent BOD.

A number of tomatoes showing marks from the slitter were canned in standard canning juice and pressure cooked. When the cans were opened the slits were no longer noticeable.

SUMMARY

A conventional dump tank was used to remove most of the soil clods and juice from broken tomatoes. Use of the rubber disc machines substantially reduced water requirements for subsequent smear soil removal and for caustic peeling, with no loss in product quality. Effective smear cleaning was obtained with about 5 gallons of water and effective peeling with about 75 gallons per ton of tomatoes. The reduction of the volume of effluent streams should result in more efficient treatment.

INTEGRATED BLANCHING AND COOLING TO REDUCE PLANT EFFLUENT

by

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INTRODUCTION

Blanching of vegetables for freezing, canning or dehydration produces a large portion of the total organic solids in a plant effluent (1). In most cases over 50% of the plant BOD is due to blanching and cooling. Reducing this effluent would give a large reduction in the 800 million pounds of BOD and 392 million pounds of suspended solids produced by the canned and frozen fruits and vegetable industry.

In recent years the National Canners Association has investigated means of reducing pollution from blanching. The characteristics of water, steam, microwave and hot gas blanching were studied (2). It was found that hot gas blanching gave a system which reduced blancher effluent to a very low volume for some products (3). However, hot gas blanching required more energy than conventional blanching, and it was applied only to canned vegetables where there is no need for cooling. Cooling can leach as much, or more, solids from the products as does blanching (4).

The USDA Western Regional Research Laboratory has conducted research on improving steam blanching so as to reduce effluent volume and BOD as well as improve product quality by reducing over-blanching. This research resulted in the development of a heating and holding technique called Individual Quick Blanching (IQB) (5). With IQB the product is heated with steam in a single layer on a conveyor to a mass average temperature sufficient for enzyme inactivation, and the product is held adiabatically in a deep bed on a second conveyor allowing enough time for temperature equilibration and enzyme inactivation. This method reduces leaching from the product and thereby reduces effluent BOD because of the uniform heating inherent in a single layer as opposed to the deep bed used in conventional steam blanching. Further reduction in leaching can be accomplished by prewarming and partially drying with hot air the feed entering the steam heater (4).

Most cooling after blanching is done in flumes or by water sprays. Both of these cause leaching of solids from the product and generate

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large volumes of effluent. Recently, air cooling equipment has been installed in some freezing plants (6,7). Water sprays are used with air cooling to reduce the evaporative weight loss in the product, and the excess water becomes effluent. At present no data are available on the amount of water needed, effluent produced or product yield when blanched vegetables are air cooled.

The work described in this paper was done to demonstrate a means of achieving a blanching and cooling method that would produce less leaching of solids from the product to the effluent stream. Vibratory conveyors provided a ready means of achieving compact equipment and a design of high heat efficiency. This work is an extension of that described by Brown, et al. (8).

PILOT PLANT EQUIPMENT

A schematic diagram of the equipment used in this work is shown in Figure 1. The equipment consists of three sections: heater, holder and cooler. The heater and holder have been completely described by Brown, et al. (8). The cooler used in that earlier work was made from a neoprene belt conveyor, while in the work described here, a vibratory conveyor was used. Figure 2 is a photograph of the assembled blanching-cooling equipment.

Solid surface vibrating conveyors were chosen as the heat transfer conveying surfaces in the heater and cooler. This type of conveyor can be more easily cleaned than the wire mesh belts used in most steam blanchers. They also provide a very compact design because they can be stacked close together and they do not have the return section required in a belt conveyor. The vibratory conveyor also gives a means of reducing heat losses since vegetable pieces can be used to form a seal at the entrance and exit. The relatively small size of the equipment reduces the cost of insulation.

Heater

A detailed description of the heater and holder are given by Brown et al. (8); thus only the main features of that equipment is given here. An electromagnetically driven variable amplitude Syntron circular conveyor was used in the heater. The conveyor operated with a motion that impelled the vegetable pieces upward and forward at 3600 strokes per minute. Two conveyor trays were stacked so that product flowed around one tray, dropped through an opening and flowed around the other tray to the outlet. The residence time in the heater was controlled by varying the feed point and the position of the opening between the trays as well as the amplitude of vibration. Steam was distributed above each tray through tubes with a series of orfices. The heater was completely insulated. The feed was introduced through a hopper attached to the steam plenum; thus the feed formed a seal on one end of the heater and the holder formed one at the other end (Figure 1).

Holder

The holder, attached to the heater plenum, was an insulated neoprene tube 6 inches in diameter and 10 inches long (Figure 1). The product leaving the heater passed over a screen to separate it from the heater condensate, and from there it dropped into the holder. The level of product in the holder was measured with a dipstick. The bulk density of the vegetable pieces, the holder cross sectional area and the feed rate were the data used to calibrate the dipstick setting for the residence time in the holder.

Cooler

The cooler (Figure 1) used in these experiments was made from a spiral vibrating elevator (Syntron, Model No. ES-22). It, like the heater, had a frequency of 3600 cycles/second and gave the product an upward-forward impulse which moved the product up the spiral. A photograph of this cooler is shown in Figure 3, where the surrounding plenum, which directed the air flow and confined the atomized heater condensate, has been partially removed to show the spiral elevator. The 36 inch high elevator consisted of five 4 inch wide flights of 14 5/8 inch diameter. The length over which the product traveled on the conveyor was 17 feet. The plenum surrounding the conveyor was supported independently so it did not contact the vibrating conveyor. The two blowers (1/5 horsepower, squirrel cage type), connected to the plenum, passed 750 cfm of air over the product co-currently. Air velocity, measured with a vane anemometer, was regulated by an orfice at the exit of each blower, and it was kept at the maximum possible without disturbing the flow of the product on the conveyor. Heater condensate was atomized into the air at each blower.

EXPERIMENTAL METHODS

Most of the operating data on this equipment was obtained with green beans (1/2 inch cross cut, mixed sieves size, Galagreen variety). Washed and screened green beans were obtained in 400 lb lots from Patterson Frozen Foods, Patterson, California. They were mixed with ice, transported in insulated containers and used 24 to 96 hours later. Since carrot dice were found to be the most difficult to convey, uniformity of flow in the cooler was tested with carrot dice as described by Brown et al. (8). Carrots were topped, diced without peeling and screened to remove fines. Raw and blanched broccoli spears and cauliflower were also tested on the cooler to observe if these could be conveyed.

An experimental run consisted of blanching and cooling approximately 50 lb. of raw vegetable. The feed, cooled product and effluent were weighed. Samples of cooler effluent were refrigerated for later analysis. Samples of the feed and cooled product, taken during the run, were frozen.

Samples of feed, product and effluent were analyzed for total solids by AOAC method 20.010 (9). Chemical oxygen demand (COD) of the effluent samples was estimated using a Beckman Total Carbon Analyzer (Model 915) (10). Peroxidase and chlorophyl were measured according to the methods described by Dietrich and Neumann (11).

RESULTS

Table 1 summarizes typical operating conditions used in these experiments.

Table 1. Typical operating conditions

	Heating Time (sec)	Holding Time (sec)	Feed Rate (lbs/hr)	Excess Steam* (%)	Cooling Time (sec)	Cooler Product Temp.(°F)
Green Beans	45	45	190	12	45	100
Carrots	25	60	145	24	60	105

*Equals percent over theoretical steam consumption. Theoretical steam consumption for 60°F initial temperature and a 195°F final mass average temperature is 13.8 lb/100 lb feed.

Table 2 gives the yield of cooled green beans obtained with the above operating conditions as compared to conventional blanching and cooling. It also shows the effluent solids loss, which measures the amount of solids lost from the feed to the effluent.

Table 3 gives the amount and COD of the effluent from the cooler. These are compared to those obtained under conventional blanching conditions.

DISCUSSION OF RESULTS

The vibratory spiral conveyor used in the cooler conveyed both the carrots and the green beans uniformly and continuously. When the conveyor was tried with cut cauliflower and broccoli spears, the 4 inch conveyor was too narrow to convey these vegetables well, but they did move up the length of the spiral.

It was found that the spiral conveyor required a product velocity of approximately 17 feet/min. to give a uniform steady flow of product. This product velocity gave a residence time of only 1 min. with green beans and carrot dice. The resulting product temperature of 100-105°F is higher than the 70-80°F usually achieved before freezing in a commercial process. A conveyor twice as long would provide a 2 min. residence time, which would give adequate cooling (8).

Table 2. Comparison of Yields and Solids Loss in Effluent for Green Beans Between Combined Blanching and Cooling vs Conventional Blanching and Flume Cooling

	Gross Yield* (%)	Effluent Solids Loss** (%)	Reference
Combined Vibratory Blanch-Cool	88	2.6	This work
Conventional Steam Blanch Flume Cool	95	5.7	(2)
Conventional Water Blanch Flume Cool	96	6.1	(2)

$$^{*}\text{Gross Yield} = \frac{\text{Wt. of cooled product}}{\text{Wt. of feed to blancher}}$$

$$^{**}\text{Effluent Solids Loss} = \frac{\%\ \text{solids in effluent} \times \text{wt. of effluent}}{\%\ \text{solids in feed} \times \text{wt. of feed}}$$

Table 3. Comparison of Effluent from Green Beans for Combined Blanching and Cooling and Conventional Blanching and Flume Cooling

	Effluent (lb/100 lb feed)	COD (lb/100 lb feed)	Reference
Combined Vibratory Blanch-Cool	7.0	0.17	This work
Conventional Steam Blanch Flume Cooling	500	0.35	(2)
Conventional Water Blanch Flume Cooling	520	0.32	(2)

The lower gross yield of green beans for combined blanch-cooling as shown in Table 2 is characteristic of air cooling (8). The condensate sprayed on the product is only partially reabsorbed, and it does not completely compensate for evaporation of moisture into the air stream. In flume cooling there is no evaporative weight loss, but the higher yield is accompanied by twice as much solids lost from the product. Since frozen vegetables are sold on the basis of weight, a lower yield means less production and can be justified economically only if the value of lost product is balanced by the cost of increased waste disposal.

The results in Table 3 show the large difference in volume of effluent between conventional processing and the combined blanch-cooling. Most of this volume (96%) is due to the flume cooling. Assuming a product temperature out of the blancher of 195°F and cooling water temperature of 60°F, it requires 5.8 lb of water per lb of product to obtain an 80°F product temperature. This amount of flume water when added to the blancher effluent results in twice the amount of COD and 70 times the volume of effluent from combined blanching and cooling.

If no change is made in the way frozen vegetables are marketed, then air cooling of any kind suffers a large cost disadvantage. Table 4 gives a comparison of the approximate operating costs of three different kinds of blanching. The basis for this cost estimate is taken from Brown et al. (8). It must be emphasized that these costs are <u>approximate</u>, and they are shown merely to make a comparison. It is obvious that the cost of lost green beans (at $0.20/lb) due to reduced yield is overwhelming in comparison to other costs. Even though the combined vibratory blanch-cooler can give substantial savings in steam and effluent costs, and a product with more retained solids, these will not balance the cost of product lost through evaporation.

Design of Large Scale Vibratory Blanch-Cooler

To evaluate fully the technical feasibility of the combined blanch-cooling approach to processing frozen vegetables it is necessary to work with larger scale equipment. Figure 4 is a schematic diagram showing the configuration and the dimensions of a 1 ton/hr. vibratory blanch-cooler. The heater and cooler would have adjustable feed points to accomodate the different residence times needed for different products. The holder would be a live bottom bin with an automatic level control, which could be adjusted to maintain different holder residence times.

The cooler would use the same type of conveyor as in the heater, but the central column of the spiral could be used to direct the air flow. The cooler spiral conveyor would have to be much longer to accomodate up to 5 min. residence time for large vegetables such as broccoli and Brussels sprouts.

Equipment of this size is available from several manufacturers at an estimated cost of $60,000. It would require a floor area of about 15 ft. x 15 ft.

Table 4. An Estimate of Water, Steam, Effluent, Electricity and Product Loss Costs in Blanching and Cooling of Green Beans*

	Water & Effluent		COD					
	Vol (gal/ton)	Cost ($/ton)	Amount (lb/ton)	Disposal cost ($/ton)	Electricity ($/ton)	Steam ($/ton)	Product** loss ($/ton)	Total cost ($/ton)
Combined Vibratory blanch-cool	140	0.06	3	0.06	0.060	0.31	28.00	28.43
Conventional Steam Blanch flume cool	1200	0.48	7	0.14	0.007	0.55	0	1.17
Conventional Water Blanch flume cool	1250	0.50	6.4	0.13	0.007	0.80	0	1.43

*Cost of utilities and waste disposal taken from Brown et al. (8).

**Frozen green beans at $0.20/lb (12).

1. NATIONAL CANNERS ASSOCIATION, "Liquid Wastes from Canning and Freezing Fruits and Vegetables," Office of Research and Monitoring, Environmental Protection Agency, Washington, D.C. (1971).

2. RALLS, J. W., MAAGDENBERG, H. J., YACOUB, N. L., ZINNECKER, M. E., REIMAN, J. M., KARNATH, H. O., HOMNICK, D. N., and MERCER, W. A. Reduced waste generation by alternate vegetable blanching systems. Proceedings of the 3rd National Symposium on Food Processing Wastes, New Orleans, La., Environmnetal Protection Technology Series EPA-R2-72-018, 25 (1972).

3. RALLS, J. W., MAAGDENBERG, H. J., YACOUB, N. L., ZINNECKER, M. E., REIMAN, J. M., KARNATH, H. O., HOMNICK, D. N., and MERCER, W. A. In-plant hot-gas blanching of vegetables. National Canners Association Publication D-2614, (1972).

4. BOMBEN, J. L., DIETRICH, W. C., FARKAS, D. F., HUDSON, J. S., DE MARCHENA, E. S., and SANSHUCK, D. W. Pilot plant evaluation of Individual Quick Blanching (IQB) for vegetables. J. Food Sci., 38: 590 (1973).

5. LAZAR, M. E., LUND, D. B., and DIETRICH, W. C. IQB: A new concept in blanching. Food Tech., 25: 684 (1971).

6. COFFELT, R. J., and WINTER, F. H. Evaporative cooling of blanched vegetables. J. Food Sci., 38: 89 (1973).

7. SMITH, W. L., and ROBE, K. Saves 300-400 gpm water, improves vegetable quality. Food Processing, 34(3): 36 (1973).

8. BROWN, G. E., BOMBEN, J. L., DIETRICH, W. C., HUDSON, J. S., and FARKAS, D. F. A reduced effluent blanch-cooling method using a vibratory conveyor. J. Food Sci., (in press).

9. AOAC. Official Methods of Analysis, 10th Ed. Association of Official Agricultural Chemists, p. 308, Washington, D.C. (1965).

10. APHA. Standard Methods for the Examination of Water and Wastewater, 13th ed., p. 257. American Public Health Association, New York (1965).

11. DIETRICH, W. C., and NEUMANN, H. J. Blanching Brussel Sprouts. Food Tech., 19(5): 150 (1965).

12. IELMINI, J. Private communication on cost of green beans. (1974).

Reference to a company and/or product name does not imply approval or recommendation of this product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

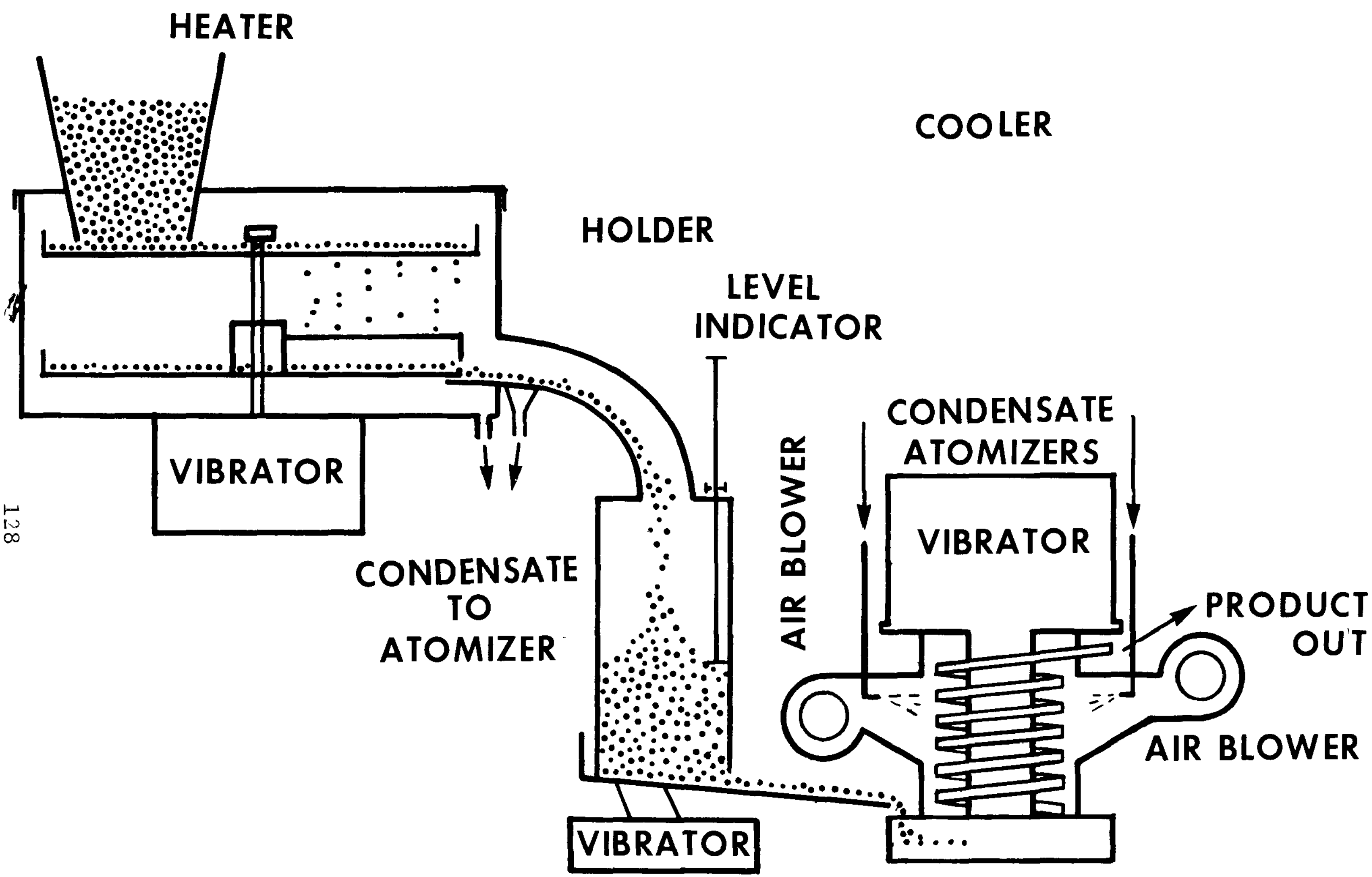

Figure 1. SCHEMATIC DIAGRAM OF VIBRATORY BLANCHER COOLER

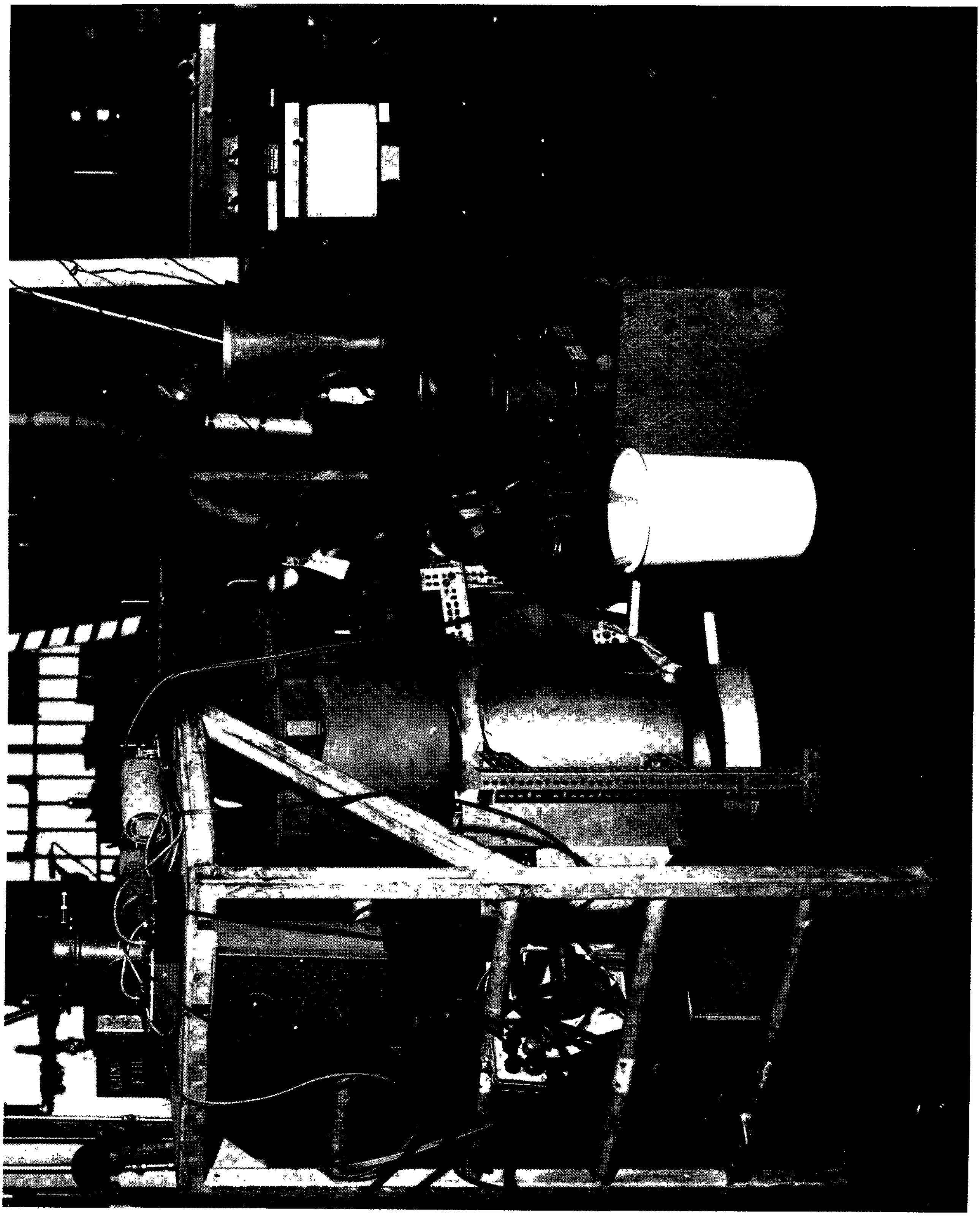

Figure 2. Photograph of Assembled Vibratory Blancher-Cooler

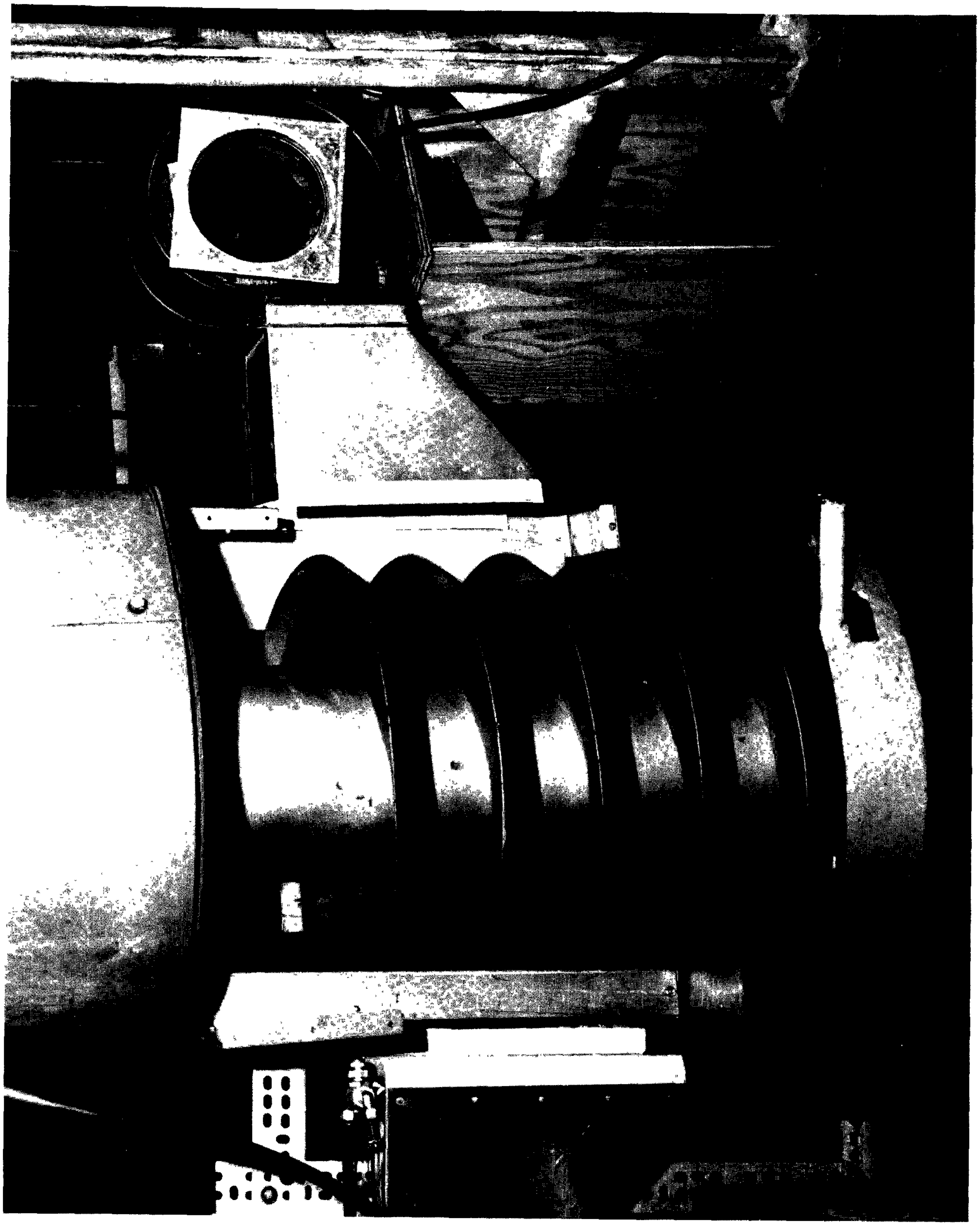

Figure 3. Photograph of Partially Assembled Vibratory Spiral Cooler

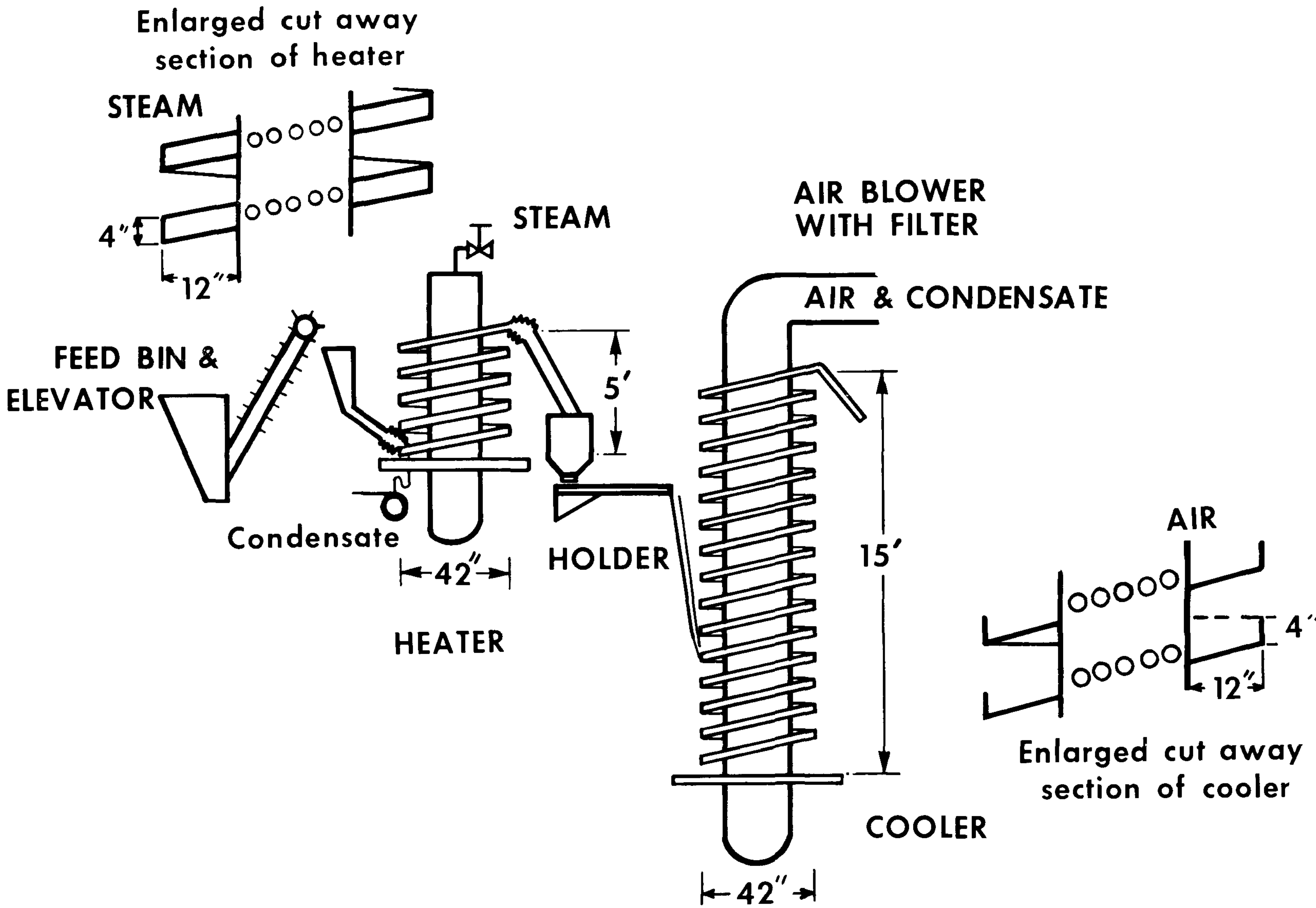

Figure 4. ONE TON PER HOUR VIBRATORY BLANCHER COOLER

RECOVERY OF ACTIVATED SLUDGE FOR POULTRY FEED ENGINEERING ASPECTS

by

Dr. Richard H. Jones* and Leonard P. Levine*

INTRODUCTION

Citrus processing plants in Florida are faced with increasingly stringent wastewater effluent limitations. The three major wastewater treatment processes being used in an attempt to meet these effluent limitations are spray irrigation, aerated lagoons and activated sludge. Activated sludge is the only alternative available for numerous plants because adequate land is not available to install other processes. One of the major problems with the operation of an activated sludge process is the handling and disposal of excess sludge.

Winter Garden Citrus Coop installed an activated sludge plant to treat their concentrated wastewater in 1968. The operation of this system has been reported in a previous publication (1). The original design called for dewatering of waste activated sludge in a solid bowl centrifuge and recovery of the sludge along with citrus peel as a cattle feed. The solid bowl centrifuge proved unsatisfactory and waste sludge had to be disposed of by placing it directly on the citrus peel prior to being dried in a rotary kiln dryer. Due to the low solids content of the waste sludge (2.0-3.0 percent) the dryers could not handle all of the excess sludge and Winter Garden Citrus was forced to dispose of excess sludge by land spreading.

Winter Garden Citrus decided to evaluate other methods of thickening and dewatering activated sludge and to determine the feasibility of recovering waste activated sludge as poultry feed. This report covers the results of both full scale gravity thickening studies, centrifugation studies and pilot plant rotary kiln dryer studies. Results of chicken feeding studies at the University of Florida are reported in the following paper.

WASTE ACTIVATED SLUDGE

Figure 1 shows a schematic diagram of the Winter Garden Citrus Products wastewater treatment plant as it presently operates. Excess activated sludge at the rate of approximately 0.5 to 0.6 lbs of solids per lb of BOD removed is wasted to a gravity sludge thickener. Table 1 shows typical chemical analyses of the waste activated sludge. The waste sludge concentration averaged approximately 8,000 mg/l. The quantity of solids wasted averaged approximately six to seven tons per day.

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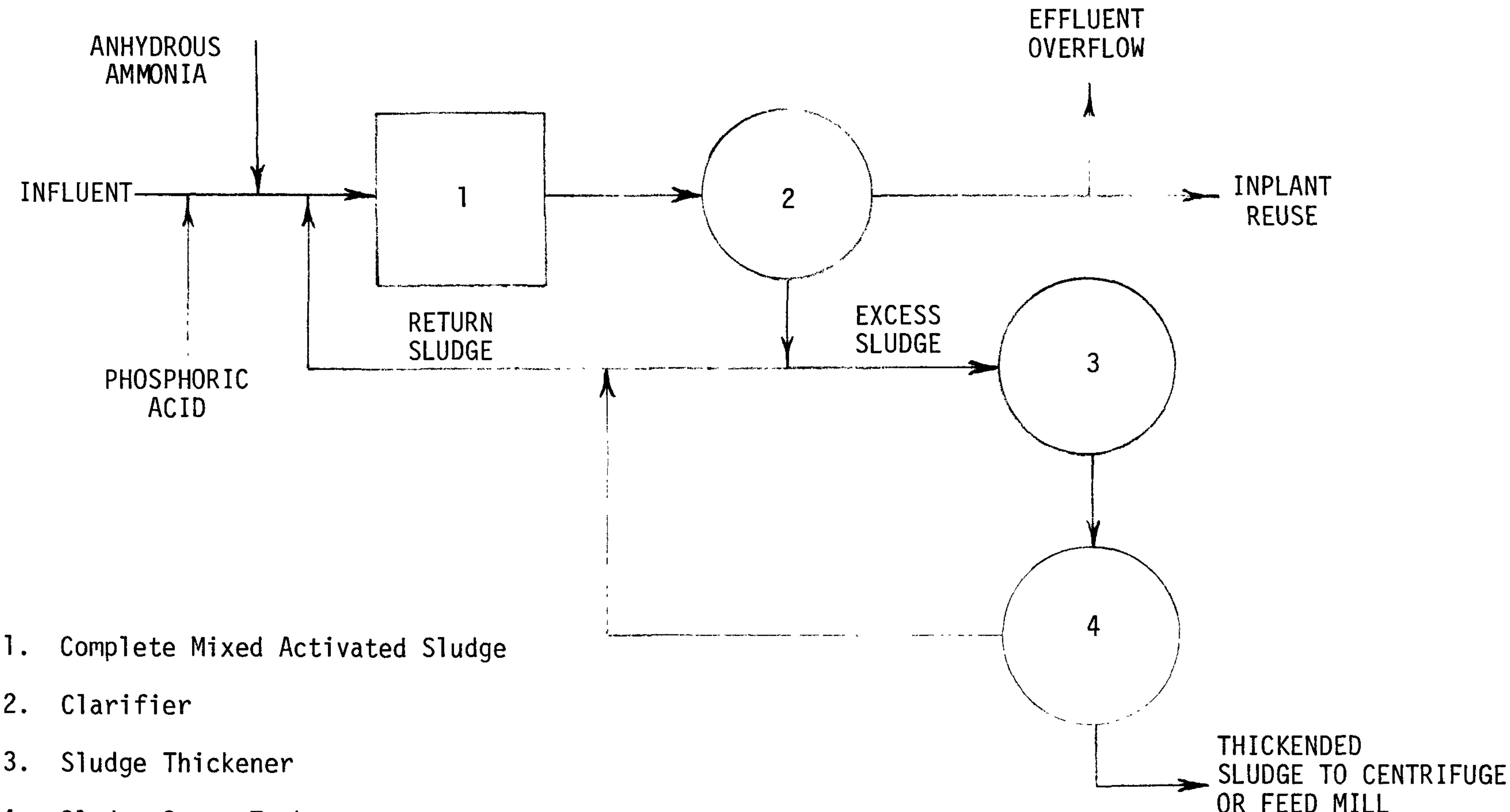

1. Complete Mixed Activated Sludge
2. Clarifier
3. Sludge Thickener
4. Sludge Surge Tank

FIGURE 1. MODIFIED WASTE TREATMENT SYSTEM

Table 1. Analyses of Waste Sludge

Month	Flow GPD	Total Solids mg/l	Volatile Solids mg/l	Waste Sludge lbs/day
1	187,000	7,320	6,440	11,420
2	178,000	11,290	10,110	16,760
3	178,000	8,420	8,070	12,500
4	187,000	7,560	6,540	11,790
5	187,000	6,670	5,600	10,450
6	187,000	8,750	7,800	13,650

EFFICIENCY OF SLUDGE THICKENER

The sludge thickener is a converted lime treatment tank. The loading averaged only 80 gallons/ft^2/day or 5 lbs of solids/ft^2/day. With proper operation a sludge thickness in the underflow of from 3.0 to 3.5 percent could be obtained. Assuming an influent and underflow total solids concentration of 0.8 and 3.0 percent, respectively the sludge thickener was able to decrease the sludge volume approximately 73 percent.

Due to the low loading rate on the thickener, periodic problems were experienced with the settled sludge becoming septic. This occurred every two or three weeks and was solved by simply pumping the total contents of the thickener back into the aeration basin and starting the thickener again with fresh sludge.

EFFICIENCY OF CENTRIFUGATION FOR SLUDGE DEWATERING

The selection of gravity thickening instead of air flotation for sludge thickening was dictated by the presence of the lime treatment tank which could easily be converted to a gravity sludge thickener. The use of rotary kiln drying of all citrus peel dictated the selection of that process for final sludge drying because of the availability of equipment. The selection of centrifugation for sludge dewatering was a matter of judgement. Solid bowl centrifugation had been proven unsatisfactory with this type sludge, however, results with a basket type centrifuge for dewatering domestic sludge showed encouraging results. For this reason, a decision was made to test both a Fletcher basket type centrifuge as well as a Westfalia disk type centrifuge for sludge dewatering following gravity thickening.

Figure 2 shows the predicted capacity of the Fletcher type centrifuge. This information was developed through extensive on-site testing using a Fletcher SST-900 centrifuge. Tests were conducted at various feed rates with and without polymer addition. The main effect of polymer addition was to increase solids recovery and decrease cake percent solids. The improvement in solids recovery was not of a sufficient magnitude that would warrant polymer addition. The solids in the cake varied from approximately 7.0 to 10.0 percent depending upon the feed rate to the centrifuge. Assuming an average sludge solids concentration from the centrifuge of 8.0 percent the combination of gravity thickening and centrifuge dewatering removed 90 percent of the water from the initial sludge wasted from the activated sludge plant.

Extensive tests were conducted using a Westfalia disk type centrifuge. Table 2 shows typical results utilizing the Westfalia Centrifuge. Tests 1 through 31 were conducted without polymer and Test 32-37 were conducted with the addition of polymer. Results of these tests showed that the Westfalia and the Fletcher provided approximately the same results.

Several problems were experienced with the Westfalia 'machine', however, the most significant being internal wear of the machine caused by sand in the activated sludge. No provision for sand removal was provided in the waste treatment plant, therefore, quantities of sand from fruit washing found its way into the system and into the waste sludge. Because of the design of the disk type centrifuge the sand caused wearing of metal surfaces resulting in the machine being taken out of service for repair. Unless all abrasive materials are prevented from entering this type of centrifuge it is questionable if it can be utilized for sludge dewatering.

PILOT PLANT ROTARY KILN DRYER

A rotary kiln dryer pilot plant was selected for drying the activated sludge solids because Winter Garden Citrus dries approximately 600 tons of citrus peel each day by this method. The pilot plant dryer was a three-pass drum type dryer constructed of two concentric rotating drums inside a third stationary insulated drum 6.0 ft. long and 30 inches in diameter. Heat was supplied by a propane torch and the kiln was operated at an inlet temperature of 1100°-1400°F. The drums rotated at a rate of 15 rpm and the kiln was hand fed from 75-125 lbs/hr. Material transport within the kiln was achieved by sets of parallel longitudinal baffels attached inside all three drums. After the third pass in the dryer, the material was pulled into a two-stage cyclone and collected in a container. Material fed into the kiln was maintained at 30-40 percent moisture by mixing recycled product with dewatered sludge.

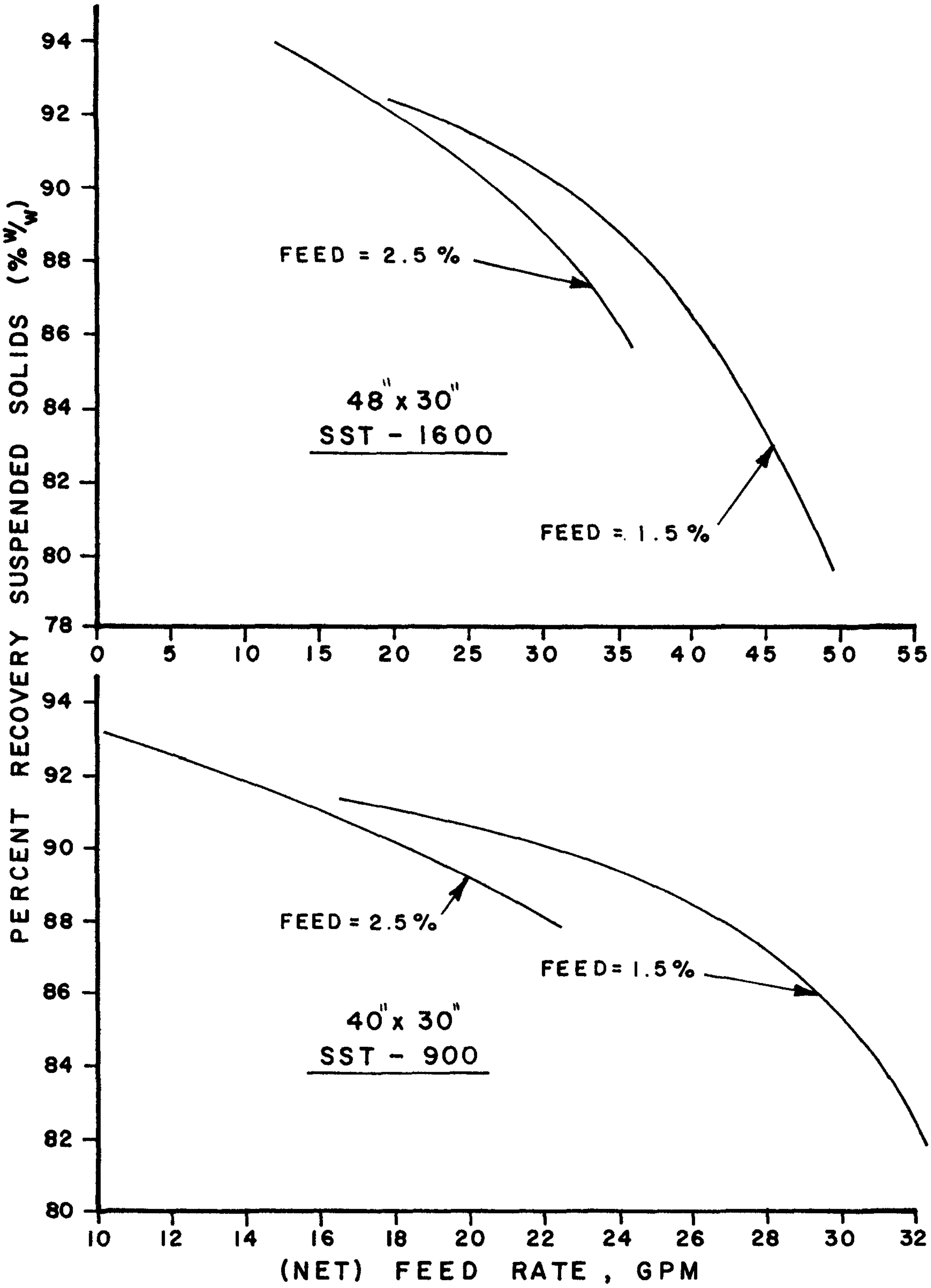

FIGURE-2 FLETCHER CAPACITIES ON WINTER GARDEN ACTIVATED SLUDGE

TABLE 2 TYPICAL RESULTS
WESTFALIA CENTRIFUGE

Test No.	Feed Rate GPD	Solids Feed Percent	Solids Cake Percent	Effluent Percent	Percent Recovery
1	9.0	1.2	7.6	0.14	89
2	9.0	1.2	7.7	0.12	90
3	9.0	1.2	5.5	0.12	90
4	9.0	1.2	8.2	0.23	81
5	5.5	0.9	8.1	0.12	86
6	5.5	0.9	5.9	0.12	86
7	5.5	1.4	9.7	0.29	80
8	5.5	1.4	8.4	0.11	92
9	15.0	1.4	6.4	0.14	90
10	15.0	1.4	6.8	0.18	87
11	9.0	2.2	8.2	0.72	67
12	9.0	2.2	6.9	0.19	92
13	9.0	2.2	7.6	0.37	83
14	-	-	-	-	-
15	5.0	2.2	9.2	0.14	94
16	5.0	2.2	7.4	0.07	97
17	5.0	2.4	8.7	0.08	97
18	5.0	2.4	8.3	0.11	96
19	6.0	2.4	8.1	0.61	75
20	6.0	2.4	9.0	0.52	79

TABLE 2 TYPICAL RESULTS
WESTFALIA CENTRIFUGE
(Continued)

Test No.	Feed Rate GPD	Solids Feed Percent	Solids Cake Percent	Effluent Percent	Percent Recovery
21	9.0	2.3	6.8	0.13	94
22	8.0	2.1	7.2	0.48	77
23	4.5	2.1	6.9	0.29	86
24	8.0	1.9	6.3	0.25	87
25	7.0	1.9	6.4	0.24	88
26	4.5	2.2	5.5	0.15	93
27	8.0	2.2	7.0	0.27	88
28	8.0	2.2	7.2	0.78	65
29	8.0	2.6	6.0	1.0	62
30	7.0	2.1	5.7	0.40	82
31	7.5	2.2	6.4	0.12	95
32	7.0	2.2	6.3	0.10	96
33	7.0	1.5	5.7	0.08	95
34	7.0	2.4	6.6	0.13	94
35	8.0	2.4	6.2	0.14	94
36	8.0	2.2	6.7	0.12	95
37	7.5	2.2	7.1	0.11	95

NOTE: Test numbers 1-33 with "open foot," 34-37 with "closed foot."
Test numbers 32-35 with 5.0 lbs Hercofloc/ton dry solids
Test numbers 33-36 with 10.0 lbs Hercofloc/ton dry solids

Table 3 shows the results of 20 separate pilot plant "runs." Each run represents a successful operating day when the pilot plant was kept in continuous operation from 10 to 12 hours. There were numerous days that either weather conditions or mechanical failure caused the pilot plant operation to be terminated.

The pilot plant not only provided engineering and cost data for the design and operation of a full scale unit but was also utilized to supply dried sludge for the chicken feeding studies. Several hundred pounds of sludge were produced in this manner, however, a sand drying bed finally had to be used to supply the large quantity of sludge required for the feeding studies.

COST OF RECOVERING WASTE SLUDGE FOR CHICKEN FEED

The following assumptions were made in conducting the preliminary cost estimate:

1. The sludge handling facilities would consist of:
   A. Sludge thickener
   B. Thickened sludge holding tank
   C. Fletcher centrifuges
   D. Rotary kiln dryer
   E. Miscellaneous pumps, pipes, conveyors, etc.

2. Maximum waste sludge volume of 0.2 mgd @ 0.8 percent solids.

3. Thickener underflow of 2.5 percent solids.

4. Centrifuge cake of 7.7 percent solids.

5. Fuel cost \$0.80/ $1x10^6$ Btu.

6. Dryer efficiency = 56 percent.

7. Dryer yield = 75 percent of input solids.

8. Operating days = 150.

9. 20 year straight line depreciation.

10. 10 percent interest on borrowed money.

EQUIPMENT	CAPITAL COST	YEARLY OPERATION & MAINTENANCE
Sludge thickener	\$150,000	\$ 5,000
Holding tank	35,000	1,000
Centrifuges	160,000	16,000
Kiln Dryer	55,000	3,000*
Pipes, pumps, etc.	50,000	5,000
Total	\$450,000	\$30,000

*Excludes fuel cost

TABLE 3 PILOT PLANT KILN DATA

Run No.	Temp. °F of Inlet	Temp. °F of Outlet	Total Solids Percent Influent	Total Solids Percent Cake	Total Volatile Solids Percent Influent	Total Volatile Solids Percent Cake	Pounds Cake Produced
1	1200-1400	150-175	3.5	74	--	--	14
2	1200-1400	150-175	4.2	89	89	74	7
3	1200-1400	165-185	2.6	90	90	74	10
4	1200-1400	175-200	2.3	94	90	75	4
5	1100-1300	175-200	3.3	94	90	66	5
6	1100-1300	175-200	3.2	91	86	72	8
7	1100-1300	175-200	3.2	92	92	70	6
8	1100-1300	175-200	4.9	92	93	69	5
9	1100-1300	175-200	3.7	93	91	69	4
10	1200-1300	175-200	3.8	93	84	69	4
11	1200-1300	175-200	3.6	95	96	73	4
12	1200-1300	175-200	2.4	98	86	75	2
13	1200-1300	175-200	2.6	98	93	70	3
14	1100-1200	175-200	4.8	96	92	71	4
15	1100-1200	175-200	3.9	94	87	69	4
16	1100-1200	175-200	4.8	92	90	70	4
17	1100-1200	175-200	4.6	95	88	76	4
18	1150-1200	175-200	6.5	95	91	79	2
19	1000-1250	175-200	4.6	96	87	76	7
20	1100-1200	175-200	5.8	94	90	77	5

The capital investment cost each year will be $45,000. The yearly operating cost will be $30,000 and the fuel cost will be $35,000. Therefore the estimated yearly cost will be $110,000 and with a waste sludge of 900 tons per season the cost will be approximately $122/ton.

There are several reasons for the high cost of drying sludge. Due to the high moisture content of the dewatered sludge it will cost $50/ton for fuel alone. If the sludge could be dewatered to 20 percent solids before entering the kiln dryer it would cost only $19.25/ton for fuel. Another reason for the relatively high drying cost is that the citrus plant operates only a portion of the year yet the capital cost must be paid for throughout the year. The capital cost when operating 150 days per year are $50/ton. If the processing plant operated 300 days per year, the capital cost would only be $25/ton.

The final cost for disposing of sludge by drying and selling for chicken feed will depend upon the value of the sludge when sold. The feasibility and value of sludge as chicken feed will be discussed in detail in a following paper.

1. U.S. Dept. of Interior, EPA, 1971. Complete MIX activated sludge treatment of citrus process wastes.

EVALUATION OF ACTIVATED CITRUS SLUDGE AS A POULTRY FEED INGREDIENT**

B. L. Damron*, A. R. Eldred*, S. A. Angalet*, J. L. Fry* and R. H. Harms*

INTRODUCTION

Activated sludge has been the subject of animal feeding trials for well over 20 years. The material is a concentrated source of nitrogen for the ruminant animal and, even though the biological value of its proteins has been determined to be in the neighborhood of 50%, research with ruminants has indicated that the nitrogen retention from activated sludge is equal to that from soybean oil meal or urea (1). Activated sludge has also been found to be a very good source of vitamin B_{12}, and feeding trials employing synthetic diets have indicated that a level of 2% sludge provides a satisfactory level of B_{12} for the pig. Similar studies with chicks yielded the information that as little as 1% sludge furnished an adequate amount of vitamin B_{12} for growth. Levels up to 3% gave an additional response which could not be attributed to the presence of vitamin B_{12} alone and was felt to indicate the presence of unknown growth factors; possibly due to the fermentation process involved. Taste panel members detected no differences between the meat of sludge-fed birds and that of birds receiving control diets (1).

A very recent study published by the Bureau of Sport Fisheries and Wildlife (2) concerning the use of dried sludge from paper processing waste in the diets of rainbow trout indicated that dried sludge has potential as a protein ingredient for trout feeds. With the exception of one abstract published in 1955 (3), the journal of the Poultry Science Association contains a paucity of information concerning the evaluation of sludge in practical-type poultry feeds.

This research was not designed to assay nutrients or determine biological availability, but rather to gain basic information about what practical levels of the material could be utilized, level of toxicity, and taste impartation to meat or eggs.

PROCEDURE

Before feeding trials were started, the basic nutrient composition of the material in terms of the common elements that would be found in a poultry diet was examined (Table 1).

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**This investigation was supported by funds from the Environmental Protection Agency, Pacific N.W. Regional Laboratory, under Grant No. S-801432.

Table 1. Sludge Composition	
	%
Moisture	6.30
Protein	38.6
Crude Fiber	12.6
Calcium	1.49
Phosphorus	1.59
Methionine	0.50
Cystine	0.20
Lysine	1.30
Metabolizable Cal./Kg.	1760

In vitro evaluations indicated that sludge contained quite a bit of protein and phosphorus which are expensive ingredients for poultry feeds, and was a good source of lysine and the sulfur containing amino acids - methionine and cystine. These are the amino acids which are normally in shortest supply in poultry feeds where corn and soybean meal are the staple ingredients. The relatively high level of fiber was also of concern since chickens do not have the enzymes necessary to digest fiber. The metabolizable energy value is approximately one-half that found in yellow corn. Much of the work reviewed dealt with the sludge as a source of vitamin B_{12}. Although sludge products did meet this need very well, that approach was not pursued in this research because most poultrymen utilize a vitamin and trace mineral package in all of their feeds, therefore, additional B_{12} activity would not be of major importance to them.

The studies being reported were divided into three experimental phases - two short-term chick trials, an eight-week broiler study, and a six-month feeding period with laying hens including pilot work with egg color and taste evaluation.

Chick Studies

The initial two experiments were conducted in electrically heated battery brooders with raised wire floors to prevent fecal recycling. This battery unit contained 24 separate pens, with ten chicks housed in each pen. In each of the two experiments four replicate pens, each containing five male and five female day-old broiler-type chicks, received dietary treatments consisting of various levels of citrus sludge for a three-week feeding period.

In the first experiment the birds received diets containing 0, 2.5, 5, 10, 15 or 20% citrus sludge. The diets were composed primarily of yellow corn and soybean meal in combination with other ingredients commonly employed in poultry feeding (Table 2).

Table 2. Diet Composition (Exp. 1 and 2)

	0%	20%	"20% +"
Yellow Corn	54.97	45.94	
SBOM (48.5%)	36.50	21.98	
Alfalfa Meal (17%)	2.50	2.50	
Citrus Sludge	0	20.0	
Ground Limestone (38%)	0.74	1.05	
Defluorinated Phosphate (18% P; 32% Ca)	2.11	0.92	
Salt	0.40	0.40	
Microingredients	0.50	0.50	
Animal Fat	2.15	6.47	
D-L Methionine	0.13	0.25	0.38
Lysine	0	0	0.26

In the interest of space only the basal and the diet containing the highest level of sludge are shown. All of the diets in the series were calculated to contain 23% protein, 1.1% calcium, 0.755% total phosphorus, 0.88% total sulfur amino acids and 3,012 kilocalories of metabolizable energy per kilogram. The inclusion of citrus sludge allowed for corresponding decreases in the amounts of yellow corn, soybean meal and defluorinated phosphate necessary to maintain equivalent diets, however, large increases in the amounts of animal fat and DL-methionine were required in order to maintain energy and sulfur amino acid levels.

Since previous work has indicated that sludge is very prone towards the destruction of unstabilized vitamin D sources, a supplemental level of 2,200 International Chick Units of vitamin D_3 per kilogram of diet was employed. This level of fortification was approximately 10 times greater than the requirement level of the starting chick as defined by the National Research Council (4).

Statements of probability are based on the analysis of variance as described by Snedecor (5), with significant differences among treatment means being determined by the multiple range test of Duncan (6).

There were no significant treatment differences among the daily feed consumption values shown in Table 3.

Table 3. Chick Performance Data (Exp. 1)

Treatment (% sludge)	Feed/Bird/Day (gm.)	Feed/Body Wt.[1] (gm.)
0	30.4	1.48[a]
2.5	29.6	1.45[a]
5.0	29.6	1.45[a]
10.0	30.5	1.51[ab]
15.0	31.0	1.59[b]
20.0	31.6	1.74[c]

[1]Means without common letters are significantly different according to Duncan's multiple range test ($P < .05$)

In terms of feed efficiency, as measured by grams of feed consumed per gram of body weight, up to 10% citrus sludge did not significantly affect this parameter. The feed efficiency value for birds fed a diet containing 15% sludge was not significantly different from the value for the 10% sludge diet, but was different from values obtained for all other diets. Birds receiving a diet containing 20% sludge had a feed efficiency significantly higher than all other treatments. *It should be pointed out* here that in any discussion of feed efficiency, the least amount of feed required for a unit of gain or body weight, or per dozen eggs, represents the best efficiency of feed utilization. In this instance, birds receiving diets containing 2.5 or 5% citrus sludge had the best feed efficiency values.

Inclusion of up to 10% citrus sludge in the diet did not significantly affect final body weights at the end of a three-week experimental period (Table 4).

Table 4. Chick Body Weights (Exp. 1)

Treatment (% sludge)	Body Wt.[1] (gm.)
0	411[ab]
2.5	413[a]
5.0	409[abc]
10.0	403[abcd]
15.0	390[cd]
20.0	365[e]

[1]Means without common letters are significantly different ($P < .05$) according to Duncan's multiple range test.

Weights of birds receiving the 15% citrus sludge diet were not significantly different from those of either the 5 or 10% sludge treatments; however, birds receiving 20% sludge were significantly lighter than any other treatment group.

From the data obtained in the first experiment it was evident that some change in treatments should be made before the next study was initiated. It was felt that the growth depression associated with the 20% sludge diet might have been due to the low availability of sulfur amino acids, or because the dietary lysine level was slightly below the National Research Council's suggested requirement. Therefore, in the second experiment the amounts of methionine and lysine supplied in the first experiment by the inclusion of 20% citrus sludge were added back to this diet in purified form, resulting in total supplemental levels of 0.38% methionine and 0.26% lysine. Thus, the dietary treatments of the second experiment consisted of 0, 2.5, 5, 10 or 20% sludge, with a sixth treatment of 20% sludge plus additional methionine and lysine. The latter diet will subsequently be referred to as the "20% plus" diet (Table 2). As in the first experiment, all but the "20% plus" diet were calculated to be isonitrogenous, isocaloric and meet all other requirements of the starting chick.

Table 5. Chick Performance Data (Exp. 2)

Treatment (% Sludge)	Feed/Bird/Day (gm.)	Feed/Body Wt.[1] (gm.)
0	35.8	1.64[abc]
2.5	35.6	1.62[a]
5.0	37.3	1.66[abc]
10.0	34.4	1.75[cd]
20.0	37.2	1.83[d]
20.0 + Lysine & Methionine	35.3	1.74[bcd]

[1] Means without common letters are significantly different ($P < .05$) according to Duncan's multiple range test.

A data summary (Table 5) similar to that prepared in Experiment 1 indicated no significant differences among daily feed intake values for birds receiving any of the dietary treatments. There were no significant differences among the feed efficiency values of groups receiving either 0, 2.5, 5.0 or 10% sludge. Also, efficiency values for birds receiving diets containing 10, 20 or the "20% plus" diets did not differ significantly. From a numerical standpoint, it appeared that levels in excess of 5% sludge adversely affected feed efficiency.

Table 6. Chick Body Weights (Exp. 2)

Treatment (% Sludge)	Body Wt.[1] (gm.)
0	455[ab]
2.5	460[ab]
5.0	472[a]
10.0	414[c]
20.0	423[c]
20.0 + Lysine & Methionine	425[c]

[1]Means without common letters are significantly different (P <.05) according to Duncan's multiple range test.

Table 6 presents average body weights at the end of the three-week experimental period. There were no significant differences among the body weights of birds receiving either 0, 2.5 or 5% sludge, however, there was some trend towards parallel sludge and body weight increases. Weights of treatment groups receiving above 5% sludge were all significantly below those of the lower sludge levels previously mentioned, but did not differ statistically from each other.

Mortality was not a factor in either experiment, as mortality records indicated that only one bird died in each trial. Throughout all experiments the addition of citrus sludge had no effect upon feed or dropping condition, other than to impart a dark color to both.

These data indicate that levels of between 5 and 10% sludge could be included in the diet of starting broiler chicks without adversely affecting growth or other performance criteria. The exact level tolerated would be dependant upon feed intake, as evidenced by the fact that birds of the second experiment tolerated a lower dietary percentage because their feed intake was higher than that of the birds utilized in the first experiment.

Broiler Trial

The next phase was a broiler study of eight-weeks duration, which is the standard growing period for commercial broilers. Three replicate floor pens, each containing 10 male and 10 female day-old broiler chicks, received each dietary treatment for the 56-day feeding period. Treatments consisted of a control diet supplemented with either 2.5, 5.0 or 10% citrus sludge. The diets used were identical in composition to those shown for previous experiments, with the exception of the inclusion of a small amount of coccidiostat at the expense of yellow corn.

No significant differences were found among 8-week body weight means (Table 7); however, as seen in the chick trials, body weights tended to increase through the 5% level of supplementation with the weights of the birds receiving 10% sludge being somewhat lower than those of controls.

Table 7. Citrus Sludge Broiler Data (8 wks.)

% Sludge	Body Wt. (gms.)	Feed/Bird/Day[1] (gms.)	Feed/Body Wt. (gms.)
0	1750	66[ab]	2.16
2.5	1772	63[a]	2.08
5.0	1800	67[b]	2.16
10.0	1732	68[b]	2.25

[1]Means without common letters are significantly different ($P < .05$) according to Duncan's multiple range test.

Daily feed intake values were rather variable within this experiment, but increased levels of intake did appear to be correlated with dietary sludge content. Again, feed required per unit of body weight was not significantly influenced by treatment and, in general, these values reflected the trends of body weight and daily feed intake. These data tend to substantiate other trials in that a level of sludge somewhere between 5 and 10% appeared to support best performance. Taste panel evaluations of muscle tissue from these birds are currently incomplete; however, preliminary results indicate no effect from citrus sludge supplementation.

Laying Hen Trial

The last phase has involved the feeding of 0, 2.5, 5.0, 7.5 or 20% citrus sludge to laying hens over a six-month period. The composition of the basal diet and the diet containing the 20% sludge addition is shown in Table 8.

Table 8. Laying Hen-Citrus Sludge Diet Composition

	Percent	
	Basal	20% Sludge
Yellow Corn	66.50	58.00
Soybean Meal (48.5%)	17.96	3.34
Alfalfa Meal (20%)	2.50	2.50
Citrus Sludge	----	20.00
Limestone (38% Ca)	6.77	6.98
Defluorinated PO_4 (18% P, 32% Ca.)	1.94	0.80
Iodized Salt	0.40	0.40
Microingredients	0.50	0.50
Animal Fat	1.10	5.22
D-L-Methionine	0.06	0.17
Filler	2.27	2.09

These sludge additions were made while maintaining a constant level of protein at 15%, calcium at 3,25%, ,65% phosphorus, ,59% sulfur containing amino acids and 2,860 kilocalories of metabolizable energy per kilogram of diet. As noted before, sludge additions allowed for the removal of yellow corn, almost all of the soybean meal, and a large portion of the defluorinated phosphate, with corresponding increases of animal fat and DL-methionine. Evaluation criteria included egg production, daily feed intake, feed required to produce a dozen eggs, mortality and egg measurements of average weight, specific gravity and Haugh units. In addition, organoleptic evaluations were conducted on the eggs produced and the differences in yolk color evaluated. Eight replicate groups of White Leghorn hens held in individual laying cages were assigned to each dietary treatment through 7.5% sludge. Four replicate groups received the 20% level. Statistical procedures employed in the summarization of production data were identical to those discussed earlier.

Egg production was not affected by the addition of levels of sludge through 7.5% (Table 9); however, the 20% level did cause a significant depression of egg production.

Table 9. Average Laying Hen Performance (6 months)

Treatment (% Sludge)	Av. Egg Prod.[1] (%)	Egg Wt.[1] (gms.)
0	69.61[a]	62.9[a]
2.5	68.32[a]	63.4[a]
5.0	67.01[a]	63.6[a]
7.5	69.21[a]	63.3[a]
20.0	42.12[b]	59.0[b]

[1]Means without common letters are significantly different ($P < .05$) according to Duncan's multiple range test.

The average weight of eggs produced followed exactly the same trends as egg production.

There was no significant effect upon daily feed intake until the 20% level of sludge was reached (Table 10).

Table 10. Average Laying Hen Performance (6 months)

Treatment (% Sludge)	Feed/Bird/Day[1] (gms.)	Feed/Doz. Eggs[1] (kgs.)
0	113[a]	2.00[a]
2.5	109[a]	1.98[a]
5.0	114[a]	2.13[a]
7.5	112[a]	2.01[a]
20.0	92[b]	2.86[b]

[1]Means without common letters are significantly different ($P < .05$) according to Duncan's multiple range test.

This feed intake trend is very definitely related to egg production rate however, it is very difficult to differentiate which is the cause and which is the effect - did the intake depression result in lowered production or did lowered production result in reduced feed intake? As you might expect, the amount of feed required to produce a dozen eggs was also a function of the egg production and feed intake trend.

Specific gravity is a measurement of eggshell quality made by moving each egg through a graded series of salt solutions, and no significant differences due to treatment were found (Table 11).

Table 11. Average Laying Hen Performance (6 months)

Treatment (% Sludge)	Specific Gravity	Haugh Units
0	1.0792	64.3[a]
2.5	1.0801	67.4[ab]
5.0	1.0787	69.4[b]
7.5	1.0780	68.9[b]
20.0	1.0781	82.0[c]

Haugh units are a measure of interior egg quality arrived at through an integration of egg weight and albumen height. A trend towards improving Haugh unit scores is seen as the level of sludge increased through 7.5%. The scores of eggs from hens receiving either 5 or 7.5% citrus sludge were significantly better than those of control birds. The extremely high value from hens receiving 20% sludge was anticipated, since interior egg quality is normally inversely related to the bird's level of egg production.

A very interesting phase of this research effort was really the offshoot of these Haugh unit determinations. The graduate students who were breaking these eggs noticed that the yolk of eggs from hens receiving citrus sludge diets appeared to be more orange in color than those from control hens.

Because proper egg yolk color is a very important commercial consideration and due to the possibility of off-flavors developing from the feeding of citrus sludge, a further investigation of the effect of sludge upon these parameters was initiated.

Initially, two eggs from each treatment group were collected and broken open into plastic petri dishes, without breaking the yolks, and the yolk color scored by comparison with a color rotor which carries a graded series of standard color spots. The scores ranged from 12 for the yolks of eggs from control hens to 18 for those receiving 20% citrus sludge (Table 12).

Table 12. Interrelationship of Dietary Citrus Sludge and Heiman-Carver Color Rotor Numbers.

Citrus Sludge (%)	Heiman-Carver Color Rotor Numbers
0.0	12
2.5	14
5.0	15
7.5	16
20.0	18

This score increase represents a definite increase of yolk color intensity, with a higher number indicating the darker color.

Subsequent yolk color measurements were made with a reflectance colorimeter, the IDL COLOR-EYE. The COLOR-EYE values represent a mathematical description of egg yolk color with all possible biases and human judgment being removed. For this evaluation, eggs were collected from hens in four replications of each dietary treatment. Four eggs from each replication were then broken out to obtain a pooled yolk sample and prepared for COLOR-EYE evaluation.

The yolk was washed under running tap water in order to remove the majority of the albumen. Then the yolk was rolled on a dampened paper towel to remove the remaining adhering albumen. It was then held over a beaker, the membrane surrounding the yolk was broken with a spatula, and the yolk contents collected. The yolk material was then hand-stirred with a wooden tongue-depressor with care being taken to keep the incorporation of air bubbles to a minimum. The Lucite sample holders of the COLOR-EYE were filled to capacity, sealed and placed on their side to allow the escape of any air bubbles from the yolk and the area where the determinations are made. The sample and holder was then placed into the viewing part of the machine and the values recorded as measured against a white standard.

The results of these COLOR-EYE determinations are summarized very briefly in Table 13.

Table 13. Color Characteristics of Egg Yolk

Citrus Sludge (%)	Dominant Wavelength (nm.)
0.0	578.5
2.5	579.3
5.0	579.5
7.5	580.8
20.0	583.5

As the level of dietary citrus sludge increased, the dominant wavelength, which is the color or hue of the egg yolk, also increased. This numerical improvement represents a change in color from yellow to a yellowish-orange hue. Increasing sludge levels dictated the removal of both yellow corn and soybean meal. Yellow corn is normally a prime source of egg yolk coloration. The removal of 12.8% yellow corn from the basal diet in order to formulate the 20% level of citrus sludge resulted in a lower contribution of yellow corn to dietary pigmentation; however, the addition of citrus sludge more than compensated for this reduction.

Flavor and color comparisons were also made by untrained taste panelists from the Department of Poultry Science, University of Florida, on eggs collected from hens receiving either the control or the 20% sludge diet. The eggs were held for five days to permit optimum peelability and then hard-cooked for sampling. A paired-comparison test was used with each panelist sampling three pairs each day, but only one pair at a time. They were asked to select separately the egg which had the darker colored yolk, the greater degree of albumen off-flavor and the greater degree of yolk off-flavor. The evaluation of 86 separate pairs (Table 14) showed that a level of 20% citrus sludge resulted in significantly darker yolks than the control.

Table 14. Taste Panel Evaluation of Eggs From Control and 20.0% Citrus Sludge Diets.

	Preference		Significant
Attribute	Control	Citrus Sludge	Difference[1]
Yolk Color	5	81	yes
Yolk Flavor	42	44	no
Albumen Flavor	40	46	no

[1]Acceptance range (52.3 - 33.8) at P <.05

Eighty-one of the 86 found the citrus sludge eggs to have a darker yolk color, which is well outside of the acceptable range of 33 to 52. No significant off-flavor was detected for either the albumen or the yolk, as these two parameters fall within the acceptable range.

SUMMARY

In summary, the thrust of these studies was not to assay the availability of nutrients within this product, but rather to determine the levels generally acceptable in diets for various classes of poultry. These data indicate that citrus sludge levels in the range of 5 to 7.5% were acceptable in poultry feeds, with proper attention to dietary requirements and formulation procedures. It would appear that the energy value of 1,700 kilocalories of metabolizable energy which was assumed for this product at the outset is approximately correct. There also appeared to be some depressing factor present which adversely affects performance at high levels. Studies with young chicks indicate that this factor is not related to a deficiency or poor availability of the amino acids - methionine or lysine. Although earlier work (1) has indicated that high levels of iron present in sludge cause very rapid destruction of unstabilized vitamin D sources, the authors are not convinced that this was the problem since stabilized vitamin D in the amount of approximately 10 times the requirement level was added to all diets.

Evaluation of yolk color differences resulting from high level sludge feeding by both machine and panelists indicated that yolk color was significantly influenced by sludge feeding. No adverse flavors were detected in either the yolk or albumen of eggs produced through the use of citrus sludge diets.

Although a rough estimate of the value of this material as a protein source could be made based on availability values established by other researchers, a great deal of additional work would be necessary in order to totally evaluate the nutritional worth of this material. The origin of the performance depressing factor which has been present in all studies would also need to be elucidated and, if possible, correction procedures developed. Based on the pilot work which we have conducted in the area of yolk color improvement, it would appear that this material has definite promise as a source of pigment for broiler skin and egg yolks.

1. HURWITZ, E. The use of activated sludge as an adjuvant to animal feeds. Purdue Industrial Waste Conference (1957).

2. ORME, L. E. AND LEMM, C. A. Use of dried sludge from paper processing wastes in trout diets. Feedstuffs 45(51): 28 (1973).

3. SCOTT, H. M. AND ADAMS, E. G. The effect of feeding graded levels of activated sludge and vitamin D on growth and bone ash of chicks. Poultry Sci. 34:1233 (1955).

4. NATIONAL RESEARCH COUNCIL. Nutrient requirements of domestic animals. Nutrient requirements of poultry, 6th revised edition. Washington, D.C. (1971).

5. SNEDECOR, G. W. Statistical Methods, 5th edition. Iowa State University Press, Ames, Iowa (1956).

6. DUNCAN, D. B. Multiple range and multiple F tests. Biometrics 11:1-42 (1955).

INVESTIGATION OF RUM DISTILLERY SLOPS TREATMENT
BY ANAEROBIC CONTACT PROCESS

by

T. G. Shea*, E. Ramos**, J. Rodriguez** and G. H. Dorion**

INTRODUCTION

The production of rum is accomplished by age-old processes that, in their modern application, are similar in function throughout the industry. The basic sequence of steps in rum production consists of: the mixing of molasses, water, nutrients, and antifoamant; acidification of the above mixture; propagation of the biomass used in the fermentation; the fermentation itself; and the distillation of the ferment.

The slops stream, i.e., the underflow produced in the distillation of the fermented molasses mixture, has the following typical characteristics:

- COD - 70 to 100 gm/l
- BOD - 20 to 60 gm/l
- Total suspended solids - 7 to 10 gm/l
- Total dissolved solids - 25 to 75 gm/l
- Total nitrogen - 1.8 to 2.5 gm/l
- Total phosphorus - 80 to 100 mg/l
- Sulfate - 2 to 10 gm/l
- pH - 4.0 to 4.7

The principal factors associated with the magnitude and variation of these characteristics are: the variable quality of sugar and ash contents of the molasses, which itself is a byproduct of sugar production; and the amount of acidification (with H_2SO_4) of the molasses-water mixture to obtain an optimal pH level for the fermentation. The slops is rich in nutrient materials having value as cattle feed extenders and soil supplements. From a biological treatment perspective, the slops stream typically contains a sufficiency of nitrogen and a deficiency of phosphorus, and most of the volatile suspended solids component of the slops stream is derived from the yeast crop produced in the fermentation. The slops stream typically contributes two thirds of the wastewater flows, and over 95 percent of the organic emissions, in the wastewater streams emanating from rum distillery operations, and constitutes the major wastewater management problem in this industry.

The general objective of the research effort described herein was to examine at the bench and pilot scales the efficacy of rum distillery slops treatment by the anaerobic contact process. The specific objectives of this paper are to present the kinetic characterization (Monod kinetics) describing the anaerobic biological treatment of slops in the anaerobic contact process,

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the design and operational criteria developed with the kinetic characterization and with an evaluation of clarification capacity requirements, as related to full scale treatment, and an economic analysis of the application.

The anaerobic fermentation process has been examined by a number of researchers (1, 2, 3, 4, 5, 6) as the initial processing step for slops treatment for a number of reasons, the foremost of which being:

- The organic content of the slops (60 to 100 gm/l COD) is well in excess of the point where the oxygen demand in an aerobic system exceeds economically attainable rates of oxygen transfer

- The anaerobic fermentation process is characterized by low kinetic reaction constants and biomass yields, the intramolecular breakdown of complex organic compounds, and the production of methane gas as an energy-containing byproduct

- Sludges produced in a properly functioning fermenter are generally more easily dewatered than are aerobic sludges, and a lesser mass of waste solids is produced per unit volume of wastewater treated in the anaerobic process than in the aerobic process

Based on prior experience with the anaerobic digestion of spent molasses wastes, as documented in the literature, the state of the art of this application appears to be that:

- The efficacy of anaerobic digestion of this type of waste is established

- High feed stream sulfate concentrations and high mixed liquor volatile acid concentrations are the commonly identified toxic/inhibitory factors in the applications

- The high sulfate concentrations, being associated with sulfide generation, have been dealt with in several cases by reduction of the strength of the waste stream to levels where its effect was deemed marginal, and

- The high volatile acids concentrations anticipated in the digestion process have been dealt with either similarly to the preceding (by dilution of the raw waste) or alternatively by control of the rates of loading of undiluted wastes at a level, wherein the rate of alkalinity production in the digestion was sufficient to maintain a suitable pH level for the methanogenic organisms independent of the rate of volatile acid generation

Unfortunately, due to the inconsistent frameworks used in reporting information derived in prior investigations, it is not possible to develop from the available information a characterization of the anaerobic digestions achieved in prior studies and/or of the operational controls applied to achieve successful digestions, on a rational kinetics basis, or even on a solids balance basis. Without such information, it is impossible to interpret the significance of empirical measures such as volumetric organic loading rate or hydraulic residence time in terms of the viable biomass inventory associated with the observed performance; nor is it possible, in the absence of information on such parameters as mixed liquor solids concentrations to ascertain, or even imply, the nature of the solids handling problems to be dealt with in the design and operation of a full scale application.

Given the absence of a transferable information base for the design and application of a full scale rum distillery slops treatment by a process train incorporating anaerobic fermentation, the overriding priority of the study described herein was directed to the development of a rational kinetic basis for unifying the understanding of the performance characteristics of anaerobic fermentation systems in the application. Given the importance of solids recycle in biological treatment systems, attention was directed to the anaerobic contact process.

ANAEROBIC CONTACT PROCESS

The anaerobic contact process (Figure 1) basically consists of two unit processes, an anaerobic fermenter and a solids separator (either gravity or mechanical), with provisions for recycle of concentrated biomass from the separator to the fermenter and complete mixing of the fermenter. Heating of the fermenter contents is provided in those cases where higher throughput rates (resulting in hydraulic residence times of hours rather than days) do not preclude its economic feasibility, or when sufficient methane is produced in the fermentation to satisfy heating requirements.

Fundamentally, the anaerobic contact process as originally described and documented (7, 8) differs from anaerobic sludge digestion in that biomass recycle and relatively low substrate concentrations are used. The literature contains reports on the use of the anaerobic contact process for the treatment of cannery, packinghouse, brewery, distillery fatty-acid, wood fiber, and synthetic-milk wastewaters.

In evaluation of the literature, it was found that an anaerobic process could be considered to be of the contact type if it met the following criteria (8): (a) an influent concentration of 4,000 mg/l BOD or less; (b) use of sludge recycle; and, (c) a liquid detention time of four days or less based on influent flow. Thus, the application of the anaerobic contact process for the treatment of rum distillery slops, in the present study, has represented an initial effort toward establishing the feasibility of the anaerobic contact process for treatment of high-strength wastes containing BOD concentrations in excess of 4,000 mg/l.

PROCESS KINETIC MODEL

The Monod model, as adapted by Gates et al (8) to the anaerobic contact process, was selected for use in the present study because of its ability to describe the performance (i.e., effluent substrate concentration) produced in the anaerobic contact process as a function of the hydraulic residence time in the fermenter, biomass recycle, and kinetic constants specific to the biodegradation of a given wastewater.

Basic Relationships

In the development of the growth kinetic model based on the work of Monod (9), it is assumed that gross bacterial growth is always exponential in character, that is:

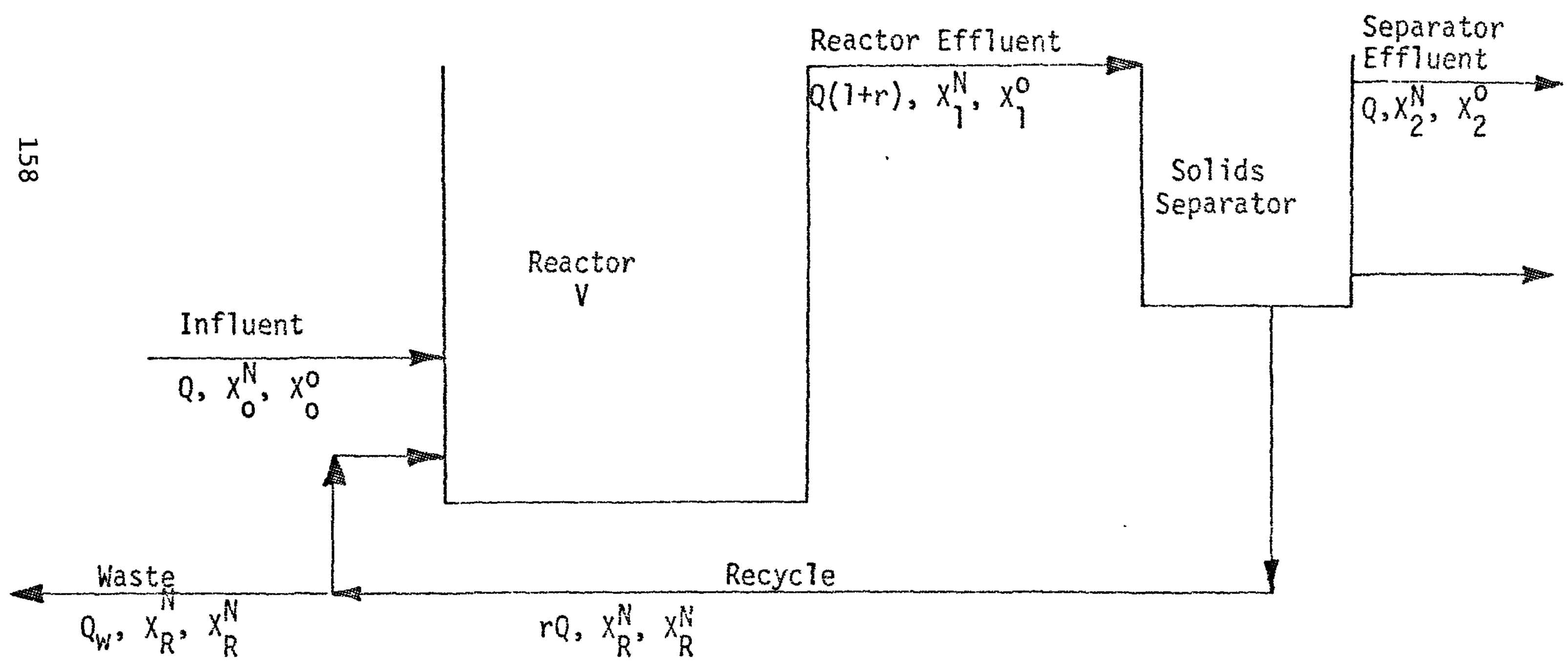


Figure 1. Schematic of General Treatment System

$$\frac{dX^\circ}{d\theta} = kX^\circ \tag{1}$$

where:

X° = organism concentration,
θ = time, and
k = specific growth rate

The expression for net growth then becomes:

$$\frac{dX^\circ}{d\theta} = (k - K^D)X^\circ \tag{2}$$

where K^D is specific autodestruction rate.

The relationship determined by Monod (9) for the growth rate constant is:

$$k = \frac{k^m X^N}{K + X^N} \tag{3}$$

where:
k^m = max specific growth rate,
X^N = concentration of controlling substrate, and
K = substrate concentration when $k = k_m/2$

Combining Equations 2 and 3 gives the overall expression for the change in organism concentration with time, that is:

$$\frac{dX^\circ}{d\theta} = \left[\left(\frac{k^m X^N}{K+X^N}\right) - K^D\right] X^\circ \tag{4}$$

For wastewater treatment processes, however, the major interest is in the change of substrate concentration with time rather than a terminal interest in the growth characteristics and capabilities of the bacteria. The relationship between organism concentration change with time and substrate concentration change with time can be expressed as follows:

$$-\frac{dX^\circ}{d\theta} = Y^\circ \frac{dX^N}{d\theta} \tag{5}$$

where Y° is mass of organisms produced per mass of substrate decrease.

Combining Equations 1, 3, and 5 yields:

$$\frac{dX^N}{d\theta} = -\left(\frac{1}{Y^\circ}\right)\left(\frac{k^m X^N}{K+X^N}\right) X^\circ \tag{6}$$

which is the working relationship describing the rate of substrate consumption when the Equation of Monod (9) is used.

When Equations 1, 2, 3, and 6 are applied to a continuous-flow, completely mixed reactor at steady state with recycle, the type employed in the bench and pilot-scale experiments, the following equations can be derived from nutrient and solids balances around the anaerobic contact system to describe the characteristics of such a reactor:

$$X_1^\circ = \frac{Y^\circ(X_\circ^N - X_1^N)}{K^D\theta_t + C^\circ} \tag{7}$$

$$X_1^N = \frac{K(K^D\theta_t + C^\circ)}{k^m\theta_t - (K^D\theta_t + C^\circ)} \tag{8}$$

$$k = K^D + C^\circ/\theta_t \tag{9}$$

$$C^\circ = X_w^\circ/X_1^\circ \tag{10}$$

where:

- X_1° = effluent organism concentration,
- $X_\circ$ = influent substrate concentration,
- X_1^N = effluent substrate concentration,
- K^D = specific autodestruction rate,
- θ_t = theoretical hydraulic detention time,
- C° = recycle factor, and
- X_w° = mass or organisms leaving system per unit time/total flow leaving system per unit time

In general, the value of X_w° is the weighted average of the organisms leaving the solids separator in the effluent and in any sludge that would be wasted. The value of C° is zero when all the organisms are recycled and one when no recycle is used.

The above equations assume that the controlling substrate is nonsettleable, thus, the substrate level in the system's effluent is the same as that in the reactor. The equations can be modified to consider a settleable substrate, as was observed to be the case in both the bench and pilot systems used in the present investigation. The modified equations as used herein were developed to account for the loss of substrate and biomass from the anaerobic contact process in both sampling and sludge wastage streams as well as the settleable character of the substrate. The modified forms of Equations 7 and 10 are as follows (no modifications were required to Equations 8 and 9):

$$X_1^\circ = \frac{Y^\circ\left\{X_\circ^N - X_1^N\left[1-r\ (C''-1)\right]\right\}}{K^D\theta_t + C^\circ} \tag{11}$$

and:

$$C^\circ = \frac{Q_w X_R{}^\circ + (Q-Q_s-Q_w)\ X_2{}^\circ}{QX_1{}^\circ} + \frac{Q_s}{Q} \qquad (12)$$

where:

$X_R{}^N$ = recycle stream substrate concentration,
$X_R{}^\circ$ = recycle stream (and sludge wastage stream) organism concentration,
Q_s = sample flow rate (average),
Q_w = sludge wastage flow rate,
C^N = degree of concentration of substrate in the solids separator ($= X_R{}^N/X_1{}^N$),
r = fraction of influent recycled,

and other symbology is as defined above. The physical significance of the symbology associated with the above equations is illustrated in the process flow sheet of Figure 1.

Operational Relationships

Equation 8 can be rewritten to formulate an operational relationship between the effluent substrate concentration, $X_1{}^N$, of the anaerobic contact process, and the basic design parameters, θ_t (hydraulic residence time) and C° (recycle factor), as follows:

$$\frac{\theta_t}{C^\circ} = \frac{K + X_1{}^N}{(k^m-K^D)X_1{}^N - KK^D} \qquad (13)$$

A plot of Equation 15 is presented in Figure 2, from which it is apparent that, for a given set of kinetic constants and a specified effluent quality, the ratio θ_t/C° is specified. The relationship defined by Equation 13 is a hyperbola which becomes asymptotic to an abscissa value equal to $K^DK/(k^m-K^D)$ and to an ordinate value equal to $1/(k^m-K^D)$. The value of $K^DK/(k^m-K^D)$ represents the minimum substrate concentration which can be realized in the effluent and is obtained when C° is zero (i.e., 100 percent recycle of biomass) or θ_t is infinity. The value of $1/(k^m/K^D)$ is approached as the effluent substrate concentration ($X_1{}^N$) approaches the influent concentration $X_o{}^N$, i.e., when biomass washout occurs.

Several basic premises of the kinetic formulation for the anaerobic contact process are embodied in this expression:

- Effluent quality as predicted by Equation 13 is directly a function of the viable biomass in the fermenter
- Effluent quality is not a function of influent quality; the only way that the biological process can respond to changes in the influent quality (or more appropriately, to changes in the mass loading rate of biodegradable matter), is by an increase or decrease in the inventory of viable biomass in the system
- For any given θ_t, an increase in C° results in a decrease in effluent quality; a decrease in the value of C° results in an improvement in effluent quality

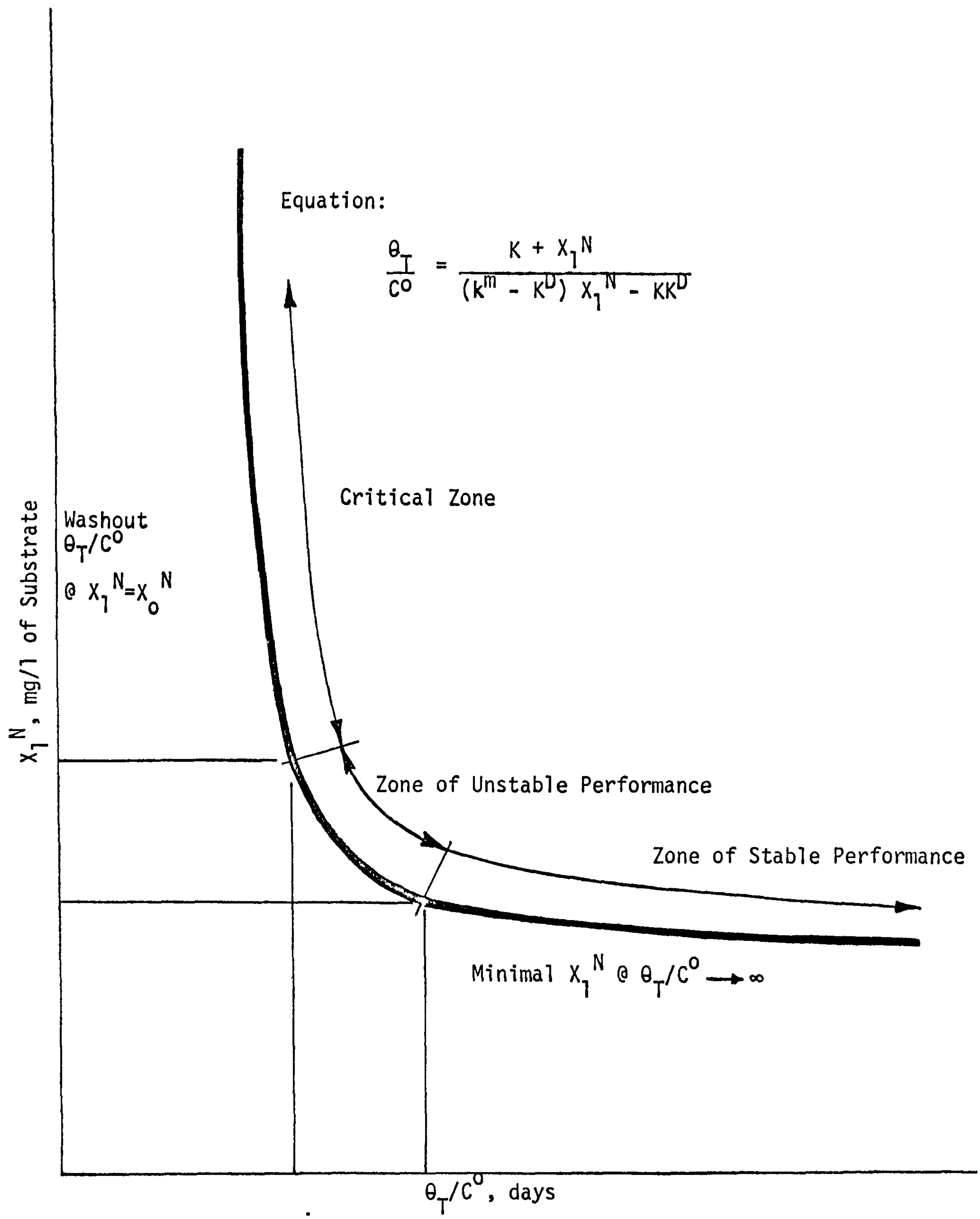


Figure 2. Unified Operational Relationship For Anaerobic Contact Process

The basic objective of the design of an anaerobic contact system is to achieve the $\theta_t/C°$ ratio as specified by the desired effluent quality and the determined kinetic constants for the least cost. The costs associated with θ_t are the tankage cost, the cost of mixing, and the optional cost of heating. The costs associated with C° are those for the solids separator and the necessary pumps and piping, and the power costs for operation of the separator and for pumping. Thus, a consideration of the costs associated with the size of the fermenter and separator, pumps and piping, mixing and power and other operational costs can be used to define the least cost region for a design of an anaerobic contact process to realize the specified $\theta_t/C°$ value.

The problems of operation are somewhat more arduous than those of design. The net result of design is almost inevitably the specification of a fermenter of fixed size (which provides the desired θ_t based on a design flow rate), a solids separator of fixed solids handling capacity, and a capacity to vary the quantity of underflow from the solids separator that is pumped back to the fermenter. Thus, in effect, the only controllable operational variable is C°. The major factors which affect C° are the effectiveness of the solids separator in controlling the biomass concentration in the liquid effluent from the separator, and the capacity to recycle biomass from the clarifier. After the design of a solids separator has been established, its effectivenes can be controlled only by the recycle rate and/or the addition of primary coagulants or coagulant aids (i.e. polymers).

Three regions of operation can be defined with the operational curve for the anaerobic contact process (Figure 2):

- A zone of "stable" performance, in which a unit change in the $\theta_t/C°$ results in little change in the effluent quality.
- A zone of transition or "unstable" performance, in which a unit change in the $\theta_t/C°$ value will generate significant change in the effluent quality.
- A critical zone, in which effluent quality deteriorates rapidly.

Because as previously discussed, C° is typically the only operational variable available, the anaerobic contact process has its greatest operational sensitivity in the "unstable" zone. Thus, when the desired effluent quality is based on a pretreatment or effluent standard (the most likely case), the objective of the operation becomes primarily that of insuring that C° is equal or less than the design value at all times. However, if the actual θ_t is variable, that is, if the actual flow rate deviates widely from the design flow value, then the objective of operation is to vary C° such that at all times, the ratio $\theta_t/C°$ is equal to or greater than that necessary to provide the desired effluent quality.

EXPERIMENTAL INVESTIGATIONS

The research effort was directed to documentation of the kinetic characteristics of rum distillery slops by the anaerobic contact process, and to evaluation of the clarification capacity required for gravity separation of mixed liquor solids in a prototype treatment system.

The kinetic characterizations were conducted using two bench scale anaerobic contact systems and a pilot scale anaerobic contact system as described below. The bench scale system was designed to provide a flexible tool for examining anaerobic biological response over a range of hydraulic residence times from five to 200 days. The pilot plant was designed to permit evaluation of gravity settling both with and without upstream vacuum degasification of fermenter effluents, gravity thickening, and hydrogen sulfide scrubbing requirements associated with a prototype design, as well as to permit examination of anaerobic biological response.

Apparatus

A schematic flow diagram of the bench scale anaerobic contact unit is presented in Figure 3, and a similar diagram for the pilot system is presented in Figure 4.

The bench scale systems (two were utilized) each consisted of a 20 liter completely mixed anaerobic fermenter, temperature-controlled at 33 to 36°C, and a four liter gas and solids separator vessel. Each system was equipped for continuous flow feeding, sludge recycle, and gas recycle. Feed was pumped continuously from a refrigerated reservoir; flow traversed upward through the reactor into the gas/solids separator, from which separated gas and sludge streams could be pumped either back to the fermenter or to wastage/ storage.

The pilot plant consisted of the following:

- A 1,130 liter (300 gallon) insulated slops storage tank used to hold feed slops batches.
- A 1,890 liter (500 gallon) insulated anaerobic fermenter, equipped with: an electric heat tape system, thermostatically controlled to maintain the temperature of the mixed liquor in the fermenter at 33 to 36°C; gas recycle at a rate of 0.15 standard cu m/min cu m of mixed liquor (20 SCFM/1,000 gallons); and, liquid recycle at a rate of 0.06 cu m/min/cu m of mixed liquor (60 gpm/1,000 gallons).
- Hydrogen sulfide scrubbers (two), each consisting of cylindrical tanks, 0.1 m diameter by 0.6 m in height (4-in diameter by 2-ft height), filled with steel wool and designed for removal of approximately 1/2 kg elemental sulfur per kg steel wool.
- Vacuum degasifier, consisting of a cylindrical tank 0.15 m diameter by 0.6 m in height (6-in diameter by 2-ft height), providing for degasification of the mixed liquor flow at a vacuum of 15 mm Hg.
- A gravity clarifier/thickener, the key features of which were as follows:
    - the clarifier (conical) sector of the unit has a cross-sectional area of one sq m (10. 7 sq ft) at the liquid surface and 0.21 sq m (2.2 sq ft) at the bottom of the cone.
    - effluent is withdrawn from the clarifier in four effluent funnels.

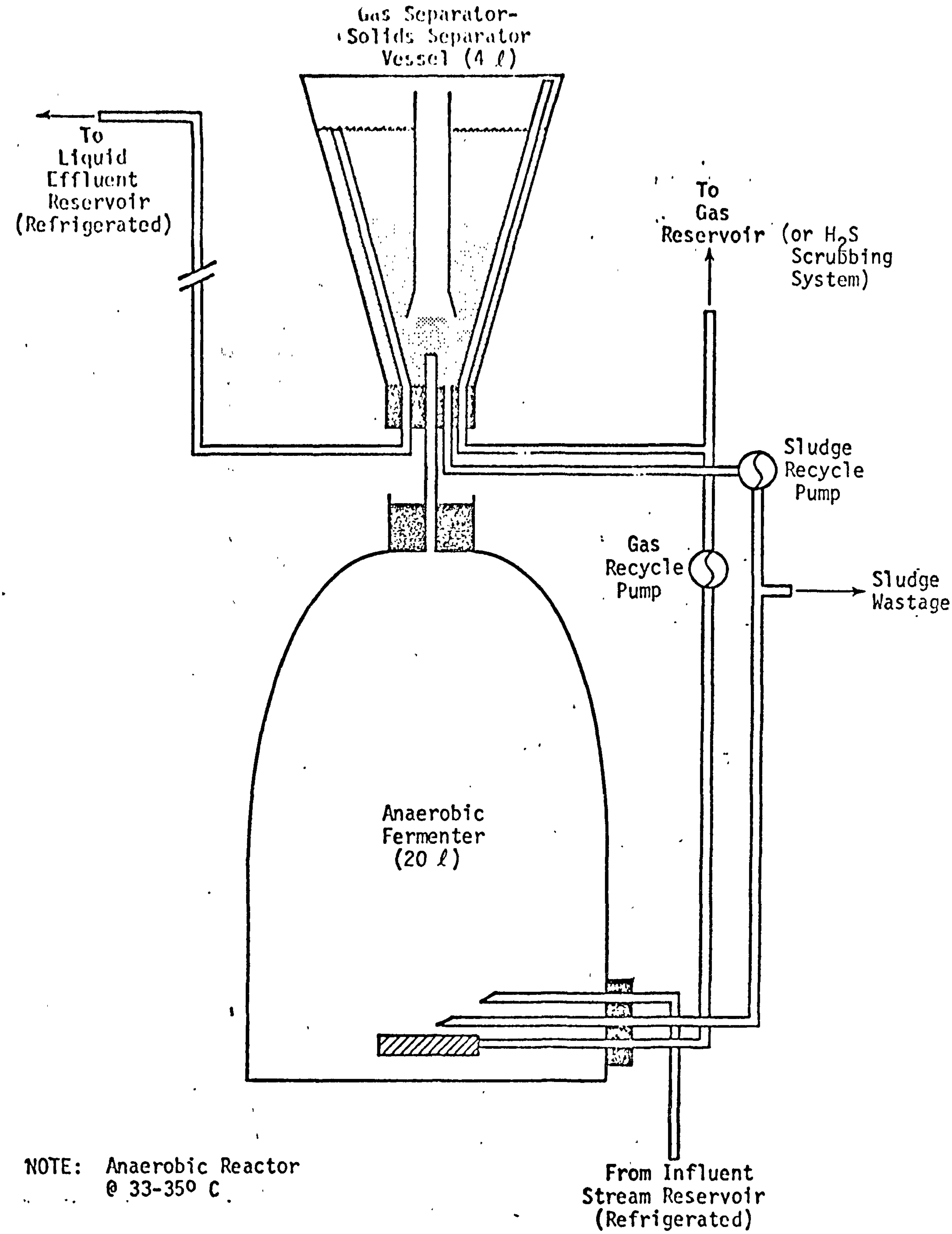


Figure 3. Bench Scale Anaerobic Contact Unit

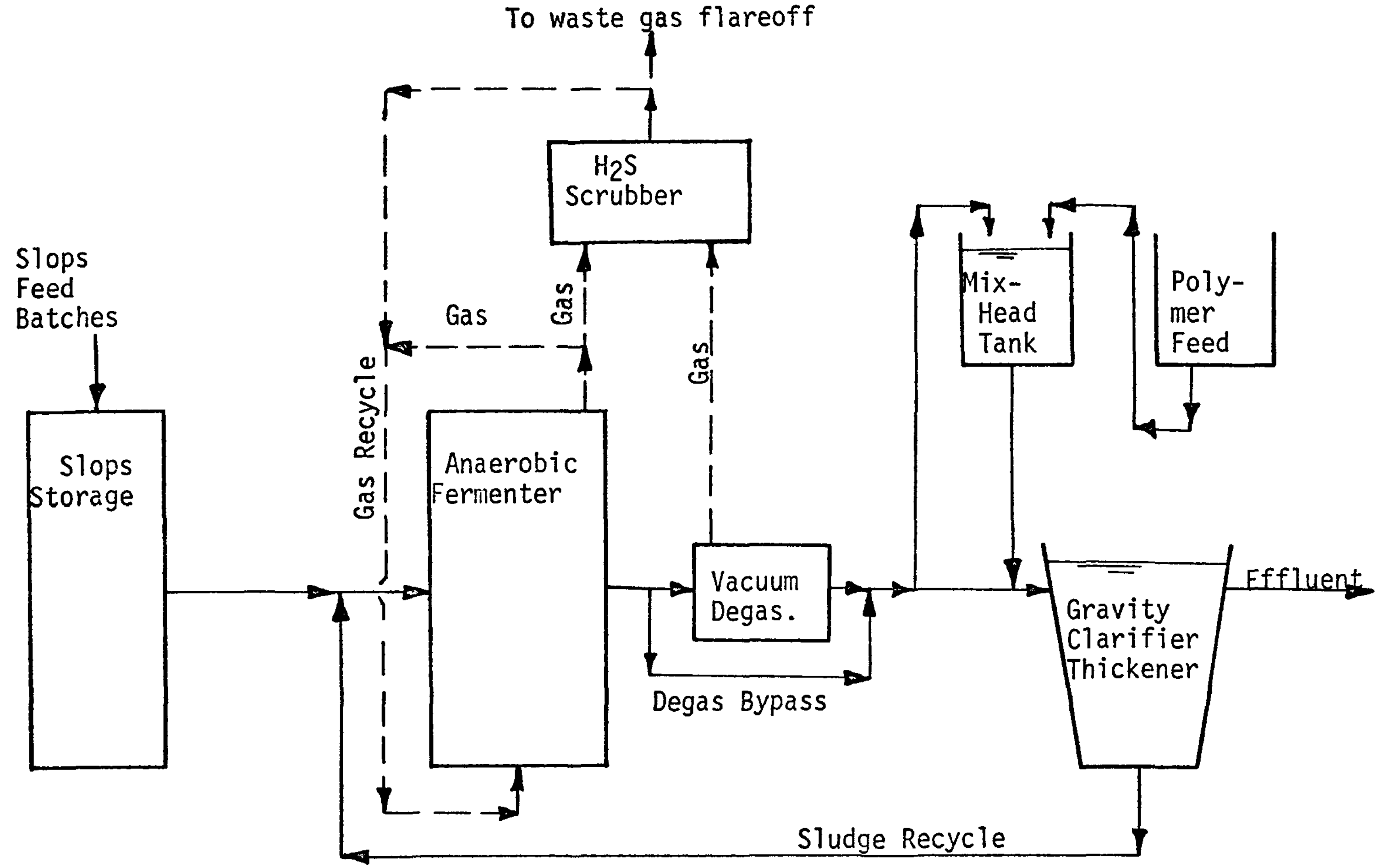


Figure 4. Pilot Plant Process Schematic

presenting a total weir length of 2.57 m (8.4 ft).

.. the thickener sector of the unit is equipped with a thickener screen that can be rotated at a rate of 1/8 to 1/2 revolution/minute.

.. sludge withdrawal is accomplished by means of a variable speed pump capable of a maximum sludge withdrawal rate of 985 liters/day (260 gallons/day).

- A 190 liter (50 gallon) mix-head tank and a stock polymer solution feed tank; the mix-head tank was equipped with a constant head overflow (the overflow being recycled directly back to the anaerobic fermenter); stock ploymer solution was fed into the mix-head tank, and the contents of this were mixed with a recycle pump at a rate of one volume every five minutes.

During the first phase of pilot plant operations (evaluation of anaerobic biological process kinetics), raw slops were fed from the slops storage tank at preselected continuous flow rates, and flows of mixed liquor from the anaerobic fermenter were transferred directly to the clarifier-thickener (i.e., the flow path through the mix-head tank was not used). During the final phase of pilot plant operations (evaluation of mixed liquor settling characteristics), all mixed liquor flows were directed to the mix-head tank, and from this point by gravity into the clarifier-thickener.

Both the bench and pilot systems were designed with the sampling ports necessary to permit characterization of liquid volumes within each component of the system, liquid and material transfer rates into, within, and from the components of systems, and gas production rates.

Procedures

Process Kinetic Characterization - The biological process kinetic studies were conducted in three phases; seed culture development; startup and acclimatization of the bench and pilot scale units, and routine operations.

Seed cultures for use in the startup of the bench and pilot systems were propagated in anaerobic vessels equipped with feed and sampling parts, and with a gas release valve. Selected as a source of methanogenic material for starting the seed cultures were the bottom mud of a brackish water inlet to San Juan Bay (Puerto Rico); this inlet has received slops discharge from a distillery and cooling water discharges from an electrical power generation station for a number of years. The seed cultures were maintained by daily batch feeding of gradully increased amounts of raw slops neutralized to pH 7.0 with sodium bicarbonate. Daily observations were made on the pH of the seed culture and the volume and composition of gas generated in each vessel. The first trace of methane was typically observed within two to four weeks after initiation of seed culturing and a minimum time of four months was allowed before the seed cultures were transferred to the fermenters. After seeding, all three units were fed neutralized undiluted slops at flow rates allowing hydraulic residence times in excess of 30 days, to permit the buildup of MLVSS (mixed liquor volatile suspended solids) concentrations to minimal levels of 300 mg/1.

An evaluation of the operating experience acquired during the four month period of acclimatization and buildup of a viable biomass inventory in each of the anaerobic contact units led to the development of the following guidelines for startup:

- The maximal rate of slops feed should not exceed one kg soluble COD/ day/kg MLVSS if the buildup of volatile acids is to be avoided.

- The pH of the mixed liquor should be maintained in the range of 7.2 to 7.3 at all times.

- Continuous mixing of the fermenter contents should be provided.

After completion of the acclimatization phase of operations in each fermenter, it was possible to sustain a methanogenic fermentation of undiluted and unneutralized slops stream at a pH in excess of 7.0 during operations at hydraulic residence times in excess of 20 days. Neutralization was required to maintain a mixed liquor pH in excess of 7.0 at residence times below 20 days, indicative of a differential between required and internally generated buffering capacity that increased with decreasing hydraulic residence times at hydraulic residence times less than 20 days. During routine operations, neutralization was accomplished, as needed, by the addition of sodium bicarbonate directly into the bench and pilot scale fermenters.

Each of the biological systems was operated for a time period averaging nine months, including the four month startup period. Throughout the nine month period, weekly balances were performed on total and volatile suspended solids (TSS and VSS), total and soluble COD, total nitrogen, and total phosphorus, on the feed stream, mixed liquor, effluent, and recycle stream of each system. Daily observations were made on pH, alkalinity, volatile acid concentration, and temperature of the mixed liquors in each system, and of the volume and methane content of the gas generated in each fermenter.

Determination of Clarification Capacity

The objective of this phase of effort was to develop a relationship between clarifier performance and loading rate that could be used to examine tradeoffs between recycle factor (C°) attainable, and a loading parameter from which (1) the size and (2) the cost of the clarifier system could be established. The pilot plant was modified for this final effort of the investigations to permit the recycle of both settled solids and clarified effluent back to the anaerobic fermenter -- a measure necessary to conserve the essentially fixed supply of mixed liquor solids available for the testing program. Also, larger pumps were installed to permit the transfer of mixed liquor into the mix head tank and thence by gravity into the clarifier, at clarifier surface loading rates up to a maximum of 10. 2 cu m/day/sq m (250 gpd/sq ft).

A jar testing program was conducted with the objective of screening a wide range of high and low molecular weight polymers, for use as a coagulant aid to improve the settleability of the mixed liquor solids. As the basis of jar testing, the polymer selected was Nalco 627, a moderately cationic, high molecular weight polymer (10), with this polymer it was possible to obtain in excess of 80 percent TSS removals in the jar test beakers after 30 minutes of quiescent settling at specific polymer doses varying from 1 to

5 mg per gm TSS.

With the selection of a polymer and the development of dosing criteria, the evaluation of clarification capacity was done as follows:

- Laboratory zone settling assays were conducted to determine the solids handling capacity of the limiting layer as a function of specific polymer dose and initial TSS concentration in the suspension.

- Two series of experimental runs were conducted with the modified pilot plant to document the relationship between TSS removal efficiency and solids loading rate; no polymers were used in the first series of runs (as a control) and polymer addition was used in the second series.

- The results of the zone settling assays were compared with the pilot plant results in the selection of a design solids loading rate for full-scale application.

RESULTS

Process Kinetics

The three biological systems were operated a total of 110 weeks, including acclimatization operations over 16 week periods with each system. Exclusive of observations made during the startup phases in each of the three units, a total of 62 weekly sets of experimental data were available for use in the kinetic characterization. This data set was screened to eliminate data points not deemed representative of steady state operation. The criteria defined for steady state operation were as follows: less than 15 percent variation in flow rate, 10 percent variation in mixed liquor/effluent soluble COD concentration, 20 percent variation in mixed liquor/effluent VSS concentration, and 20 percent variation in $\theta_t/C°$, based on average values of each during three consecutive weekly periods. Based on these criteria, a total of 14 sets of experimental data representative of steady state were identified, seven from operation of the two bench units, and seven from the pilot plant operations.

The characteristics of the fermentations in these units at each steady state point are summarized in Tables 1 and 2 and illustrated by the data presented in Figure 5. The values of $\theta_t/C°$ at which steady state was obtained varied from 35 to 220 days, and the values of θ_t (hydraulic residence time) varied from 19 to 140 days.

The soluble COD loading rate, expressed in rational units of mass/time-mass of MLVSS, varied from a minimum of about 0.26 kg/day/kg MLVSS (0.26 lb/day/lb MLVSS) at a $\theta_t/C°$ of 220 days, to a maximum of 0.74 kg/day/kg MLVSS at a $\theta_t/C°$ of 35 days. The soluble BOD loading rates corresponding to the above were 0.059 kg/day/kg MLVSS at $\theta_t/C°$ of 220 days, and 0.449 kg/day/kg MLVSS at $\theta_t/C°$ of 35 days. Thus, the maximum soluble COD loading rate observed under steady state conditions (0.74 kg/day/kg MLVSS) was approximately 25 percent less than the maximal loading rate of 1 kg soluble COD/day/kg MLVSS recommended for startup.

On a volumetric basis, the soluble COD loading parameter varied from a minimum of about 0.4 kg/day/cu m (0.024 lb/day/cu ft) at $\theta_t/C°$ of 35 days, to a maximum

Table 1. Steady-State Operations: Summary of Loading Rate, Mixed Liquor, and Effluent Characteristics

Syst.	Wk.	θ_t (days)	Loading Rates: Kg SolCOD Day-Cu M	Kg SolBOD Day-CuM	Kg Sol COD Day-KgMLVSS	Kg Sol BOD Day-KgMLVSS	Mixed Liquor Characteristics: Sol COD (X_1^N) mg/1	VSS (X_1^o) mg/1	MLTSS mg/1	pH[1]	Alkalinity (mg/1@CaCO3	Vol.Acid (mg/1@HAc)	Effluent Sol COD (X_2^N), mg/1
B/S 1	25	35.1	1.69	1.03	0.729	0.443	21,230	2,320	3,287	7.21	9,170	94	20,070
	26	35.4	1.95	1.19	0.738	0.449	21,250	2,647	3,367	7.20	9,410	87	19,390
B/S 2	29	221	0.38	0.086	0.261	0.059	17,790	1,458	2,120	7.32	9,280	59	--
	30	149	0.56	0.127	0.380	0.086	16,460	1,475	2,400	7.31	9,180	60	20,910
	31	147	0.57	0.129	0.390	0.088	16,790	1,462	2,200	7.23	9,080	57	16,030
	33	145	0.58	0.131	0.395	0.089	14,500	1,469	2,518	7.27	8,570	54	--
PP	21	25.2	2.67	0.701	0.622	0.163	18,950	4,293	6,587	7.15	8,710	92	16,530
	22	20.6	2.90	0.760	0.557	0.146	22,770	5,200	7,360	6.12	8,780	143	21,780
	24	19.0	3.57	0.935	0.700	0.183	21,570	5,100	6,990	7.16	8,900	436	20,430
	25	20.3	3.33	0.872	0.582	0.152	23,810	5,720	7,853	7.16	8,860	549	23,430
	26	19.3	3.44	0.901	0.686	0.159	24,420	5,020	7,333	7.11	9,070	618	22,900
	33	31.0	3.36	0.991	0.560	0.165	26,260	6,000	8,600	7.20	11,010	220	28,040
	34	36.9	3.01	0.888	0.497	0.147	29,450	6,067	9,027	7.19	10,820	154	28,270

pH controlled by buffer addition

Table 2. Steady State Operations: Summary of Operating and Performance Characteristics

			Gas Production Parameters					Sol. COD Removal		
System	Week	θ_t (days)	Recyc. Factor (C°)	Daily Gas Production (1/day)	% CH_4	1 CH_4 per gm VSS-day	1 CH_4 per gm Sol COD removd	Influent Mixed Liquor(%)	Influent Separator Effluent(%)	$\frac{\theta_t}{C°}$ (days)
B/S 1	25	35.1	0.604	14.7	53.7	0.160	0.317	69.3	71.0	58.1
	26	35.4	0.523	16.7	54.6	0.106	0.316	69.3	72.0	67.7
B/S 2	29	221	1.004	16.6	54.4	0.291	0.333	78.8	--	220
	30	149	0.992	18.0	58.7	0.336	0.289	80.4	75.0	150
	31	147	1.000	17.5	59.9	0.337	0.290	79.9	80.9	147
	32	143	1.012	18.6	58.5	0.345	0.282	82.0	80.5	142
	33	145	1.002	19.8	58.8	0.372	0.303	82.7	--	144
PP	21	25.2	0.410	2,053	58.3	0.147	0.329	71.7	75.3	51.5
	22	20.6	0.372	2,045	56.9	0.120	0.324	66.0	67.5	63.0
	24	19.0	0.359	2,386	54.8	0.131	0.285	67.8	69.5	53.0
	25	20.3	0.525	2,379	59.4	0.131	0.333	64.5	65.1	38.7
	26	19.3	0.598	2,181	59.5	0.136	0.313	63.6	56.9	34.6
	33	31.0	0.417	2,055	58.0	0.105	0.249	74.7	73.0	74.3
	34	36.9	0.492	1,860	58.1	0.094	0.265	71.6	72.7	75.0

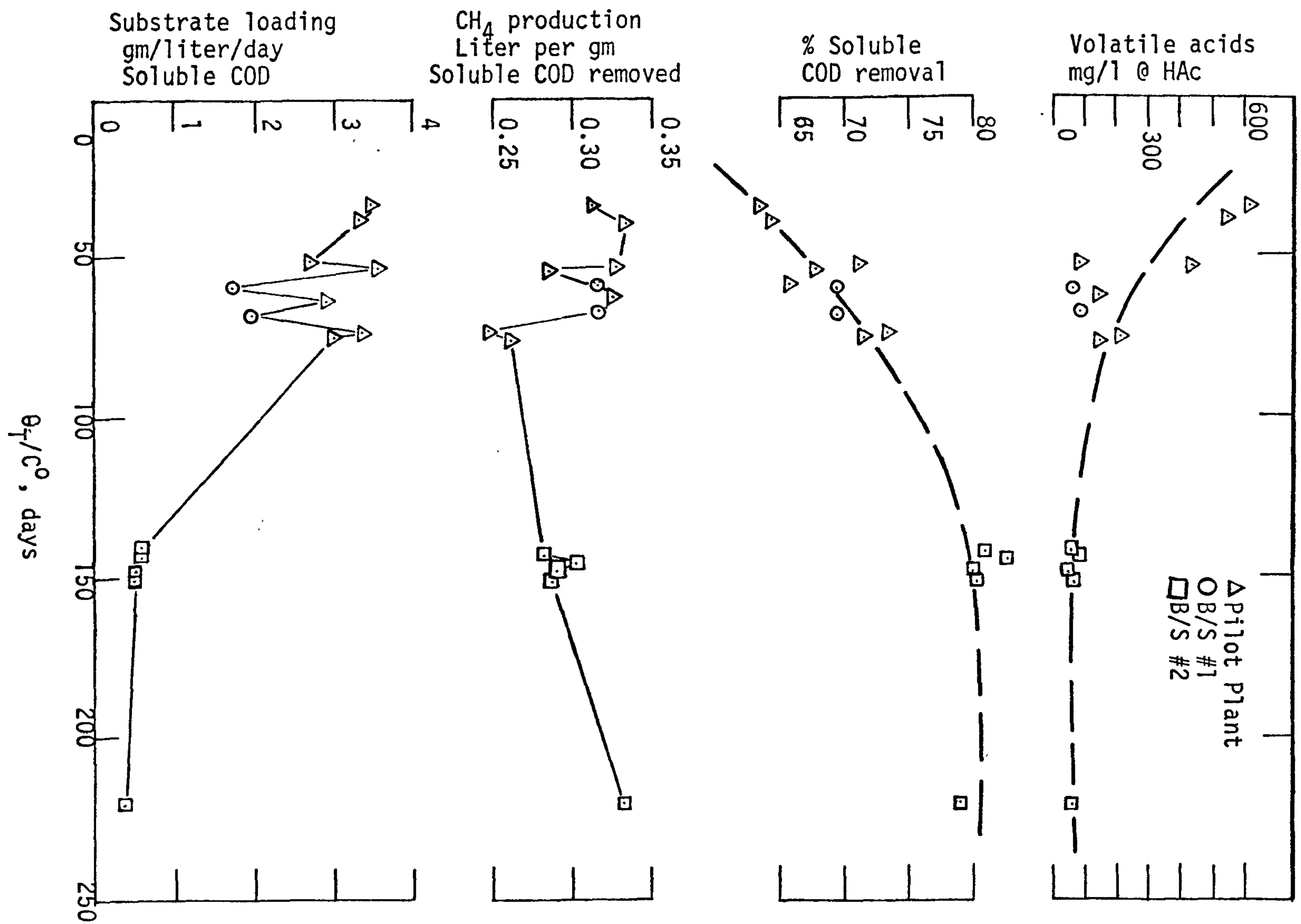


Figure 5. Steady State Characteristics Rum Distillery Slops Treatment by Anaerobic Contact Process

of 3.44 kg/day/cu m (0.215 lb/day/cu ft) at $\theta_t/C°$ of 220 days, as shown in Figure 5. The volumetric soluble BOD loading rates varied from 0.086 to 1.19 kg/day/cu m (0.005 to 0.074 lb/day/cu ft), increasing with decreasing $\theta_t/C°$ values in a pattern similar to that for the soluble COD pattern as shown in Figure 5.

The alkalinity of the mixed liquors varied from 8,500 to 11,000 mg/l @ $CaCO_3$, and the pH levels varied from 7.11 to 7.32, the ranges of values of each of these parameters reflecting the effect of buffer addition as necessary to maintain the pH of the mixed liquors at about 7.2. The volatile acids concentrations in the fermentations varied from less than 100 mg/l (as acetic acid) at $\theta_t/C°$ values in excess of 100 days, to maximal values of 600 mg/l at $\theta_t/C°$ values of 35 days. As shown by the plot of data on volatile acids concentrations vs $\theta t/C°$ in Figure 5, the volatile acid concentration tended to increase at an increasing rate with decreasing $\theta_t/C°$ values.

The MLVSS (mixed liquor volatile suspended solids) concentrations (Table 1) varied from a minimal level of about 1,500 mg/l at $\theta_t/C°$ of 220 days to maximal levels of 6,000 mg/l at $\theta_t/C°$ of 35 to 40 days. The volatile fraction of the MLTSS (mixed liquor total suspended solids), i.e., ratio of MLVSS:MLTSS concentrations for the steady state points varied between 0.55 and 0.73; for all 14 data points the average volatile fraction was 0.67.

The soluble COD removal efficiencies in the three units at the steady state points are reported in Table 2 and illustrated in Figure 5. The soluble COD removal (influent-mixed liquor basis) increased with increasing $\theta_t/C°$ from a minimal value of about 65 percent at $\theta_t/C°$ values in excess of 150 days. From a comparison of soluble COD removal efficiencies computed on (1) an influent -- mixed liquor basis and (2) an influent -- separator effluent basis (Table 2), it is evident that the additional soluble COD removal obtained in the separator sector is insignificant relative to removals obtained in the anaerobic fermenters.

The methane (CH_4) content of the gas produced in the fermentations varied from 53 to 60 percent, and averaged 57.4 percent for the 14 steady state points. The methane production varied from 0.28 to 0.33 liters of CH_4 per gm of soluble COD removed (4.5 to 5.3 cu ft/lb soluble COD removed), and averaged 0.302 liter/gm soluble COD removed (4.8 cu ft/lb soluble COD removed) for all observations. That is, an average of 86.3 percent of the soluble COD (or about 82 percent of the total COD) removed from the feed stream was recovered in the form of methane during the steady state observations.

Determination of Process Kinetics - For purposes of determining the kinetic constants, it was assumed that the VSS parameter represented viable biomass concentration ($X_1°$), and the soluble COD parameter represented the rate controlling substrate concentration (X_1^N). Linear forms of Equations 11 and 12 were used to analyze the data. From Equation 11:

$$\frac{X_o^N - X_1^N \left[1-r(C''-1)\right]}{C^\circ X^\circ_1} = \frac{1}{Y^\circ} + \frac{K^D}{Y^\circ}\left[\frac{\theta_t}{C^\circ}\right] \qquad (14)$$

From Equation 12:

$$\frac{\theta_t}{K^D\theta_t + C^\circ} = \frac{1}{k^m} + \frac{K}{k^m}\left[\frac{1}{X_1^N}\right] \qquad (15)$$

Presented in Figure 6 is a plot of Equation 14, in which the intercept is the inverse of the value of Y°, and the slope represents the ratio K^D/Y°. The steady-state data are presented in Figure 7 for determination of the values of K and k^m using Equation 15. The intercept of the straight line fit in Figure 7 is the inverse of the value of k^m, and the slope is equal to K/k^m.

The values of the kinetic constants obtained from this analysis are as follows:

Y° = 0.225 mg VSS/mg soluble COD
K^D = 0.0667 $days^{-1}$
K = 12,270 mg/1 soluble COD
k^m = 0.129 $days^{-1}$

In order to provide some basis of comparison for the values of the kinetic constants, a summary of the kinetic constants determined in this and prior studies is presented in Table 3. Included in Table 3 are data for a packing-house waste (11, 12), synthetic milk waste (8), and the results reported by Andrews and Pearson (13).

The value of k^m for the slops and synthetic milk wastes are similar in magnitude (0.13 $days^{-1}$). Given the 10°C difference in temperature used in these two studies, it was anticipated based on observations by Schroepfer and Ziemke (11, 12) that the anaerobic stabilization rate for the slops would have been about double that for the synthetic milk waste. However, since the temperatures used by Andrews and Pearson (13), Schroepfer et al (11), Schroepfer and Ziemke (12), and in this study were nearly equal, it would appear that k^m is influenced by substrate composition as well as temperature.

The K^D value obtained for slops treatment by the anaerobic contact process is nearly equivalent to that reported for the synthetic milk waste (8). The Y° value obtained for rum slops is greater than that reported by Andrews (13) for the methane organism dominated system and less than that reported by Gates et al (8) for the synthetic milk waste. The variation in Y° value appears to be attributable both to temperature and to different relative combinations of organisms existing in the different systems. The K value for the rum slops is several hundredfold greater than the value reported for the other wastes. That K did change with temperature and/or substrate composition is apparent; however, too little is known about the effect of transport-controlled mechanisms to support any definite conclusions about the impact of the environment on K.

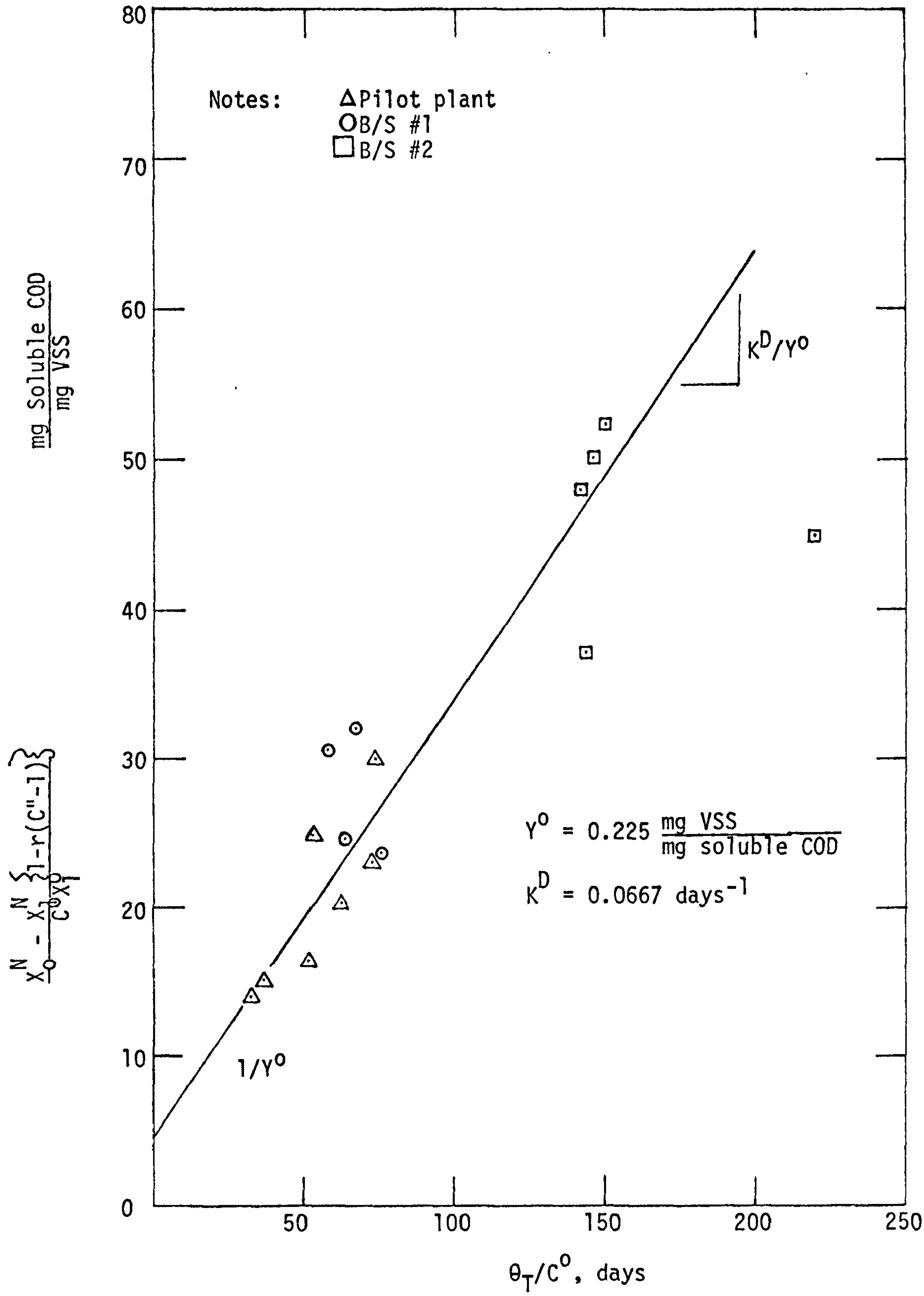


Figure 6. Rum Distillery Slops Treatment by Anaerobic Contact Process-Determination of Values of Y° and K^D for steady-state Data

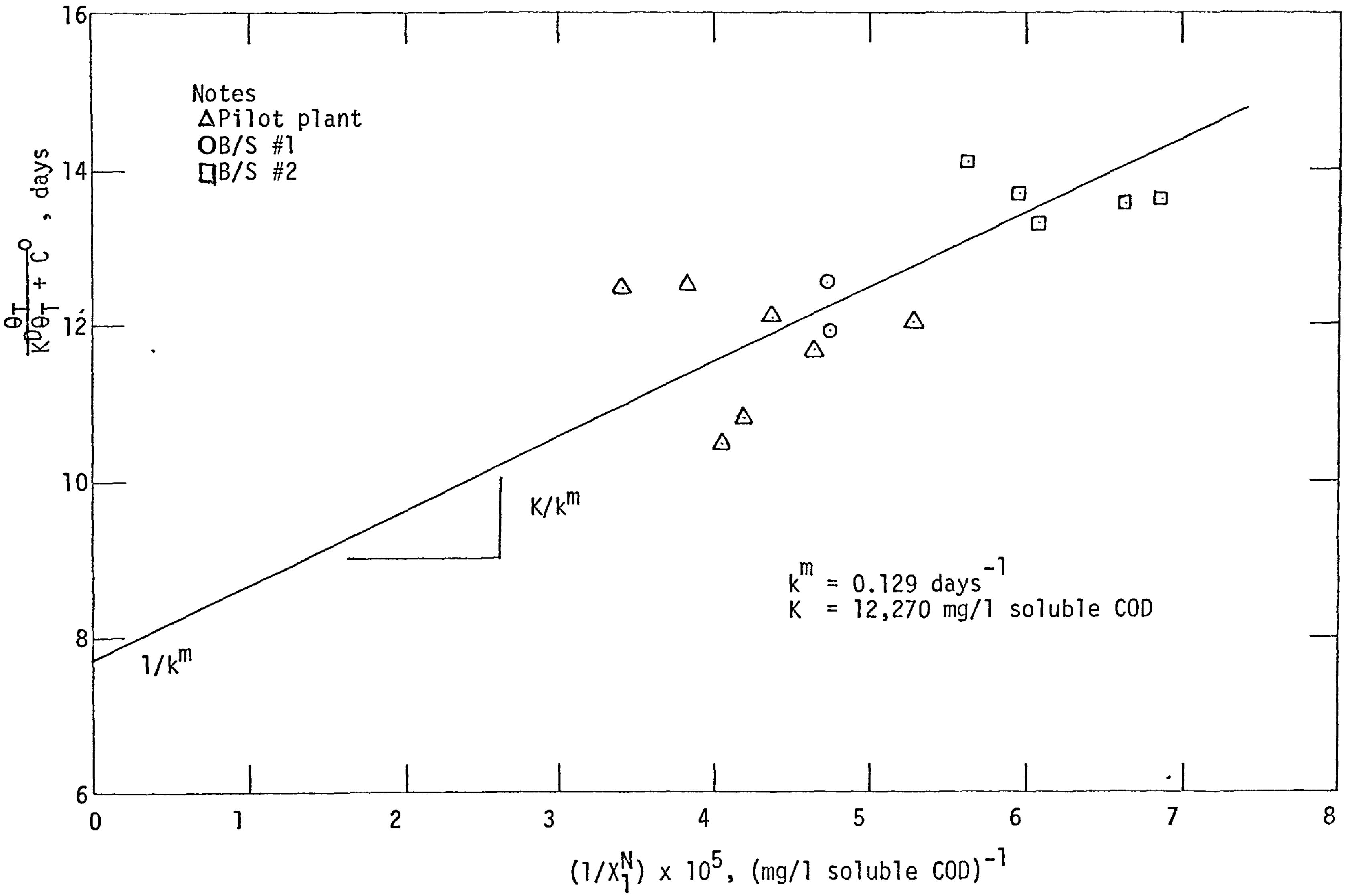


Figure 7. Rum Distillery Slops Treatment by Anaerobic Contact Process Determination of Values of k^m and K for Steady-State Data

Table 3. Values of Constants in Various Studies

Source	k^m(days^{-1})	K^D(days^{-1})	K(mg COD/1)	$\frac{mg/VSS}{Y° (mg\ COD)}$	Temp °C
Packinghouse waste (11, 12)	0.25	0.17	5.5	0.76	35
Anaerobic digester (13)					
Acid-formers	1.33	0.87	--	0.54	38
Methane Formers	1.33*	0.02	--	0.14	38
Synthetic Milk Waste (8)	0.14	0.07	24.3	0.37	20-25
Rum Slops (this Study)	0.129	0.0667	12,270	0.225	33-36

*At least some of the methane formers exhibited this value

Operational Relationship - Equation 13 and the values of the constants for rum slops treatment by the anaerobic contact process were used to formulate the operational relationship defining process performance as a function of θ_t and C°, as presented in Figure 8. The measure of process performance is the soluble COD concentration of the process effluent, X_1^N. The operational relationship is a hyperbola which becomes asymptotic to an abscissa value equal to $K^D K/(k^m - K^D)$ and to an ordinate value equal to $1/(k^m - K^D)$. The equation describing the operational relationship is as follows:

$$\frac{\theta_t}{C^\circ} = \frac{12,270 + X_1^N}{0.0623\ X_1^N - 818} \qquad (16)$$

The value of the abscissa asymptote represents the minimum effluent substrate concentration which can be obtained when C° is equal to zero (i.e., 100 percent biomass recycle), or when θ_t is infinity. The value of the ordinate asymptote is approached as the effluent substrate concentration X_1^N approaches the influent concentration ($X_\circ^N$), i.e., when biomass washout occurs. In the present case (treatment of rum distillery slops) these asymptotic values are X_1^N = 11,430 mg/l and θ_t/C° = 14.7 days, respectively.

Three regions of operation can be defined with the operational curve (Figure 8) for rum slops treatment by the anaerobic contact process:

- A zone of stable operation (small ratio of $\Delta X_1^N : \Delta\theta_t/C^\circ$), existing at θ_t/C° values greater than 75 days.
- A zone of transition (in which X_1^N varies significantly with changes in θ_t/C°), existing at θ_t/C° values between 40 and 75 days.
- A zone of instability (occurring at θ_t/C° values less than 40 days), in which the effluent quality rapidly deteriorates.

Within the zone of stable operation, effluent soluble COD concentrations of less than 20,000 mg/l were obtained with the anaerobic contact treatment of rum slops. This effluent concentration is equivalent (for a slops feed stream concentration of 80,000 mg/l soluble COD), to a soluble COD removal efficiency of 75 percent.

Clarification Capacity

Both laboratory zone settling tests and pilot clarification tests were conducted to permit the development of the desired relationship between clarifier TSS removal efficiency and solids loading rate.

Zone Settling Tests - The results of the six zone settling assays, conducted using three initial MLTSS concentrations and two polymer doses per initial MLTSS concentration, are presented in Table 4. The actual MLTSS concentrations at which the tests were conducted were approximately 7,500 mg/l, 12,000 mg/l, and 28,000 mg/l, the lower and upper vlaues being representative of the anticipated range of MLTSS concentrations to be carried in a full scale application. The data on solids loading rate in the limiting layer (Table 4) were calculated using the zone settling curves (plots of interface height vs settling time) for each test, and an assumed underflow concentration of 50,000 mg/l (TSS). The allowable liquid loading rate was then calculated from the initial MLTSS concentration and solids handling rate data for each test. The allowable liquid loading rate and initial MLTSS data have been plotted in Figure 9 to

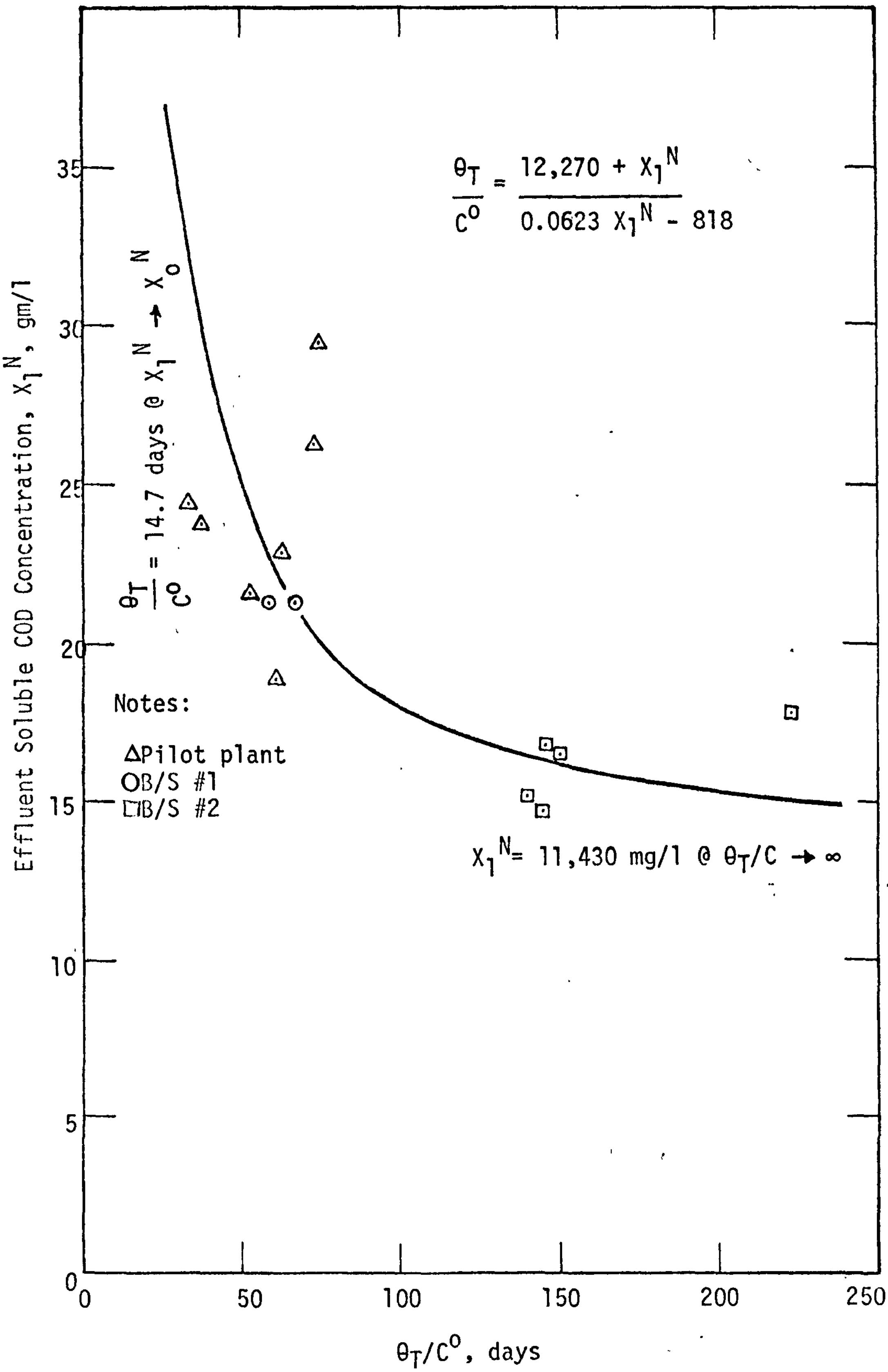


Figure 8. Unified Operational Relationship for Rum Distillery Slops Treatment by Anaerobic Contact Process

Table 4. Summary of Zone Settling Data

Test #	Initial MLTSS (mg/l)	Poly-mer dose (mg/gm)[1]	Solids Loading in Limit. Layer (KG/day-sq m)[2]	Allowable Liquid Loading Rate (cu m/day/sq m)	Superna-tant TSS (mg/l)[3]	% TSS Removal
1	6,770	1.44	178	26.4	1,450	78.5
2	6,295	7.25	112	17.9	3,130	50.2
3	12,850	1.06	293	22.8	1,200	90.7
4	11,635	5.26	381	32.8	1,700	85.4
5	30,527	0.63	317	20.5	2,230	92.7
6	26,594	3.15	1,001	37.7	2,930	89.0

Notes: [1]Nalco 627

[2]Assumed underflow TSS concentration - 50,000 mg/l

[3]Sampled after 30 minutes of settling

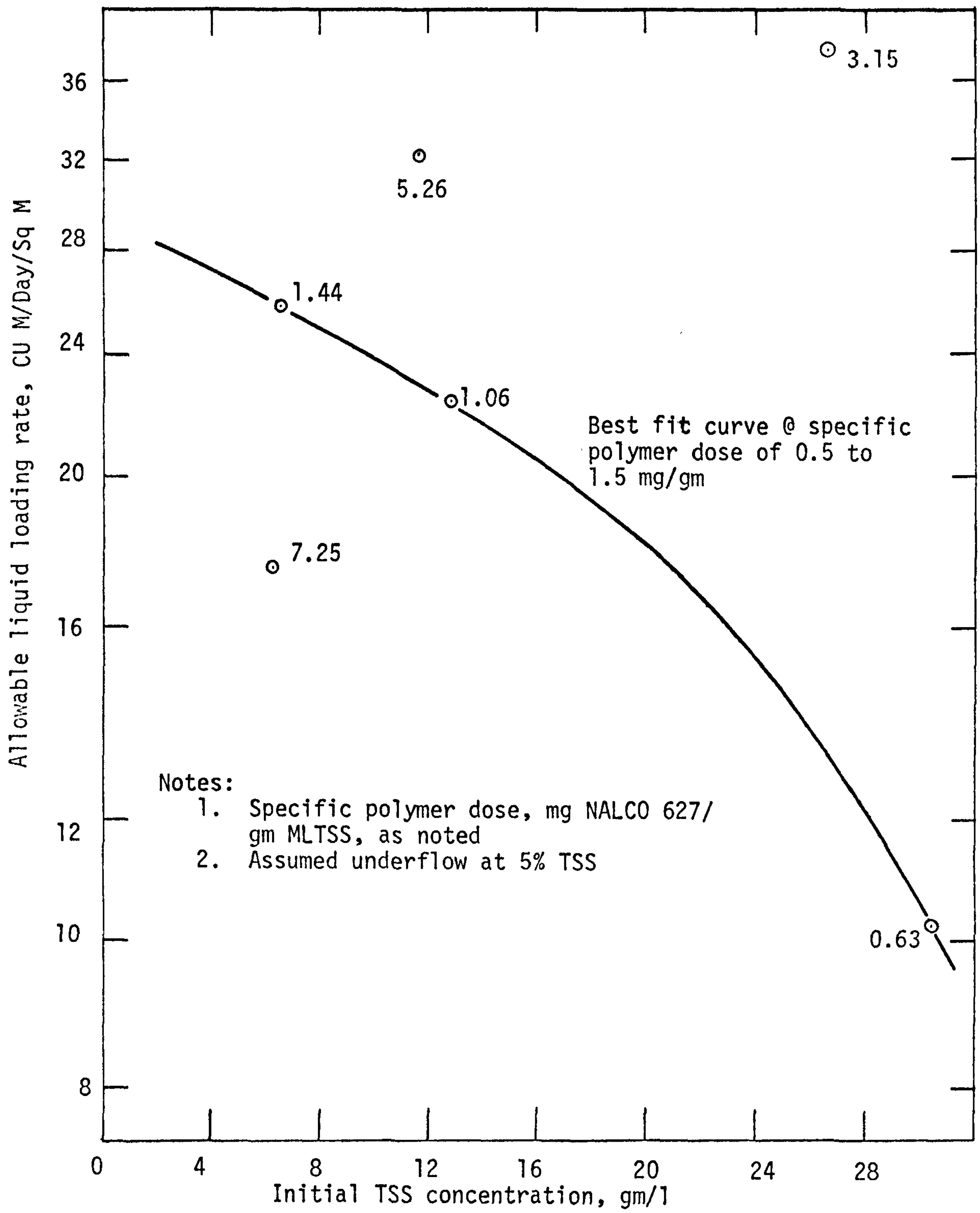


Figure 9. Allowable Mixed Liquor Surface Loading Rate vs. MLTSS Concentration - Zone Settling

determine, for the laboratory data, a relationship between maximum rate of clarification as related to the settling velocity of the limiting layer, and initial MLTSS concentration.

A trend can be defined from the data presented in Figure 9 between allowable liquid loading rate and initial MLTSS concentration at the lower range of polymer doses (0.63 to 1.44 mg/gm MLTSS); this trend is exemplified by the best fit curve in Figure 9. Based on this curve, the allowable liquid loading rate decreased at an increasing rate with increasing initial MLTSS concentration from 26 cu m/day/sq m (635 gpd/sq ft) at an initial concentration of 7,000 mg/l to 11.5 cu m/day/sq m (260 gpd/sq ft) at 30,000 mg/l.

While insufficient points were available to define similar trends for liquid loading rates associated with the high polymer doses, it is apparent from the data presented in Figure 9 that, at polymer doses greater than 1.5 mg/gm MLTSS, the allowable liquid loading rate at any given MLTSS concentration increased with increasing polymer dose to a maximal level at a polymer dose of about 3 mg/ym, and then decreased with increasing polymer dose to a minimal level at the polymer dose of 7.25 mg/gm, in comparison with the results obtained at polymer doses in the range of 0.63 to 1.44 mg/gm. The decrease in polymer effectiveness with increased polymer dose is also evidenced by the TSS removal efficiency data presented in Table 4, i.e., the percent removal of initial MLTSS as determined by sampling the supernatants after 30 minutes of settling decreased from 85 percent at a polymer dose of 5.26 mg/gm MLTSS to 50 percent at a dose of 7.25 mg/gm. Thus, the results of the zone settling assays confirmed the conclusions from the jar testing that the polymer selected (Nalco 627) would be effective at doses from 1 to 5 mg/gm MLTSS.

Pilot Plant Clarification Tests - The pilot plant clarification tests were conducted in two series of runs, the first series without polymer addition, the second series with polymer addition, in the developing of efficiency vs. loading relations for each operating mode. A summary of the results obtained in each series/run is presented in Table 5, and the relationships between solids removal efficiency and solids loading rate derived from these results are presented in Figure 10.

The information presented in Table 5 includes: run duration; average cumulative polymer dose; liquid and solids loading rates; and average MLTSS removal efficiency over the duration of the run. The average cumulative polymer dose reported in Table 5(Series II) is equal to the cumulative mass of polymer added per mass of MLTSS in the entire pilot plant system, averaged over the run duration; the actual rate of polymer dosing into the mixed liquor stream during the Series II runs was paced at from one to three mg polymer per gm of MLTSS transferred into the mix-head tank. The "overflow" liquid and solids loading rate data reported in Table 5 were calculated on the basis of the clarified effluent flow rate, and the "total" liquid and solids loading rate data were calculated using the sum of the clarified effluent and sludge recycle flow rates. The influent MLTSS concentrations averaged about 11,000 mg/l during the Series I runs and 14,000 mg/l during the Series II runs; the solids loading rates for each run were computed using the corresponding liquid loading rates and influent MLTSS concentrations as reported in Table 5.

Table 5. Summary of Results-Pilot Plant Clarification Tests

Series run	Run Duration (hours)	Average Cumulative Polymer Dose[a]	Liq Load Rates (cu m/da/sq m) Overflow basis	Total[b] basis	Sol Load Rate (kgMLTSS/da/sq m) Overflow basis	Total[b] basis	Influent MLTSS (mg/l)	Average MLTSS Removal Efficiency (%)
I-1	1.0	--	2.63	5.48	48.0	100.0	10,833	21.8
I-2	4.0	--	7.96	10.8	88.5	120.3	11,144	8.8
II-1	2.0	0.29	8.45	11.3	124	165	14,660	45.3
2	3.0	0.80	7.65	10.5	102	140	13,330	49.8
3	1.5	1.20	5.08	7.94	73.5	115	14,500	36.7
4	4.0	1.85	5.03	7.88	69.6	109	13,880	50.1
5	1.5	5.91	4.86	7.71	63.7	101	13,150	68.6

Notes: [a]Cumulative mass of polymer (Nalco 627) added per mass of MLTSS in pilot plant

[b]Based on overflow as clarified effluent plus sludge recycle flow

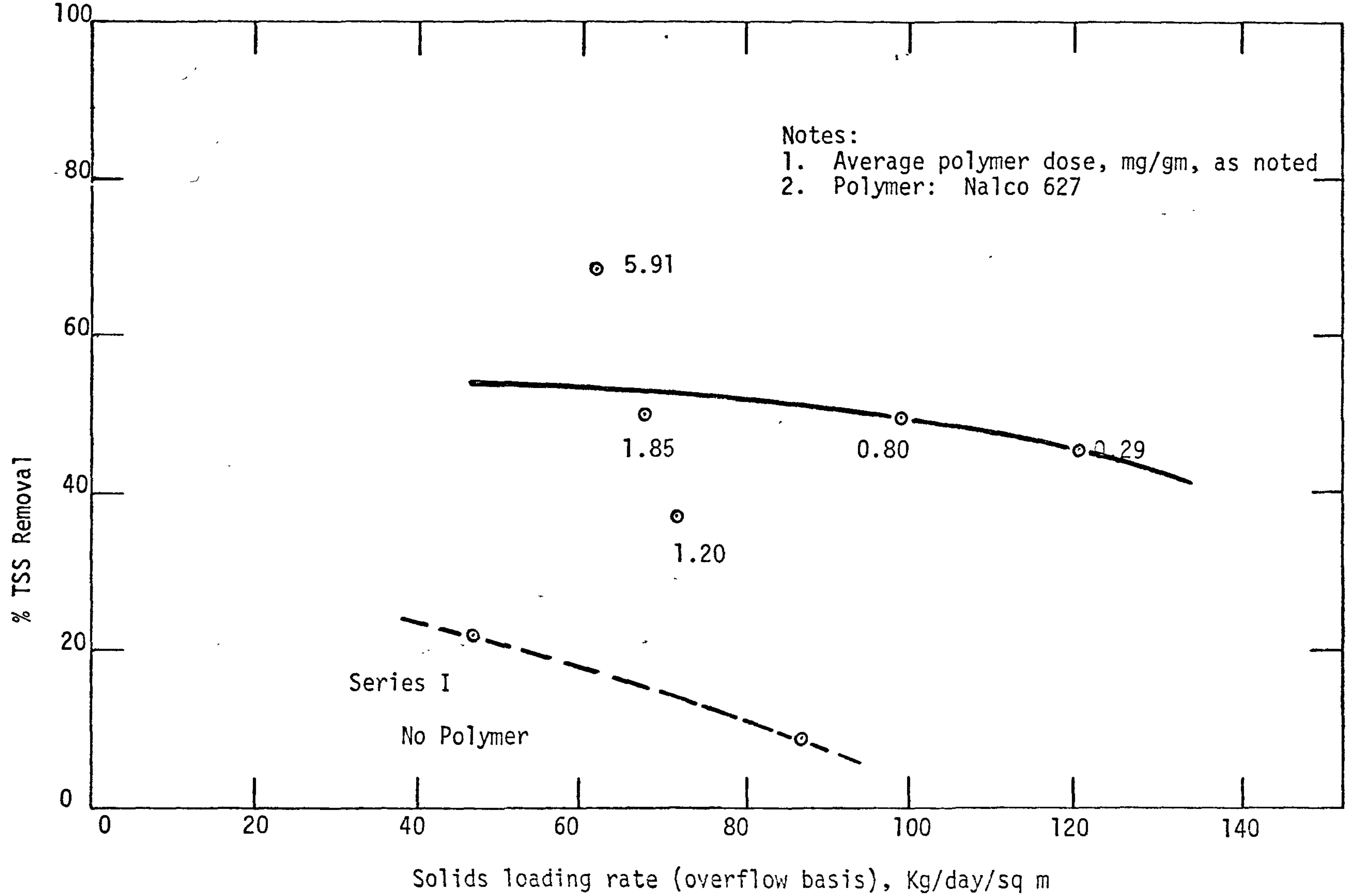


Figure 10. Relationship Between Solids Removal Efficiency and Solids Loading Rate (With and Without Polymer)

The effectiveness of the polymer addition in improving the settleability characteristics of the mixed liquor solids is evident from the relationships presented in Figure 10 for the Series I and II data. In the Series I relationship, the TSS removal efficiency decreased from 22 percent at a solids loading rate (overflow basis) of 48 kg/day/sq m (9.8 lbs/day/sq ft) to a level of 8 percent at a solids loading rate of 88.5 kg/day/sq m (18 lb/day/sq ft); i.e., the mixed liquor solids were effectively unsettleable at these solids loading rates. With polymer addition in the Series II runs, the TSS removal varied from an average of 52 percent at a solids loading rate of about 70 kg/day/sq m (14.3 kg/day/sq m) to 45 percent at 120 kg/day/sq m (24.6 lb/day/sq ft). The solids loading rates of 70 and 120 kg/day/sq m were equivalent to liquid loading rates (overflow basis) of 5 cu m/day/sq m (123 gpd/sq ft) and 8.4 cu m/day/sq m (205 gpd/sq ft) respectively. Additionally, at the solids loading rate of 70 kg/day/sq m, the TSS removal efficiency tended to increase with increasing cumulative polymer dose in the pilot plant system, varying from 37 percent at a cumulative dose of 1.2 mg/gm to nearly 70 percent at a cumulative dose of 5.9 mg/gm.

Based on the preceding observations, it is evident that polymer addition is a requisite for any full-scale application, and that the "residual" effect of the polymer recycled in the system (as measured in the present study by the average cumulative dose), was beneficial, within the range of average cumulative doses at which the tests were made, to the settleability of the mixed liquor solids.

A major equipment limitation in the pilot plant, which could not be resolved in the course of the pilot plant testing, was the clogging of several of the funnel weirs in the clarifier, the result of which was the availability of 0.32 m (1.05 ft) of the design weir length of 2.57 m. As a result, the weir loading rates varied from approximately 15 cu m/day/m (1,210 gpd/ft) to 26.4 cu m/day/m (2,120 gpd/ft) during the Series II runs. While these weir loading rates are low in comparison with the weir loading rates used in design of primary sedimentation tanks (greater than 50,000 gpd/ft), the malfunction of the funnel weirs disrupted the flow distribution pattern at the surface of the clarifier. Because of the short circuiting of the surface flow pattern in the clarifier, and the associated disuption of quiescent settling within the clarifier, it is anticipated that clarifier performance on a full-scale application can be increased at least 20 percent by the careful design of the flow pattern in the clarification units, and the use of weir loading rates of less than 12.4 cu m/day/m (1,000 gpd/ft).

A comparison can be made between the zone settling results and the pilot plant clarification tests by using the curve of Figure 9 to determine the allowable solids loading rate as the product of the allowable liquid loading rate and initial TSS concentrations. The allowable solids loading rate in the initial TSS concentration range of 10,000 to 14,000 mg/l, as determined from the zone settling results, is 239 to 302 kg/day/cu m (49 to 62 lbs/day/sq ft). Allowing a scaleup factor of 3 to 4 conservatively account for scaleup differences (hydrodynamics) between the laboratory apparatus and the pilot plant, then a comparability of clarification efficiency at the pilot scale would be expected at a pilot plant solids loading rate (overflow basis) of 80 to 100 kg/day/cu m (16.4 to 20.5 lbs/day/sq ft). Given the stability of pilot plant performance observed over this range of pilot plant solids loading rates (Figure 10), and in consideration of the above cited short circuiting problem in the pilot plant clarifier, the comparability of the zone settling results and the pilot plant results was reasonable. On this basis, it was concluded that, with a properly designed full-scale clarification unit, a clarification efficiency of 70 percent can be attained at a solids loading rate of 100 kg/day/sq m (20.5 lbs/day/sq ft), and, a weir loading rate of 12.4 cu m/day/m (1,000 gpd/ft) or less, with polymer doses in the range of 1 to 5 mg/gm MLTSS in the clarifier influent stream.

DESIGN AND OPERATIONAL ANALYSIS

The results of the bench and pilot studies and the process kinetic relationships were used in the selection and specification of a steady state operating region for the application, from which a process flow sheet and design criteria for the physical system were developed.

Steady-State Operating Region

The specification of a steady-state operating region requires (1) the selection of a desired effluent quality, (2) determination of the $\theta_t/C°$ value for this effluent quality from the relationship of Figure 8 (3) selection of a value of C° and the associated solids loading rate from the clarifier efficiency/loading relationships of Figure 10, and (4) calculation of the design θ_t value for the values of $\theta_t/C°$ specified and C° selected. The specification can then be completed using the above $\theta_t/C°$ values, the process kinetic constants, and the kinetic relationships presented earlier.

The selected treatment objective, i.e., the desired effluent quality in a full scale application, will vary with factors such as effluent standards, additional treatment required, existing facilities available, etc. The treatment objective selected as the basis for example process specification subsequently is a design effluent soluble COD concentration of 29 gm/l, for which a $\theta_t/C°$ value of 40 days is specified (Figure 8). This design "point" was selected because it represents the lower limit of the zone of transition in the operational relationship and because of the demonstrated stability of the anaerobic contact process at $\theta_t/C°$ values in excess of 35 days. A C° value of 0.375 (equivalent to a TSS removal efficiency of 62.5 percent), and a solids loading rate of 100 kg/day/sq m (approximately 20.5 lbs/day/sq ft) were selected as design values based on the pilot plant clarification testing results. For the selected values of $\theta_t/C°$ @ 40 days and C° @ 0.375, the required hydraulic residence time, θ_t, is 15 days.

In the specification of the steady-state operating region for the above conditions, the following relationships and parameter values were used:

- Ratio of effluent soluble COD: total COD concentration = 0.95
- Volatile fraction of MLTSS = 0.67
- Methane production factor=0.30 liter CH_4 per gm soluble COD removed
- Average methane content of gas stream = 60 percent
- Design influent COD concentration = 100 gm/l

Thus, for the selected design point:

- The required MLVSS concentration is equal to 6,915 mg/l, and the MLTSS concentration corresponding to this MLVSS concentration is equal to 10,320 mg/l.

- At the above MLVSS concentration, and a design hydraulic residence time of 15 days, the required MLVSS inventory is equal to 104 kg MLVSS per cu m/day of slops treated (865 lbs MLVSS per 1,000 gpd of slops heated).

- The rational organic loading rate is equal to 0.964 kg soluble COD/day/kg MLVSS, and the corresponding volumetric loading rate is equal to 6.67 kg/day/cu m (0.416 lb/day/cu ft).

- The methane gas production rate is estimated to be 21.3 cu m CH_4 per cu m of slops treated (2,850 cu ft CH_4 per 1,000 gal); for an average methane content of 60 percent in the gas stream, the gas production is equal to 35.5 cu m per cu m of slops treated (4,750 cu ft per 1,000 gal).

- The waste MLVSS production is equal to 2.60 kg per cu m of slops treated (21.7 lb/1,000 gal), and the waste MLTSS production is equal to 3.87 kg per cu m of slops treated (32.4 lb/1,000 gal).

- The clarifier liquid loading rate specified at a design solids loading rate of 100 kg MLTSS/day/sq m, and an influent MLTSS concentration of 10,320 mg/l, is 9.7 cu m/day/sq m (238 gpd/sq ft).

- At a C° value of 0.375 (design MLTSS removal efficiency of 62 1/2 percent), the estimated TSS concentration in the clarifier effluent is 3,870 mg/l.

From the perspective of operation of the anaerobic contact process in any of its three stages (startup, routine operation, and reinitialization), the common factors of concern are the operating objectives used and the environmental and control variables available to the operator in each stage. Because a common goal to each stage of operation is the attainment and/or sustenance of steady-state operation, the specification of operatinb objectives common to each stage can be done in consideration of the preceding analysis of the steady-state operating region.

As stated earlier, the only way that process control can be effected is by control of the viable biomass inventory in the system, and the single transferrable parameter specifying the viable biomass inventory in the system is $\theta_t/C°$. Thus, in the present case, the primary operating objective is the maintenance of a $\theta_t/C°$ value of 40 days at any point in any stage of operation, if the selected design effluent quality is to be maintained. To meet this objective requires, for a design C° value of 0.375, the attainment of an MLVSS inventory of 104 kg MLVSS per cu m/day of slops treated (865 lb MLVSS per 1,000 gpd) during startup, and the maintenance of this inventory during routine operation and reinitialization (should the latter be necessitated by seasonal production schedules). The secondary operating objective common to each stage is the provision of temperature, pH, and mixing at levels as specified below on the basis of operating experience:

- Temperature to be maintained at 35 $\pm$ 2°C.

- pH to be maintained at 7.2.

- Complete and continuous mixing; the capacity of gas mixing provided in the pilot plant system (0.15 cu m/min/cu m of mixed liquor, or 20 SCFM/1,000 gallons) was sufficient to accomplish this.

A final operating objective, common only to the startup and reinitialization stage, is the pacing of the rate of pretreated (neutralized, phosphorus-amended) raw slops at rational loading rates not to exceed 1 kg soluble COD/day/kg MLVSS until the required biomass inventory for the selected design point is attained in the fermenter.

Process Flow Sheet and Design Criteria

The process flow sheet and design criteria for full scale rum distillery slops treatment by the anaerobic contact process were developed in consideration of the preceding evaluations and the base of operating experience accrued during the investigation. The process flow sheet is presented in Figure 11, and the recommended design criteria are summarized in Table 6, and discussed below:

Unit Processes/Operations - The function of the slops storage tank is to provide equalizing of hour-to-hour flow variation, and to permit the cooling of the slops stream emanating from the distillation columns to a temperature of 32 to 38°C. The excess sensible heat in this tank can be used to maintain the digester temperatures at 35 $\pm$ 2°C, as an option to using a portion of the methane gas production for this purpose. A minimum storage capacity of one cu m per cu m/day of slops flow (1,000 gal per 1,000 gpd slops flow) is suggested, exclusive of situation-specific storage requirements for reinitialization should the latter be required.

The digester capacity required at the selected hydraulic residence time of 15 days is 15 cu m per cu m/day of flow (2,000 in ft per 1,000 gpd), and a minimum of two digesters should be provided for operational flexibility. The digesters should be heated to 35 $\pm$ 2°C. A gas mixing capacity of 0.15 cu m/min/cu m of digester volume (20 SCFM/1,000 gal) is suggested as a criterion for full scale design based on the satisfactory pilot plant experience at this level.

The clarifiers should be sized to provide for a solids loading rate of 100 kb/day/sq m (20.5 lbs/day/sq ft), which, at an MLTSS concentration of 10,320 mg/l, is equivalent to a liquid loading rate (overflow basis) of 9.69 cu m/day/sq m (238 gpd/sq ft). A recycle ratio of at least 2:1 (ratio of slops feed flow: sludge recycle flow) is recommended based on the experience of Steffen and Bedker (14) in a slaughterhouse waste/anaerobic contact process application; for a recycle ratio of 2:1, the TSS concentration in the recycle stream is equal to 13,550 mg/l, and the design liquid loading rate (total basis) is equal to 29 cu m/day/sq m (713 gpd/sq ft). A design weir loading rate not to exceed 12.4 cu m/day/m (1,000 gpd/sq ft) is recommended on the basis of pilot plant experience.

In the specification of criteria for the thickener, it was assumed that: the settled solids can be thickened at a loading rate of 122 kg/day/cu m (25 lbs dry solids/day/sq ft); and that the thickened sludge will have a dry solids concentration of 10 percent. These values were selected on the basis of design parameters typically associated with the thickening of primary sludges in municipal wastewater treatment plants.

The functions intended for the waste sludge storage are to (1) provide waste sludge storage for a reserve sludge quantity equal to one-third of the biomass

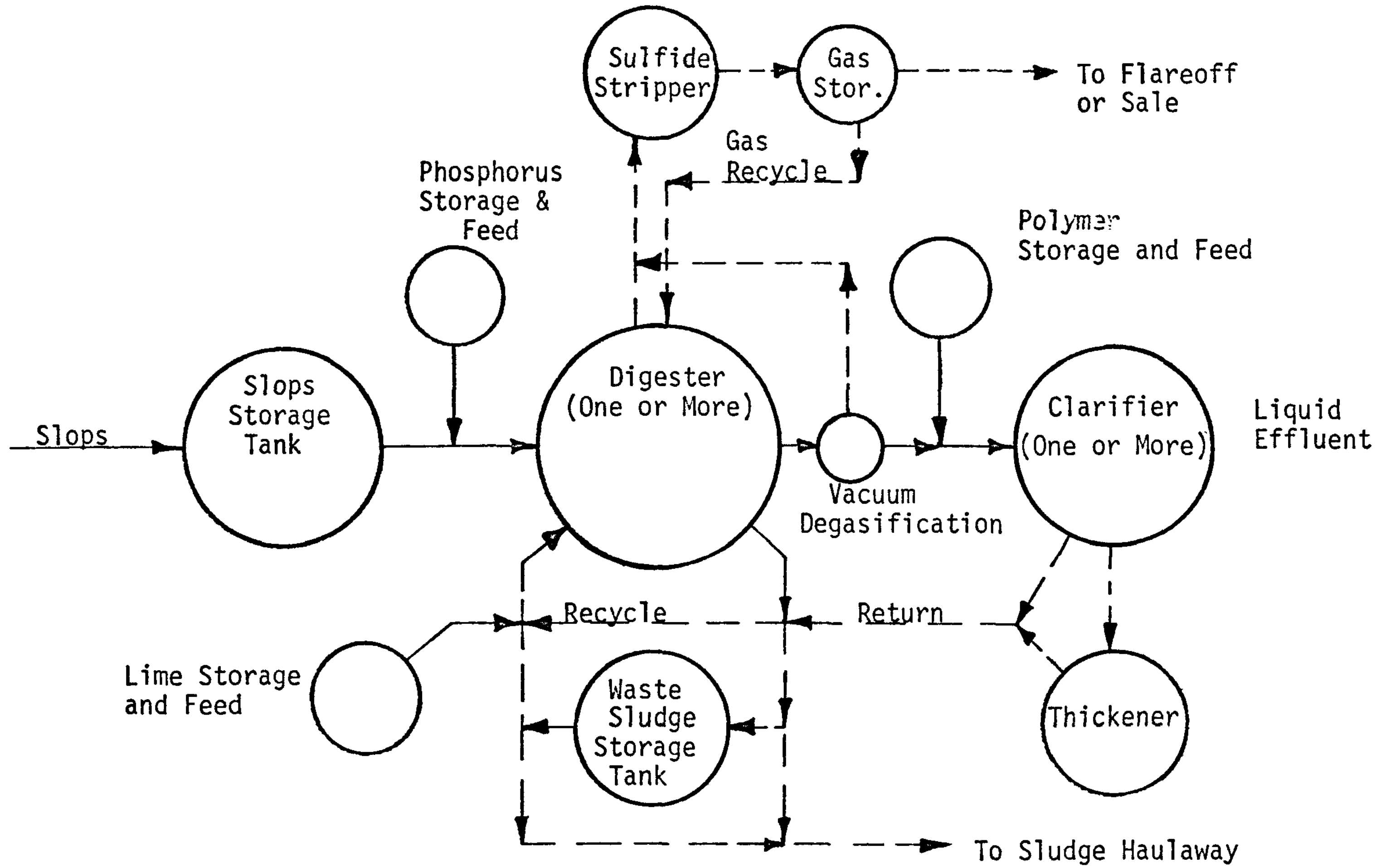


Figure 11. Process Flow Sheet - Rum Distillery Slops Treatment by Anaerobic Contact Process

Table 6. Design Criteria for Anaerobic Contact Process

Process Element	Recommended Design Criteria (Units as Noted)	
Slops storage tank	1 cu m per cu m/day slops flow	1,000 gal per 1,000 gpd slops flow
Digesters		
1. Capacity	15 cu m per cu m/day slops flow	2,000 cu ft per 1,000 gpd slops flow
2. Gas Mixing	0.15 cu m/min per cu m digester cap.	20 SCFM/1,000 gal digester volume
3. Heating	35 ± 2°C	95 ± 3°F
Clarifiers		
1. Liquid loading rate (overflow basis)	9.69 cu m/day/sq m	238 gpd/sq ft
2. Weir loading rate	12.4 cu m/day/m	1,000 gpd/ft
3. Recycle ratio	2:1	2:1
Waste sludge storage tank	0.52 cu m per cu m/day slops flow	70 cu ft per 1,000 gpd slops flow
Thickeners		
1. Dry solids loading rate	122 kg/day/sq m	25 lbs/day/sq ft
Gas handling system	36 cu m of gas per cu	4,750 cu ft of gas per 1,000 gpd slops flow
Sulfide Stripper	0.43 kg S per cu m/ day slops flow	3.6 lb S per 1,000 gpd slops flow
Chemical feed systems		
1. Lime	4 kg CaO per cu m/day of slops flow	33.3 lbs CaO per 1,000 gpd slops flow
2. Phosphorus	0.3 kg P per cu m/day slops flow	2.5 lbs P per 1,000 gpd slops flow
3. Polymer	15 gm per cu m/day slops flow	0.125 lb per 1,000 gpd slops flow

inventory in the digesters, to be available for transfer to the digesters as needed; and (2) to provide interim sludge storage prior to haulaway. The MLVSS biomass inventory required (104 kg MLVSS per cu m/day of slops heated), at a volatile fraction of 0.67, is equivalent to an MLTSS inventory of 155 kg MLTSS per cu m/day. For the storage of one third of this inventory in the waste sludge storage tank, at an average concentration of 10 percent solids, the storage capacity required is equal to 0.52 cu m per cu m/day of slops treated (70 cu ft/1,000 gpd). At a waste MLTSS production rate of 3.87 kg/day per cu m/day, the waste sludge storage capacity provided is sufficient to store 13 days of waste sludge production.

The gas handling system should be sized to handle 36 cu m of gas production per cu m/day of slops treated. Assuming that the gas stream contains 0.8 percent hydrogen sulfide by volume, then the sulfide stripper should be sized to handle 0.43 kg elemental sulfur per cu m/day of slops flow (3.6 lb per 1,000 gpd of slops flow).

Chemical feed systems are required for addition of lime, phosphorus and polymer; it is suggested that these systems be sized as follows

(1) Lime - feed at 4 kg as CaO per cu m/day of slops flow (33.3 lbs/1,000 gpd)

(2) Phosphorus - feed at 0.3 kg as P per cu m/day of slops flow (2.5 lbs as P/1,000 gpd)

(3) Polymer - feed at 15 gm polymer per cu m/day of slops flow (0.125 lb polymer per 1,000 gpd)

<u>Layout</u>

The layout as exemplified by the process flow sheet of Figure 11 incorporates the following material/liquid transfer capabilities:

- from either digester to another or the same digester,
- from the waste sludge storage tank to the digesters or to sludge haulaway,
- from the digesters to the clarifier,
- from the clarifier to the thickener, the waste sludge storage tank, and/or directly to the digesters

The above transfer capabilities are required to support the types of material/liquid transfers required in the operational phases discussed earlier.

ECONOMIC ANALYSIS

Estimates of capital and O/M (operating and maintenance costs) (January, 1974) for rum distillery slops treatment by the anaerobic contact process were developed at two design capacities, 190 cu m/day (50,000 gpd) and 1,140 cu m/day (300,000 gpd), respectively, using the design criteria of Table 6 and process flow sheet of Figure 11 as the costing basis. The heating requirements for the digesters at each design flow rate were then estimated in consideration of ambient conditions in Puerto Rico, wherein most of the North American rum distilling capacity is located, and the value of the energy available as methane byproduct (after digester heating requirements were deducted) was assumed to be equal to the cost of purchasing an equivalent amount of energy in the form of fuel oil. The cost estimates at each design flow rate were then converted to unit treatment costs ($/volume treated,) from which a cost capacity relationship, incorporating the value of the methane byproduct as a function of fuel oil price, was constructed.

Economic Value of Methane Production

The factors considered in determining the economic value of the methane production were:

- The gross methane production,
- The allocation required, from the gross methane production, to heat the digesters,
- The net methane production, i.e. the excess available after deduction of the digester heating requirement from the gross methane production.

The first step in the evaluation was the estimation of digester heating requirements at each scale. The requirements were estimated using the procedure of Babbitt and Baumann (15) and the following assumptions (assuming location of the facilities in Puerto Rico):

- Average ambient temperature: 21°C (70°F)
- Digester feed stream and sludge recycle stream temperatures: 27°C (80°F)

On this basis, the estimated BTU requirements for digester heating were: 2.45×10^9 BTU/year at the design capacity of 190 cu m/day; and 13.8×10^9 BTU/year at the design capacity of 1,140 cu m/day. Given that a barrel of fuel oil has a BTU equivalent of approximately 6,000,000 BTU's, the preceding BTU requirements for digester heating are equivalent to fuel oil consumption rates of: 408 bbl/year at a design capacity of 190 cu m/day; and 2,300 bbl/year at a design capacity of 1,140 cu m/day.

The fuel oil equivalent of the gross annual methane production was estimated using the following:

- The gross methane production factor of 21.3 cu m CH_4 per cu m slops treated (2,850 cu ft per 1,000 gallons treated).
- An energy equivalent of 1,000 BTU/cu ft of methane, or 5.90 bbl of fuel oil/1,000 cu m of methane (0.167 bbl of fuel oil/1,000 cu ft of methane).
- An assumed annual production schedule of 300 days.

For these conditions, the fuel oil equivalent of the gross annual methane production is 37.7 bbl/year per cu m/day of capacity (143 bbl/year per 1,000 gpd); i.e., is equal to 7,160 bbl/year at a design capacity of 190 cu m/day (50,000 gpd), and 42,900 bbl/year at design capacity of 1,140 cu m/day (300,000 gpd).

The allocation of gross methane production required for digester heating purposes can be evaluated by comparing the ratio of fuel oil equivalent consumption for digester heating with the above fuel oil equivalent production rates, at each design scale. This ratio is equal to 408/7, 160 (5.7 percent) at 190 cu m/day capacity, and 2,300/42,900 (5.4 percent at 1,140 cu m/day capacity). Thus, at either scale, less than six percent of the gross methane production must be allocated for digester heating, and the net methane production is equal to at least 94 percent of the gross methane production. At 94 percent, the fuel oil equivalent of the net methane production is equal to 35.4 bbl/year per 1,000 gpd). On a dollar basis, this fuel equivalent is worth $0.119 per cu m of slops treated ($0.45/1,000 gallons treated) for each $/bbl fuel oil cost on the open market.

TREATMENT COSTS

Annual treatment costs ($/cu m or $/1,000 gal of slops treated) were estimated on an unadjusted basis (assuming a fuel oil value of $0/bbl) and on an adjusted basis assuming fuel oil values up to $28/bbl. A summary of the unadjusted annual costs at each design flow rate is presented in Table 7. The capital and operating costs at each design scale reported therein were obtained from detailed cost estimates presented in the final project report (16). The amortization cost in Table 7 were developed assuming an interest rate of eight percent, a 15-year life for 40 percent of the capital investment, and a 25 year life for 60 percent of the capital investment.

The unadjusted total annual cost of the full scale applications is $212,800 at the design capacity of 190 cu m/day (50,000 gpd), and $726,500 at 1,140 cu m/day (300,000 gpd). For a 300 day production schedule, the unadjusted total annual costs are equivalent to unit treatment costs of: $3.74/cu m treated ($14.18/1,000 gallons treated) at the design capacity of 190 cu m/day; and $2.13/cu m treated ($8.07/1,000 gallons treated at the design capacity of 1,140 cu m/day.)

The unadjusted unit treatment cost data of Table 7 were used to construct the cost vs capacity curve of Figure 12 at the fuel oil value of $0/bbl. The adjusted unit treatment cost curves of Figure 12, at fuel oil prices of $4 to 28/bbl in $4/bbl increments, were developed by deducting $1.80/1,000 gallons treated for each $4 increment from the unadjusted costs, using the factor for value of fuel oil equivalent presented above.

The significance of design capacity and fuel oil price on the unit cost of rum distillery slops treatment by the anaerobic contact process are clearly evident from the cost curves of Figure 12. The unit treatment cost (in units of $/1,000 gallons treated) is $.80 less in a 100,000 gpd facility than in a 50,000 gpd facility and an additional $3.30 less in a 300,000 gpd facility than in a 100,000 gpd facility, for any given fuel oil price. If it is assumed (conservatively) that fuel oil prices will soon average $12/bbl, then the incorporation of methane byproduct recovery in a plant scale installation can reduce unit treatment costs from 35 percent (in a 50,000 gpd facility) to 65 percent (in a 300,000 gpd facility), as compared with unit treatment costs for installations without recovery.

CONCLUSIONS

The conclusions of the present investigation of rum distillery slops treatment by the anaerobic contact process are as follows:

1. Rum distillery slops are amenable to treatment by the anaerobic contact process.

2. The Monod model describes the response of the anaerobic contact process for the treatment of rum distillery slops even when engineering-type

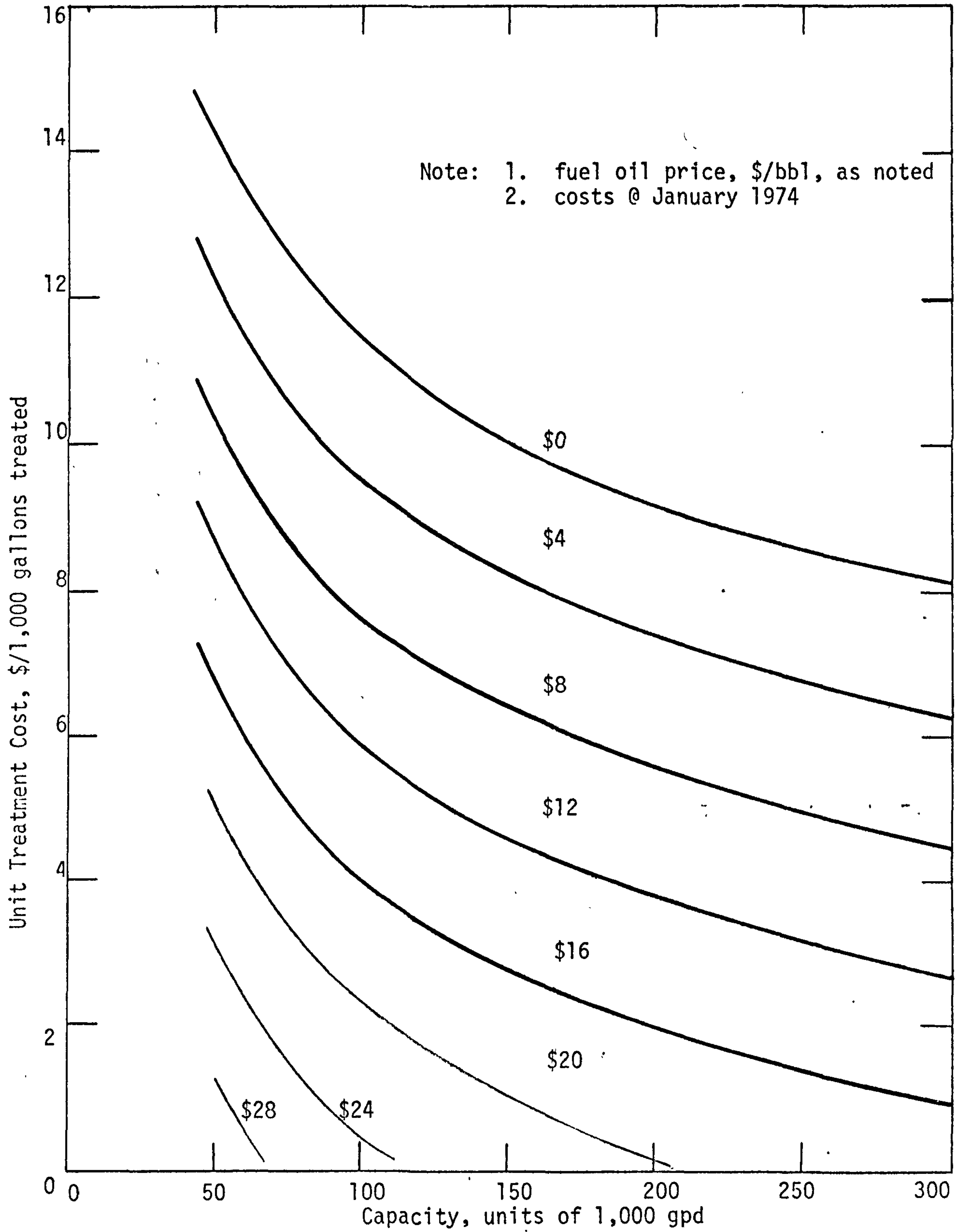
Table 7. Unadjusted Annual Costs for Rum Distillery Slops Treatment by Anaerobic Contact Process

Item	Capacity @ 190 cu m/day (50,000 gpd)	Capacity @ 1,140 cu m/day (300,000 gpd)
Capital costs	$1,683,200	$5,596,300
Annual costs ($/year)		
. Amortization[1]	173,269	576,083
. O/M costs	39,500	150,400
. Total annual cost[2]	212,769	726,483
Unit treatment costs		
. Per cu m treated	3.75	2.13
. Per 1,000 gallons treated	14.18	8.07

[1]Amortization at 8% interest rate; 15 year life for 40% of capital investment and 25 year life for 60% of capital investment

[2]Exclusive of methane credit

[3]Based on 300 day production schedule



'igure 12. Rum distillery slops treatment by anaerobic contact process unit treatment costs parameters such as VSS (volatile suspended solids) and COD (chemical oxygen demand) are used as measures of viable biomass and limiting substrate, respectively, and is a useful tool in engineering design and analysis of full scale applications.

3. The operational relationship between effluent quality and the primary variables θ_t (hydraulic residence time) and C° (recycle factor) provide a unifying basis for examining the design problem and establishing operating objectives in the application of the anaerobic contact process for treatment of rum distillery slops.

4. The recovery of methane as an energy byproduct of rum distillery slops treatment by the anaerobic treatment process can reduce the unit treatment costs ($/unit volume treated) in a plant scale installation, at current energy costs, by at least one third at a design capacity of 190 cu m/day (50,000 gpd) and as much as two thirds at a design capacity of 1,140 cu m/day (300,000 gpd).

ACKNOWLEDGEMENTS

This investigation was supported in part by Demonstration Grant S800935 from the Industrial Pollution Control Division of the United States Environmental Protection Agency. Mr. W. E. Paterson deserves special acknowledgement for his contributions to the project. Drs. A. D. Carr, J. F. Andrews, and Paul Smith served as project consultants. The assistance of John Stockton, T. J. Smith, and Eric W. Jerome, and the counsel of Dr. W. E. Gates are gratefully acknowledged, as is the participation and contributions of the U.S. EPA personnel, Messrs. H. G. Keeler, and K. A. Dostal.

NOMENCLATURE

K = a constant equivalent to the substrate concentration when $k = k^m/2$

K^D = specific autodestruction rate, $time^{-1}$

k = specific growth rate, $time^{-1}$

$Y°$ = mass of organisms produced/mass of substrate removed, mg/mg

$X°$ = concentration of organisms, mg/l

$X_o°$, $X_1°$, $X_2°$ = influent; reactor effluent, and separator effluent organism concentrations, mg/l, respectively

$X_w°$ = mass of organisms leaving system per unit time/total flow leaving system per unit time, mg/l

$X_R°$ = recycle stream (and sludge wastage stream) organism concentration, mg/l

$C°$ = recycle factor = $X_w°/X_1°$

X^N = concentration of controlling substrate, mg/l

X_o^N, X_1^N, X_2^N = influent, reactor effluent, and separator effluent substrate concentrations, mg/l, respectively

$X_R{}^N$ = recycle stream substrate concentration, mg/l

C'' = degree of concentration of substrate in the solids separator $= X_R{}^N/X_1{}^N)$

θ = time

θ_t = theoretical hydraulic detention time, time

Q = influent flow rate, 1/day

Q_s = sample flow rate, 1/day (average)

Q_w = sludge wastage flow rate, 1/day

r = fraction of influent recycled

REFERENCES

1. PETTET, A. E., TOMLINSON, T. G., and HEMENS, J. The treatment of strong organic wastes by anaerobic digestion. J. Institution of Public Health Engineers: 170 (1959).

2. HIATT, W. E., CARR, A. D., and ANDREWS, J. F. Anaerobic digestion of rum distillery wastes. 28th Purdue Industrial Conference: (1973).

3. STANDER, G. J. and SNYDERS, R. J. Institute of Sewage Purification IV: 447 (1950).

4. RADHAKRISHMAN, I., DE, S. B. and NATH, B. Evaluation of the loading parameters for anaerobic digestion of cane molasses distillery waste. J. Water Pollution Control Federation 41: R431 (1969).

5. BHASKARAN, T. R. Utilization of materials derived from treatment of wastes from molasses distilleries. Advances in Water Pollution Research, Pergamon Press, London, (1965).

6. JACKSON, C. J. J. Institute of Sewage Purification, Part III: 206 (1956).

7. MCCARTY, P. L. Discussion. J. Sanitary Eng. Div, Proc. American Society of Civil Engineers 89: SA6, 65 (1963).

8. GATES, W. E., SMITH, J. H., LIN S., and RIS, C. H. A rational model for the anaerobic contact process. J. Water Pollution Control Federation 39: 1951-70 (1967).

9. MONOD, J. The growth of bacterial cultures. Annual Rev. Microbiol. 3: 371 (1959).

10. Product Bulletin PC-627, Nalco Chemical Company, (1973).

11. SCHROEPFER, G. J. ET AL. The anaerobic contact process as applied to packinghouse wastes. Sewage and Industrial Wastes 27: 4, 460 (1955).

12. SCHROEPFER, G. J., and ZIEMKE, N. R. Development of the anaerobic contact process. I. Pilot Plant Investigations and Economics. Sewage and Industrial Wastes 31: 2, 164 (1959).

13. ANDREWS, J. D. and PEARSON, E. A. Kinetics and characteristics of volatile acid production in anaerobic fermentation processes. 55th National Meeting American Institute of Chemical Engineers (1965).

14. STEFFEN, A. J., and BEDKER, M. Operation of full scale anaerobic contact treatment plant for meat packing wastes. 16th Ind. Waste Conference (1961).

15. BABBITT, H. E., and BAUMAN, E. R. Sewage and Sewage Treatment. John Wiley and Sons, New York (1958).

16. SHEA, T. G. ET AL. Rum distillery slops treatment by anaerobic contact process. USEPA Project S800935, (1974)

GULF SHRIMP
CANNING PLANT WASTEWATER PROCESSING **

by
A. Frank Mauldin and A. J. Szabo *

INTRODUCTION

The canning of shrimp was first successfully done in 1867 by George W. Dunbar, an enterprising New Englander who settled in New Orleans and operated a cannery after the Civil War. From this difficult and trying beginning, an industry has developed which consists of approximately 70 shrimp canners in the United States, 25 of which are located on the coast of the Gulf of Mexico. The Gulf Coast Canneries are primarily in Louisiana and Mississippi on bays or bayous or within short trucking distance of the docks. These canning plants have for many years been and most remain family enterprises. The canneries compete for the available supplies of raw shrimp and generally obtain and process the smaller sizes. Therefore, the economical operating period is generally during the short spring and fall seasons when shrimp may be taken in the regulated coastal waters. Because of the controlled seasons, the variables of supply and the market price, the competition for the raw shrimp is great and no plant is assured that it will operate on a continuous schedule. Nevertheless, each plant which operates must be able to handle its perishable raw shrimp supply in a short time. Therefore, plants have developed along the same, most efficient mechanical operating basis. Most of the equipment is of the same or similar manufacture and the wastes created by the operating units have very similar characteristics.

Because of the high strength and relatively large volume of wastewater discharged by shrimp canneries, a joint effort at developing an economical pollution control technology through cooperative effort was aimed at accomplishing what many small canners could not individually achieve. The Environmental Protection Agency and the American Shrimp Canners Association, consisting of twenty-two member plants sponsored this study for this purpose.

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** This study was supported by funds from the Environmental Protection Agency, Office of Research and Development, under Grant No. S 800 904 and the American Shrimp Canners Association.

SHRIMP PROCESSING AND CANNING

The operations in a shrimp cannery are basically the same the world over, as shown in Figure 1 (1). Raw shrimp are first thoroughly washed and separated from debris or trash and unsuitable materials. The raw shrimp are peeled and deveined with mechanical devices developed especially for the shrimp industry. Heads and hulls are removed, pieces of shell and legs are separated and the remaining tail meat is separated from the waste.

Raw shrimp are mechanically peeled by Laitram Model A peelers. This machine removes the head and shell by mechanical and hydraulic action. It basically consists of inclined steel and rubber coated rollers which form a squeezing gap where the head and shell is loosened and removed from the shrimp meat. Water is used primarily to facilitate movement of the shrimp down the inclined rollers.

In the deveining operation the back of the shrimp is split by a unique razor edge device. The shrimp with the exposed vein then drops into a rotating drum with inside "fingers" which remove the vein. The veins are then washed out of the drum and are discharged with the wastewater. The deveining operation is generally not used on all shrimp processed but only on the larger sizes.

After deveining, the shrimp are pre-cooked or blanched for approximately 3 minutes in a boiling brine solution which curls the meat, extracts moisture and solubles and develops the pink or red color of the finished product. Blanching can either be a batch process, where the blanching water is dumped several times daily, or continuous, where the shrimp are fed through the tank on a conveyor and brine water is continuously added and washed from the tanks.

After cooling, drying, further inspection and grading, the shrimp are packed, on a scaled weight basis, into the appropriate size can, then mechanically sealed and retorted for 12 minutes at 250^{o} F. After cooling, the cans are labeled and are ready for shipment to market.

WASTEWATER CHARACTERISTICS

Table 1 shows BOD-5 and suspended solids characterization for the primary shrimp processing and canning operations. The peeling operation contributes approximately 70 % of these parameters to the total discharge. The miscellaneous operations include water flume dumps, canning, retort cooling and inspection. The BOD-5 concentration for the total discharge varies from 1,000 mg/l to 1800 mg/l and the suspended solids concentration for the total discharge varies from 400 mg/l to 800 mg/l.

Figure I (I)

GENERAL PROCESS SCHEMATIC
SHRIMP CANNING

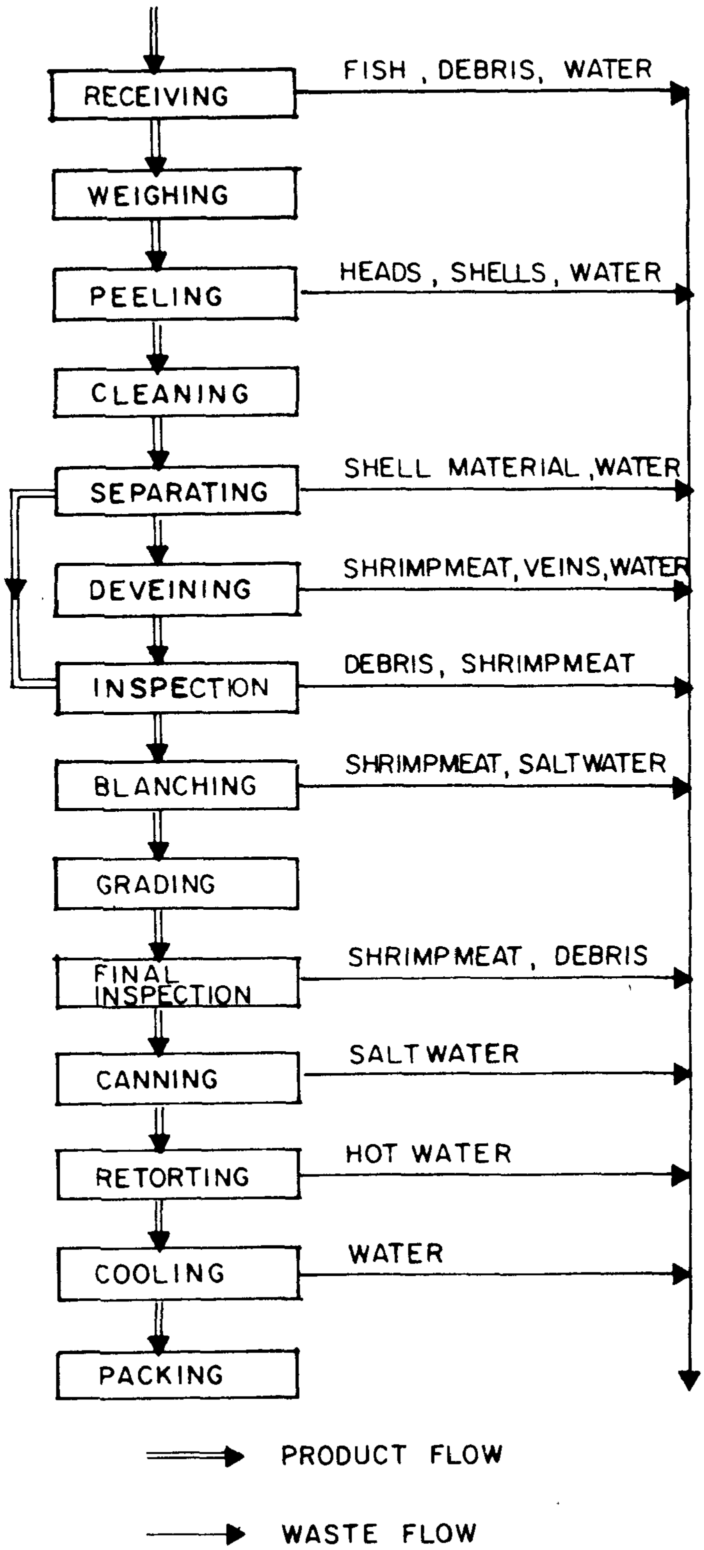


TABLE 1
WASTEWATER CHARACTERIZATION
SHRIMP PROCESSING AND CANNING

Plant Operation	BOD-5 lbs/100 lbs Shrimp	% Total Discharge	Suspended Solids lbs/100 lbs Shrimp	% Total Discharge
Peeling	4.89	72	2.63	68
Deveining	0.51	7	0.45	12
Blanching	0.15	2	0.19	5
Receiving & Raw Washing	0.66	10	0.25	6
Miscellaneous	0.62	9	0.35	9
Total Discharge Processing Only (No Washdown)	6.83	100	3.87	100

TREATMENT BY SCREENING

Several different screens were pilot tested during the study. The purpose of the screening tests was to evaluate the efficiency and ease of operation of the tested screens. Several of the larger canners had obtained experience in screening the shells and the heads from their peeler wastewater with vibrating screens. These screens operated satisfactorily but were expensive to purchase and maintain. It was felt that ease of operation and economical maintenance should be a prime consideration in evaluating the pilot screens.

The following screens were tested with raw peeler wastewaters:

1. Sweco "Vibro-Energy Separator".
2. Hydrocyclonics "Rotostrainer".
3. Bauer "Hydrasieve".
4. Dorr Oliver "DSM".
5. Hydrocyclonics "Hydroscreen".

A description and evaluation of each of these screens follows:

Sweco "Vibro-Energy Separator". This screen was 48" in diameter with a 20 mesh (approximately 0.84 mm opening) screen fabric. This screen was circular, mounted on coil springs, and wastewater enters from the top. The underflow passed through the screen and the screened solids were vibrated with a spiral rolling motion to the sides of the screen where they were discharged through two ports 180 degrees apart. The vibrations were caused by an electric motor whose shaft was eccentrically loaded. This screen was a permanent plant installation at the test cannery. Wastewater from eight peeling machines and four separators was lifted by centrifugal pumps to the screen. With eight peeling machines operating (the usual practice), the flow to the screen was approximately 500 gpm.

This screen was effective in removing suspended solids, approaching 40%. The screen was not the most effective for removing settleable solids; the removal was less than 60% leaving a mean settleable solids residual of approximately 20 ml/l in the underflow. BOD-5 and total solids removal appear to average at around 15% reduction. The screened solids were fairly dry with an average value of 84% moisture.

Hydrocyclonics "Rotostrainer". This screen had a diameter of 25 inches and a length of 24 inches. The pilot unit had a screen opening of 0.5 mm (32 mesh equivalent). The cylindrical screen had the appearance of a water well screen with a wedge wire grid. The unit was equipped with a weir influent box for even influent distribution to the screen. The water passed through the screen openings on the top of the screen, fell through the center of the cylinder and passed through the screen openings again on the bottom, thus backwashing any solids trapped in the screen. The solids were carried on the top surface of the screen to a scraper bar where the solids were removed.

The removal of suspended and settleable solids was somewhat less for this screen than for the vibrating screen even though the screen opening for the rotating screen (0.5 mm) was less than for the vibrating screen (0.84 mm). The screenings, at 22% dry solids were fairly dry.

Bauer "Hydrasieve". This pilot tangential screen was 18 inches wide and 33.5 inches high. The test screen was supplied with four different screen openings: 0.020 inches (32 mesh), 0.030 inches (22 mesh), 0.040 inches (16 mesh) and 0.060 inches (11 mesh).

This screen had a headbox and a weir for even influent distribution and for feeding the wastewater onto the screen tangentially. The screen bars were wedgewire and ran transverse across the screen. The wedgewire bars curved downward between the vertical supports to cause the flow to divide into separate streams between the vertical supports. The manufacturer claims this helps prevent clogging and blinding.

This screen was tested as a primary screen on raw peeler wastewater. All the screen openings available were tested at 50 gpm. The evaluation was limited, however, because only one short run was made with each screen opening. These results indicate that the 0.020 inch opening screen produced the best results. This size tended to blind fairly quickly with a slime build-up. This unit with a 0.030 inch (0.75 mm) opening screen performed excellently during the short test run. Residual settleable solids in the under-flow was only 14 ml/l. The other screen openings (1.0 mm and 0.5 mm) also performed without blinding problems but solids removal was inferior to the 0.75 mm opening screen. The screened solids were extremely wet upon leaving the screen but tended to gravity drain very quickly. The screenings were 92% moisture at the point of leaving the screen. This was due probably to a noticeable amount of water continuously trickling from the end of the screen. The test unit had been used at many locations and the seals between the sides of the wedge wire screen and frame were worn causing water to channel down the inside walls. This was probably the major cause of the wetness of the screenings solids.

Dorr-Oliver "DSM". This pilot tangential screen was 12 inches wide and approximately 6 feet tall. Test runs with screen openings of 0.020 inch, 0.030 inch and 0.040 inch were made. The velocity across the face of the screen was very fast. As a consequence, a slight blinding of the 0.020 inch screen caused a complete failure with water discharged over the end of the screen. With the 0.030 inch opening screen, residual settleable solids of only 13 ml/l in the underflow was found. The 0.040 inch opening had residual settleable solids of 18 ml/l. No indication of blinding was observed with these two screens. The screened material had approximately 82% moisture when leaving the screen.

Hydrocyclonics "Hydroscreen". This pilot tangential screen was also tested with raw peeler wastewater. This screen was similar in design to the Bauer screen. Several differences included: the screening surface was actually three separate screens, all at slightly different angles to the vertical; the influent weir did not direct the water tangentially to the screen but was actually a small jump; and the screening surface of the test unit was about one foot longer than the Bauer screen. This screen unit was apparently new and was in excellent condition.

The differences in the screen design were apparently significant. The residual settleable solids in the underflow was 22 ml/l. This was considerably higher than the Bauer screen. However, screenings contained approximately 18% dry solids when leaving the screen. This was due to the solids staying on the screen much longer, and no noticeable amount of water was discharged from the end of the screen. Only one test run was made with this screen, using a 0.020 inch screen opening and a flow of 50 gpm. No blinding problems were observed during the test run.

Figures 2 and 3 show a comparison of effluent and screenings quality with the above screens tested on raw peeler wastewater.

On screening peeling wastewaters, the investigators evaluations are:

> Of the three types of screens, the tangential screens produced the best and the poorest effluent as evaluated by residual settleable solids concentration in the effluent. The rotating screen produced the driest screenings and the vibrating screen performed midway to the other two types for both criteria.
>
> The tangential screens consumed no power, therefore, were best for this category. The vibrating screen was the poorest and the rotating screen was only slightly more power demanding than the tangential screens, because it was physically lower than the tangential screens and the pumping head required was lower.
>
> In ease of operation, the rotating screen was best. During a short evaluation it showed no tendency to blind or clog. The vibrating screen required a frequent water hosing and was midway in this category. The tangential screens required frequent hosing and periodic brushing with a steel brush.
>
> In anticipated operating cost, the rotating screen may be the best because maintenance should be minimal. The tangential screen would likewise rate high if equipped to provide maintenance from blinding in lieu of man power. The vibrating screen because of its mechanical nature is last because of expected high maintenance costs and the need for operating manpower.

PILOT SCREEN EVALUATION
WITH
PEELER WASTEWATER

Figure 2

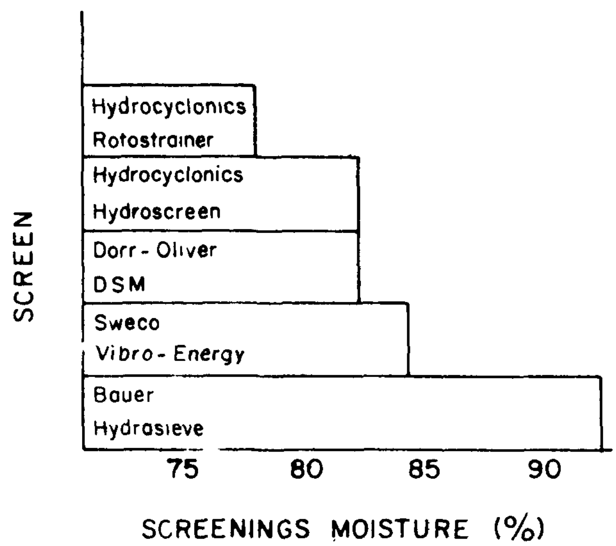
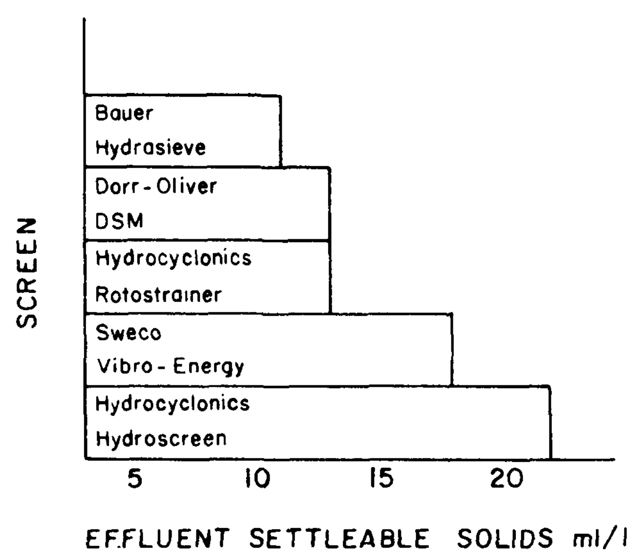


Figure 3



TREATMENT BY DISSOLVED AIR FLOTATION (DAF)

The DAF pilot plant evaluation was made during the fall, 1972 and the summer, 1973 canning seasons. Objectives were to intensely evaluate the operational variables of the DAF process while treating shrimp canning wastewaters. The ultimate objective of the pilot plant studies was to develop design criteria for full scale plant design.

The purpose of any DAF treatment system is to separate and concentrate suspended and colloidal particles in the feed wastewater. Larger particles of the settleable solids size should be removed prior to DAF treatment by screens and cyclones if high density particles are present. Separation of small suspended and colloidal solids depends more on their structure and surface properties than on their size and density. Therefore, DAF treatment plants can not be designed theoretically or rationally by mathematical equations, but must be planned by the use of laboratory (bench scale) and pilot scale studies. Factors of greatest importance in designing DAF plants are as follows (2):

1. Pressurization Piping (Full flow or recycle).
2. Chemical Optimization.
3. Air/solids Ratio.
4. Cell solids loading.
5. Sludge Concentration.

The selection of a pressurization piping mode for the pilot plant unit was one of the first major decision points that the investigators faced. Schematics of full flow pressurization DAF and recycle pressurization DAF are shown in Figures 4 and 5, respectively (3). The full flow pressurization system is a single pass system. The recycle is only for protection of the process pump during periods of low influent flow. The recycle pressurization system pressurizes only a recycle stream. The raw influent is fed to the flotation cell by gravity.

The full flow pressurization system offered the very large advantage of lower capital costs. The major disadvantage to this system, technically, was that any flocculation prior to pressurization would be sheared in the pressurization pump. All flocculation would then have to occur in a short period within the flotation cell and could result in immature floc and poor separation. If this occurred, then this type of system would not be suitable for treating shrimp canning wastewaters.

The recycle pressurization system had the reported disadvantage of high capital costs. Its advantage was that a floc could be preformed in a separate flocculation tank and be fed to the air flotation cell by gravity, thus preserving the fully matured floc. This would facilitate good separation of the floc from the remaining water.

Figure 4
FULL FLOW PRESSURIZATION
DISSOLVED AIR FLOTATION

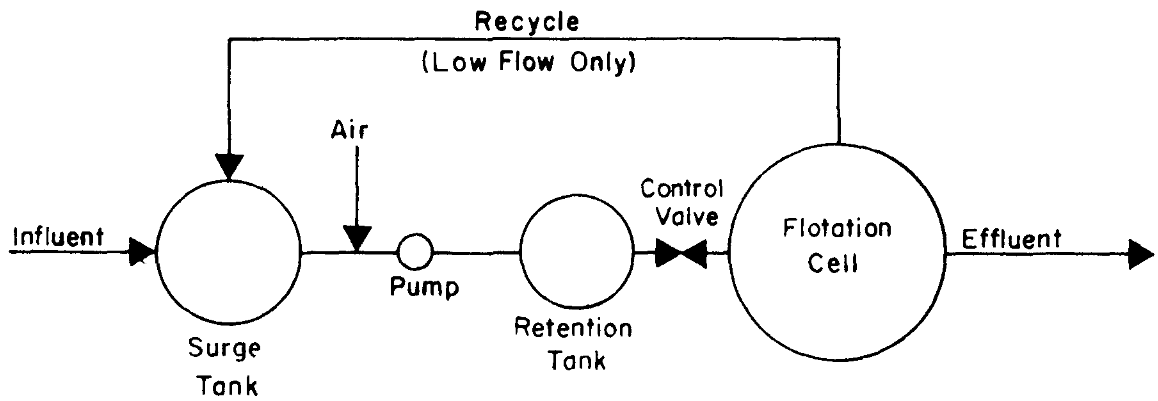
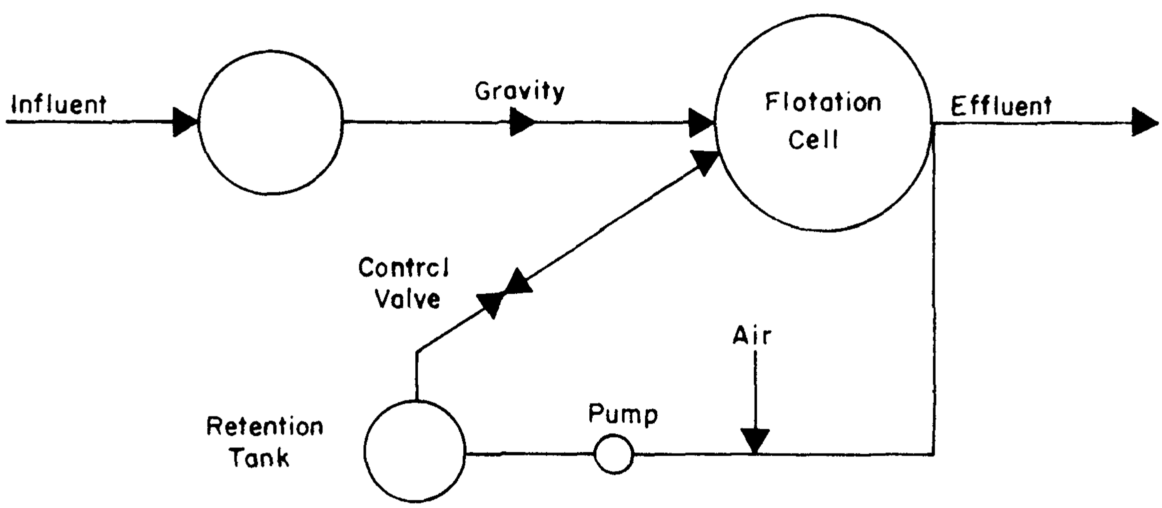


Figure 5
RECYCLE PRESSURIZATION
DISSOLVED AIR FLOTATION



Preliminary jar testing was performed at the study plant during the summer of 1972. A coagulant system consisting of pH adjustment, alum and anionic polymer was found to give an extremely tough, stable floc. The decision was then made to pilot test a total pressurization system for the first season and, if results were unacceptable, to then change to a recycle pressurization system.

A total pressurization DAF pilot system, shown in Figure 6, manufactured by the Carborundum Company was tested during the Fall, 1972 canning season. There was considerable lost time during this season because of mechanical problems, the investigators inexperience with the pilot test equipment and short canning runs. However, the test unit did show good potential, because when the proper controls could be maintained, very efficient treatment resulted. Because of the potential this unit demonstrated, it was decided to pilot test the unit a second season.

Bench scale jar tests and pressure bomb tests (2) were performed in the summer of 1972. Acid titration tests showed the protein isoelectric point to be about pH 4.5. The raw wastewater had a pH of about 6.9, therefore, pH adjustment was necessary for protein precipitation. Many combinations of coagulants, polymers and water conditioners were tried in the jar tests, but the best combination found was as follows:

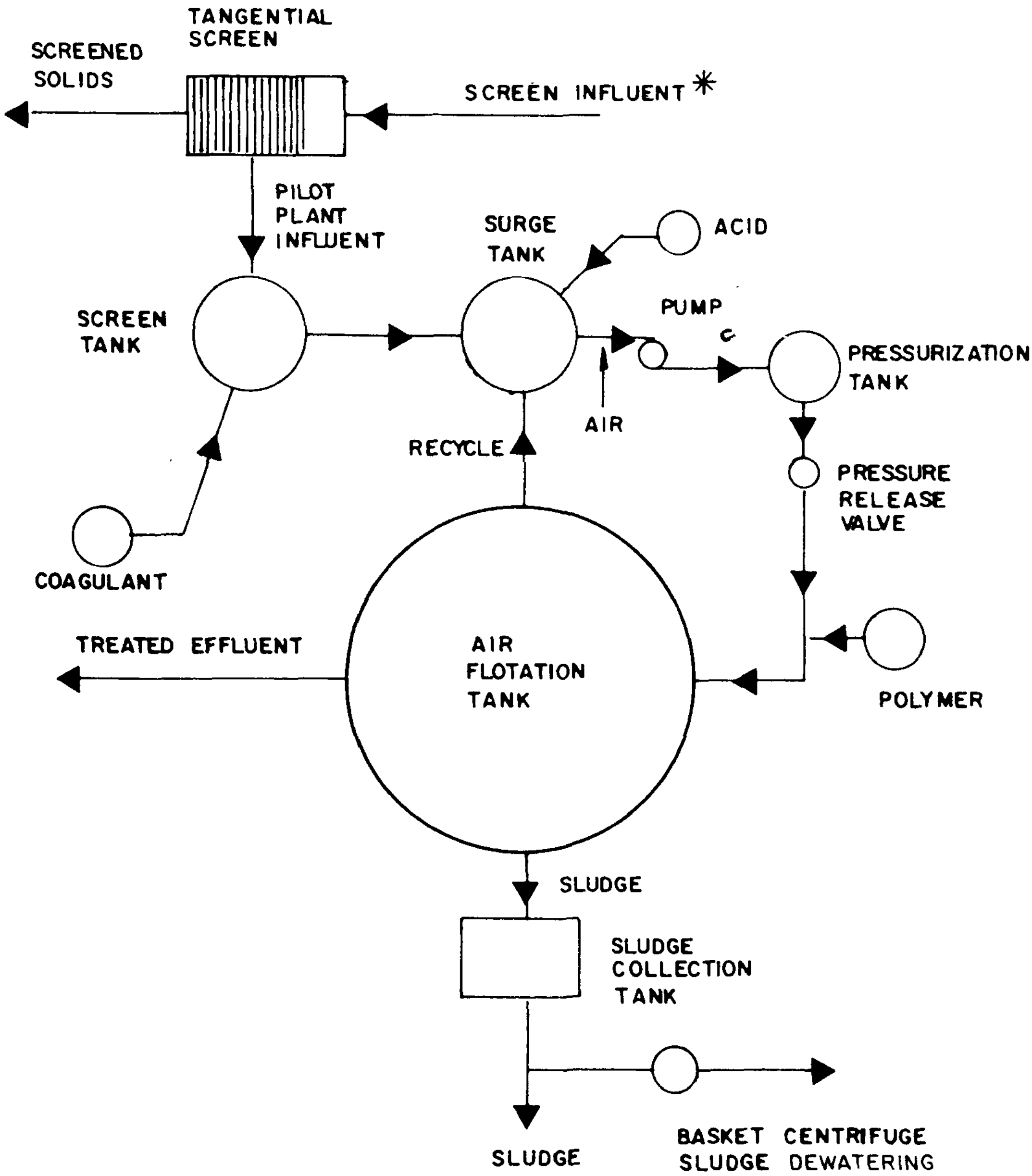
Coagulant: Aluminum sulfate - 75 mg/l
Polymer: Magnifloc 835 A - 2 mg/l
pH: 5.2 $\pm$ 0.2.

These chemicals and dosages were confirmed with the pilot unit to be optimum.

Floc carryover was a minor problem with the DAF unit during the testing period. There was no observable relationship between effluent COD and minor degrees of floc carryover. The minor floc carryover was probably an after-floc formed by inorganic non-COD demanding solids. The processing water used by the plant was high in chlorides (1000 mg/l). A major floc carryover problem was observed when runs were made with polymer dosages of less than 2.0 mg/l. This was in contradiction to the jar tests where good separations were made with lower polymer dosages. This probably demonstrates the economic trade off necessary when using a full pressurization system; capital costs will be lower but operating costs will probably be somewhat higher.

Several preliminary runs or parts of runs were made using no chemicals or pH adjustment but using air flotation only. The effluent was not tested because there was no observable treatment. The effluent appeared to be of exactly the same quality as the influent and the floated sludge was extremely light and bubbly. Very few captured solids were observed in this type of sludge. Flotation bomb bench scale tests were made with no chemicals but with full air. Virtually no reduction in TOC resulted. Runs were made with the DAF pilot plant with inefficient coagulant systems and virtually no removals of COD, turbidity or suspended solids occurred. These facts

Figure 6
DISSOLVED AIR FLOTATION PILOT PLANT SCHEMATIC



* RAW CANNERY WASTEWATER AFTER SCREENING THROUGH 20 MESH VIBRATING SCREEN

made it very clear to the investigators that an efficient coagulant system must be used if significant pollutant reductions are to be achieved.

Table 2 shows the average operating conditions for the pilot DAF testing and Table 3 shows the pollutant removal efficiencies for this testing. BOD-5 removals averaged 65% but had a range of 80 % to 50 % with suspended solids removal being about the same. The effluent during good runs was almost crystal clear with a turbidity of less than 20 units. The small amount of floc carryover that persisted caused this small amount of turbidity. The effluent was visually clear between floc particles. The effluent BOD-5 for good runs was below 400 mg/l, the effluent COD was below 1200 mg/l, the effluent suspended solids was below 100 mg/l and the effluent protein was below 600 mg/l. This range of results has generally been confirmed by Petersen (4) and Claggett (5 and 6) with shrimp and salmon wastes, respectively.

Three runs were made for the purpose of optimizing the cell solids loading rate. All of the runs were performed with optimum chemical dosages developed previously. Three runs were completed with influent flow rates of 25 gpm, 50 gpm and 75 gpm. The influent suspended solids concentration for each run was slightly different; therefore, flow and solids loading were not directly proportional. The results are shown in Figure 7.

From Figure 7 it appears that optimum cell solids loading was approximately 0.25 $lbs/hr./ft^2$ and for the particular pilot unit tested, the optimum influent flow was approximately 40 gpm.

Several values of air/solids ratios were computed from similar runs made during the testing program. The results of these computations are shown in Figure 8 where A/S ratios are plotted against removal of suspended solids. From Figure 8 it appears optimum A/S ratios are within the range of 0.10 and 0.15.

The concentration and flow rate of the flotation sludge was measured for most of the pilot runs. Mean results are shown in Table 4.

SLUDGE DEWATERING BY CENTRIFUGATION

The flotation sludge skimmed from the top of the DAF pilot plant was concentrated in a basket type pilot centrifuge manufactured by De Laval. The centrifuge had the following characteristics:

Method of Feed:	Batch
Feed Volume:	2.5 gallons
Basket Type:	Solid
Material Removal Method:	Skimmer

TABLE 2
DAF PILOT PLANT
AVERAGE OPERATING CONDITIONS

Flow:	50 gpm
Pressurization:	40 psig
Air/Solids	0.14
Cell Solids Loading:	0.33 $lbs/hr/ft^2$
Acid Addition:	Surge Tank
Alum Addition:	Screen Tank
Polymer Addition:	Flotation Cell Influent

TABLE 3
DAF PILOT PLANT EVALUATION
Pollutant Removal Efficiencies

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
BOD-5	65.1	80.0	50.0
COD	59.0	69.5	43.5
Total Solids	14.9	42.9	0.0
Suspended Solids	65.6	85.8	7.0
Protein	52.5	91.1	25.7
Turbidity	83.0	97.5	61.9
Ortho Phosphate	27.5	38.2	15.4
Total Organic Carbon	61.4	62.8	60.0

Figure 7
PILOT DAF PLANT EVALUATION
SOLIDS LOADING VS. TURBIDITY REMOVAL

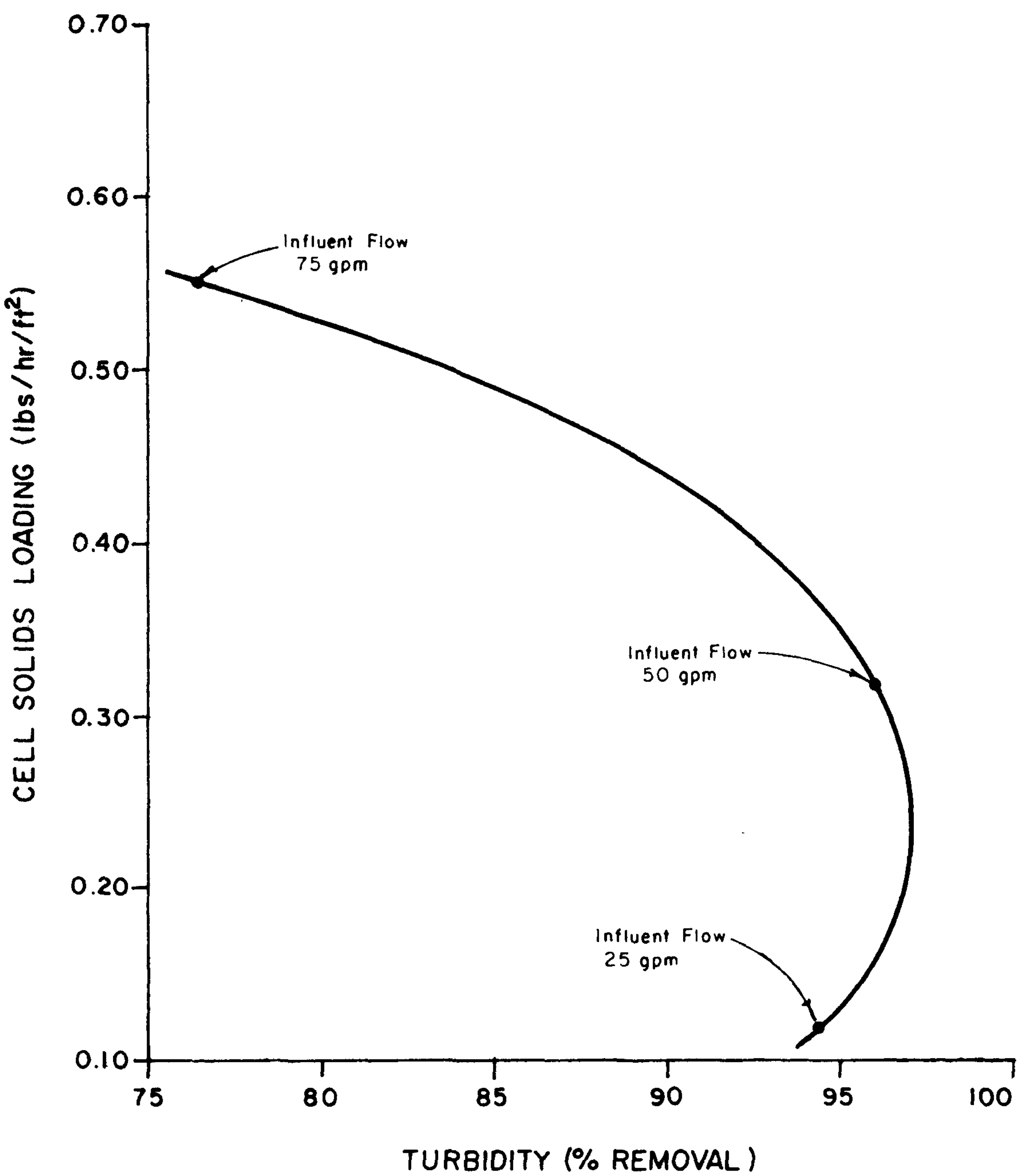


Figure 8
PILOT DAF PLANT EVALUATION
A/S RATIO VS. SUSPENDED SOLIDS REMOVAL

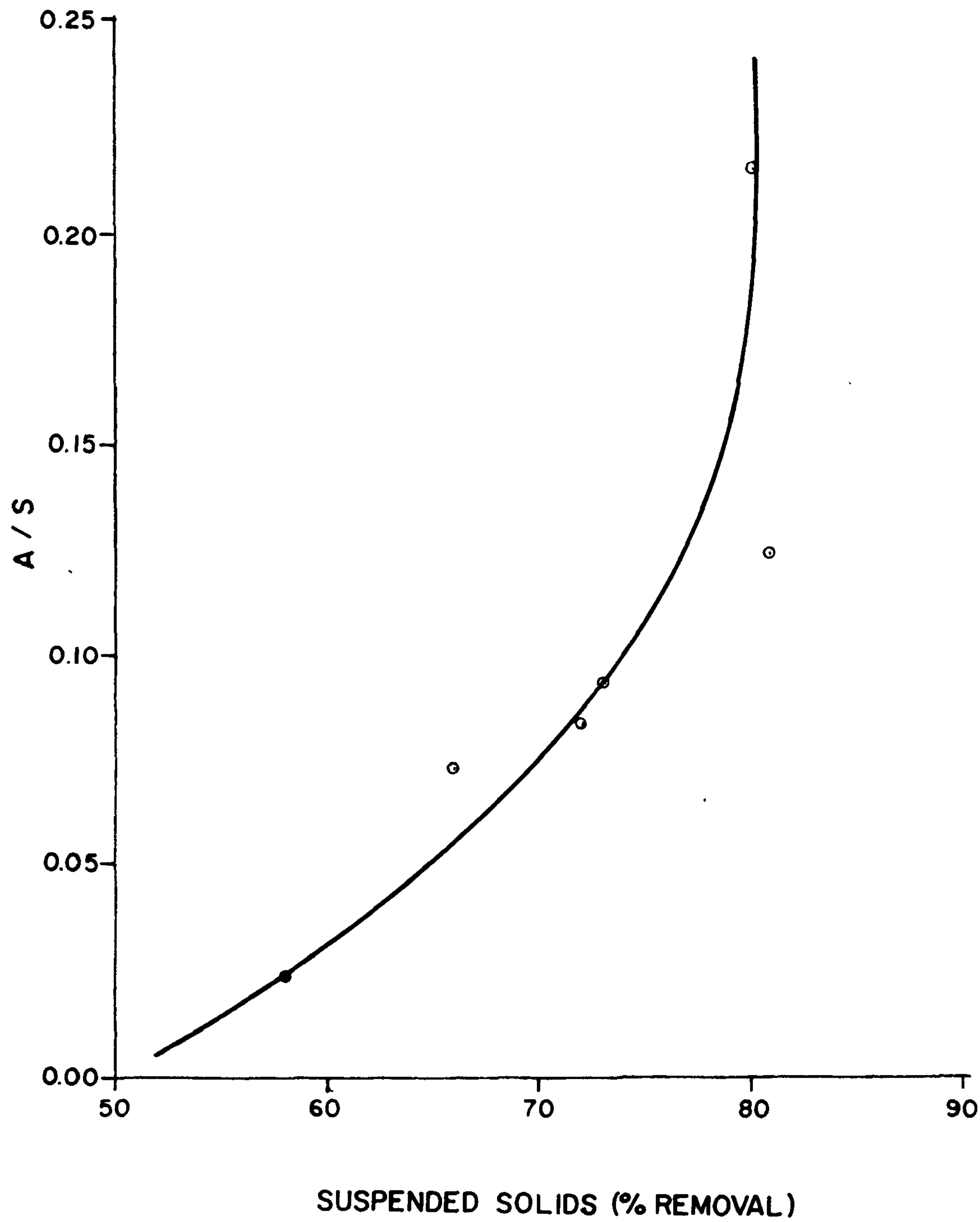


TABLE 4
DAF PILOT PLANT EVALUATION
Flotation Sludge Characteristics

Parameter	Units	Mean	Maximum	Minimum
Dry Solids	%	2.98	4.02	1.58
Flow	gpm	4.28	5.97	1.17
Protein	mg/l	15,819	26,318	6,963

TABLE 5
PILOT CENTRIFUGE EVALUATION
Mean Results

Parameter	Mean % Dry Solids	Mean Volume (gallons)
Feed Sludge	3.36	2.50
Centrifuge Cake	6.23	0.58
Centrate	1.05	0.98
Air	0.0	0.94

Average results obtained are shown in Table 5.

TREATMENT ECONOMICS

The total costs of wastewater treatment for seafood processors are difficult to present in general. Total costs involve the characteristics of the wastewater, plant piping, capital costs of equipment, operation and maintenance costs, administrative costs, engineering costs and the salaries of operating personnel. These costs can vary widely from plant to plant.

A cost of a waste treatment system for a hypothetical 8 peeler shrimp processing plant is presented here. The assumed wastewater flow is 600 gpm. Screenings and dewatered sludge are assumed hauled to a land fill.(The alternative to hauling would be a reduction plant where screenings and sludge would be dried and sold as by product waste meal. Because the capital and operating costs of a reduction plant are large and the market conditions for waste meal are very uncertain (7), this alternative has not been considered).

The treatment system consists of screening, dissolved air flotation, chemical addition system, sludge dewatering,centrifuge sludge and screenings holding tank, tank truck and all necessary pumps and conveyers. The operation and maintenance costs/day assume eight hours of processing and include chemical costs, power costs, a plant operator, a truck driver and a land fill fee.

The installed capital costs for the above described treatment system, the operation and maintenance costs/day and the amortized cost /day (assumed 10 year life, 7% cost of money and 120 days operation/year) are as follows:

Capital Costs -	$210,000.00
Operation and Maintenance Costs	$ 155.00/day
Amortized Costs	$ 280.00/day

REFERENCES

1. Soderquist, M. R., Canned and Preserved Fish and Seafoods Processing Industry Development Document for Effluent Limitations Guidelines and Standards of Performance, EPA. Contract No. 68-01-1526, July, 1973.

2. Eckenfelder, W. W., Jr., Industrial Water Pollution Control, McGraw-Hill, 1966.

3. Snider, Irvin, Corborundum Company, Knoxville, Tennessee, (Personal Communication).

4. Peterson, P. L., Treatment of Shellfish Processing Water by Screening and Air Flotation, (unpublished), National Marine Fisheries Services, Kodiak, Alaska, 1972.

5. Claggett, F. G., and Wong, J., Salmon Canning Wastewater Clarification, Part II. Fisheries Research Board of Canada, Vancouver Laboratory, British Columbia, February, 1969.

6. Claggett, F. G., and Wong, J., Salmon Canning Wastewater Clarification, Part I. Fisheries Research Board of Canada, Vancouver Laboratory, British Columbia, January, 1968.

7. Mendenhall, V., Utilization and Disposal of Crab and Shrimp Wastes, University of Alaska, Marine Advisory Bulletin No. 2. NTIS, COM-71-01092, March, 1971.

WASTEWATER CHARACTERIZATION FOR THE SPECIALTY FOOD INDUSTRY

by

Curtis J. Schmidt*, Ernest V. Clements III*, and John Farquhar**

INTRODUCTION

Specialty foods, as used in this project, includes frozen and canned items containing several major ingredients. Included are such varied products as frozen dinners, frozen and canned pre-cooked fish, beef, and poultry dishes, frozen and canned stews and soups, frozen or canned ethnic/nationality foods, frozen vegetables in sauce, frozen bakery products and other prepared and/or pre-cooked foods. Specialty food firms generally fall within SIC Codes 2032, 2035 and 2037.

The magnitude of this segment of the food industry is made obvious by a stroll through any supermarket: more shelf and freezer space is taken by specialty foods than by ordinary canned and frozen fruit and vegetable items. Exact production data on a national scale is lacking. However, combined statistical sources estimate that specialty foods production exceeds other types of food production.

The estimated number of specialty food plants is approximately 2,300 with the largest number in the states of California, New York, Illinois and Pennsylvania. Meat specialties has the largest number of individual plants among the categories.

During the second half of 1973 the American Frozen Food Institute (AFFI) conducted a study to characterize wastewater generation by the specialty food industry. AFFI was aided by the National Canners Association (NCA), which

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**The American Frozen Food Institute, Washington, D.C.

***This investigation was supported by funds from the Environmental Protection Agency, Office of Research and Development, under Grant No. R-801684, and by the American Frozen Food Institute, Washington, D.C.

performed all laboratory analyses, and SCS Engineers (SCS), which performed all field work and prepared the final report. Financial assistance was provided by the Environmental Protection Agency (EPA) under Grant No. R-801684.

The major objectives of the project were to:

- Inventory and categorize the specialty foods industry.
- Investigate typical raw waste loads generated by major categories of the specialty foods industry.

This information is needed by AFFI, NCA and EPA to increase their background knowledge in answering questions concerning waste generated by the specialty food industry and to regulate industry waste generation in an equitable manner.

FIELD INVESTIGATIONS

A preliminary assessment of the types, number and locations of specialty food plants was prepared, and a tentative determination made of representative plants in the west, midwest, and east which appeared to be desirable candidates for field investigation. Each candidate plant was contacted by phone and letter, given a description of the project, and requested to indicate a preliminary assurance of cooperation. A series of meetings were arranged by AFFI in San Francisco, Chicago, and Washington, D.C. at which the project technical team met with company representatives to work out details of individual plant investigations. Every attempt was made to insure that the participating industry plants were cognizant of their responsibilities to the project. The final selection of participating plants was made to provide diversity in type of product and geographical area. The plants were located as follows:

East		6 plants
Midwest	-	9 plants
West		11 plants

During the field investigations, the procedure followed at each plant was generally similar. Once plants in the same geographic region had agreed to participate, the project technical director visited each plant to review the plant layout; determine a proper location for installation of a composite sampler; initially educate plant personnel in their responsibilities to extract and store samples; advise the necessity for obtaining concurrent information on production and wate volume; observe waste treatment facilities, and agree upon a date to begin waste sampling. On the agreed date, the field engineer installed the automatic sampling unit at a site pre-selected by the project director and plant staff. The sampling sites were located to obtain representative samples of screened raw waste prior to pretreatment units. Areas of turbulence were chosen to insure mixing and suspension of solids. Once the engineer had installed the sampler, he instructed the plant personnel in proper sampler operation and sample handling. In most cases this involved merely turning the unit on and off at the beginning and end of shifts, filling a sample bottle from the large 2-1/2 gallon sample collection container, after swirling the latter to achieve a homogeneous wastewater solution, and placing the sample in the Coleman cooler in the plant freezer. The engineer also advised plant managers as to what supplemental data would be needed on production tonnages and wastewater volumes and urged them to compile this information during the sampling period.

During the sampling period, the investigator returned to the plant every 3 or 4 days to insure proper operation and to pick up frozen samples. These samples were packed in dry ice in the styrofoam lined boxes and transported by the quickest means to the NCA Laboratory in Berkeley, California. Most of the samples were shipped air freight to San Francisco for pickup by the laboratory. Samples collected from plants in northern California were delivered by car to the laboratory the same day.

At the end of the sampling period, the engineer picked up the last of the frozen samples, shipped them to the lab, and acquired whatever volume and production data was available at that time.

Sampling frequency, type, and procedures were somewhat dependent upon circumstances found at each plant. Approximately ten "end of pipe" time interval composite samples for ten consecutive operating days were collected at each plant. These samples were generally 24 hour composites, but exceptions were made due to plant operation or collection time requirements. If distinct "processing" and "clean-up" shifts existed, samples of each shift were taken along with related wastewater volume data. At two of the plants additional grab samples were taken of major waste streams (i.e., sauce room clean-up). Some food plants investigated had their own permanent automatic sampler. In these situations, the field engineer supplied the sample bottles, and storage cooler. Plant personnel took their routine composite samples and divided the sample for use by this study, and for their own analysis work.

ANALYSIS

Field determination was made of pH, temperature, volume (existing records and metering devices) and any unusual visual characteristics of the waste. Laboratory analysis included chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD), suspended solids (SS), volatile suspended solids (VSS), total kjeldahl nitrogen (TKN) as mg/l N, total phosphorus (TP), and oil and grease.

When shipments of samples arrived at the NCA lab, they were kept frozen until lab analysis was to begin. Samples were analyzed for the following constituents using the standard procedures listed below:

Test	Procedure
COD	Standard methods (13th edition)
BOD	Standard methods: 5-day, 20°C, cylinder dilution procedure.
SS	Standard methods using glass fiber filter paper.
VSS	Standard methods.
Total P	From Methods for Chemical Analysis of Waste and Water, EPA, 1971, 16020 -- 07/71.
TKN	Standard methods.
Grease and oil	From Methods for Chemical Analysis of Waste and Water, EPA, 1971, 16020 -- 07/71.

Two of the 26 plants studied were not sampled, but provided comprehensive historical information on wastewater concentrations, volumes, and production weights. Productivity factors were calculated from this data just as it was for the other plants.

APPROACH TO CATEGORIZATION

Categorization of the specialty foods industry is made complex by the great number of plants and wide diversity of products. In addition, many plants make several products and it is virtually impossible to relate wastewater characteristics back to a certain product because a variety of products are processed simultaneously and the mix is often continually changing. Another hindrance to categorization is the fact that although two plants may produce virtually the same final products, one may employ more intensive raw material processing than the other, and thus their wastewater properties could vary significantly. Moisture content of products can vary between product styles, affecting productivity factors based on final product weight.

Other factors which may have a significant effect upon wastewater generation from a particular plant include, plant size, number of shifts, percentage of production capacity in use, cost of water supply and wastewater disposal, degree to which ingredients have been pre-processed elsewhere, managements desire to reduce waste generation, and economic ability of the plant to modernize equipment.

Each of the factors described above may have an important effect upon waste generation from a particular plant. This study obtained data from an average of less than three plants per category. Considering the many uncontrollable variables involved and the limited number of plants investigated, the category selections and wastewater characteristics presented in this report should be considered as preliminary.

In order to obtain the most equitable categorization, within the bounds of the scope of work, we based our decisions for plant groupings on three basic factors:

- Primarily: Type of product.
- Secondarily: a) Type and degree of raw material processing, b) wastewater productivity factors (kg pollutant/kkg product).

The advantages of this approach to industrial categorization are as follows:

- Simplicity and ease of initial categorization - rough grouping by "type of final product" is a comparatively simple task and provides a point of departure for more detailed analysis. After "product" grouping, processing differences or wastewater characteristics can be reviewed to further substantiate categorial selections or to reclassify the plants that appear misplaced.
- Provides easy comparison to other plants - grouping by product allows members of the specialty food industry to compare their overall plant wastewater

characteristics to similar plants preparing the same same products.

- Good probability of similarity in other parameters-plants initially grouped by product type frequently show good correlation in overall wastewater properties (concentrations, volume per unit product, etc.) if similar raw ingredient processing operations are performed.

In full recognition of the difficulties involved in categorizing a complex industry of over 2,000 plants, the following ten categories were established for the purpose of this investigation.

1. Prepared dinners
2. Frozen bakery products
3. Dressings, sauces and spreads
4. Meat specialties
5. Canned soups and baby foods
6. Tomato-cheese-starch combinations (Italian specialties)
7. Sauced vegetables
8. Sweet syrups, jams and jellies
9. Chinese and Mexican foods
10. Breaded frozen products

On the following pages we discuss the results of the field analyses performed at plants in each of the above categories. Note that in many of the categories only one or two plants were investigated. Table 1 on the following page summarizes the average values for BOD, SS and volume.

Table 1. AVERAGE POLLUTANT CONCENTRATIONS, WEIGHTS PER UNIT PRODUCTION, AND WASTEWATER GENERATION BY CATEGORY

Category	BOD		SS		
	Ave. conc. (mg/l)	Wt. per unit production (kg/kkg)	Ave. conc. (mg/l)	Wt. per unit production (kg/kkg)	Wastewater volume per unit production (l/kkg)
1	1,900	17	1,500	14	12,000
2	3,200	23	2,200	14	11,000
3	2,600	7.5	1,200	3.5	2,800
4	820	9.5	460	6.1	10,000
5	560	12	320	7.6	22,000
6	370	7.2	220	6.0	29,000
7	310	25	250	21	85,000
8	2,400	5.1	400	1.0	2,400
9	570	6.9	200	2.8	14,000
10	2,400	26	3,700	26	48,000

Category 1 - Prepared Dinners

Plant letter codes included in this category are A, B, C, D, E, and F. The major products of this category are frozen prepared dinners and pot pies including meat, poultry or fish, vegetable, and starch (potato, rice, noodles). Plant A produces significant frozen bakery products and Plant E significant vegetable dishes in addition to prepared dinners.

The plants in this category do very little processing of raw materials. The meat portions have been slaughtered and dressed elsewhere, and the vegetables have also generally been pre-processed elsewhere and shipped frozen in bulk. The ingredients are usually cut into meal size portions, cooked, assembled and frozen. Figure 1 on the following page illustrates in a simplified flow diagram the "assembly plant" nature of plants in this category.

The primary wastewater generating activity is plant clean-up, which is generally concentrated during a late night or early morning "clean-up" shift. However, cleaning of equipment is carried out continuously as the product mix changes or spills occur. Other wastewater sources may include, vegetable rinsing and blanching operations, frying, cooking, and cooling water.

This category was the most thoroughly covered of the ten categories with six plants investigated. The plants are usually very large, and are often located in small towns or in rural areas where their wastes may constitute a significant potential treatment problem.

Tables 2 and 3 show the waste generation and waste strength of the effluents from plants in this category. BOD generation ranges from 9 to 34 kilograms per 1,000 kilograms (kg/kkg) or 18 to 68 lbs/ton of production. Waste strength varies from 600 to 4,000 milligrams per liter (mg/l) of BOD. We believe that the highest levels represent plants which (1) produce a higher proportion of rich foods and/or (2) have not instituted a rigid in-plant program to avoid excessive disposal of food materials into the sewer. Plant E, for example, claims to have greatly reduced its waste generation through a comprehensive program of personnel education and in-plant modifications.

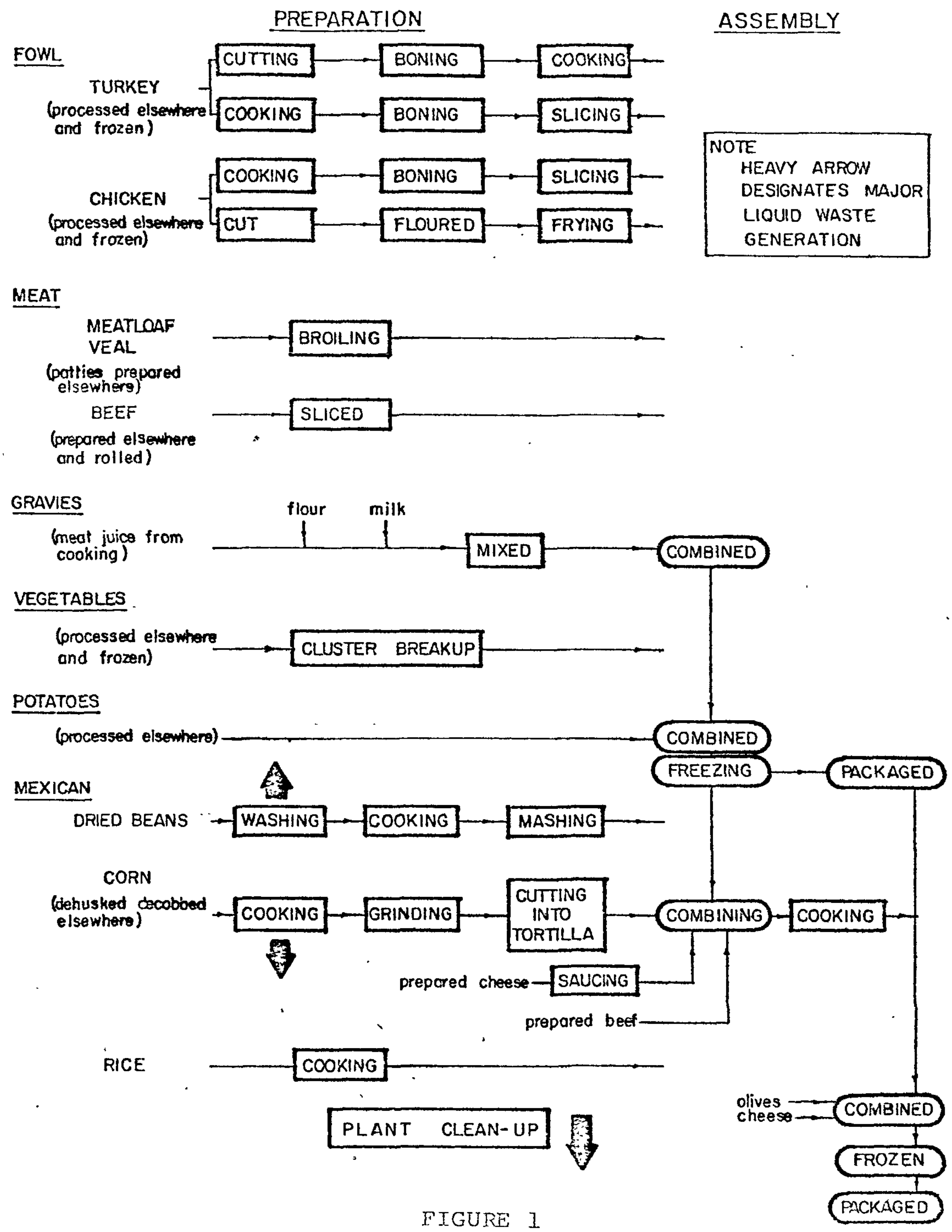

FIGURE 1

PREPARED DINNER PLANT
SIMPLIFIED PROCESS FLOW DIAGRAM

Table 2. CATEGORY 1, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
A	69	35	34	33	0.25	0.44	44	8,700
B	42	18	11	11	0.18	0.25	21	6,200
C	28	13	11	11	0.24	0.61	-	22,000
D	27	15	14	14	0.16	0.55	2.9	21,000
E	20	11	6.6	6.0	-	-	3.8	9,400
F	17	8.8	6.2	6.2	0.12	0.37	4.8	4,400
Average	34	17	14	14	0.19	0.44	15	12,000
Range	17- 69	9- 34	6- 34	6- 33	.12- .25	.25- .61	2.9- 44	4,400- 22,000

Table 3. CATEGORY 1, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
A	7,900	4,000	3,900	3,800	29	51	5,100
B	6,800	2,900	1,800	1,700	30	34	3,400
C	1,300	620	530	510	11	28	-
D	1,300	720	680	650	7.6	26	140
E	2,100	1,240	700	640	-	-	400
F	3,800	2,000	1,400	1,400	28	85	1,100
Average	3,900	1,900	1,500	1,500	21	45	2,000
Range	1,300- 7,900	620- 4,000	530- 3,900	510- 3,800	7.6- 30	26- 85	140- 5,100

Category 2 - Frozen Bakery Products

Plant letter codes included in this category are G and H. The major products of this category are frozen bakery dessert products such as cakes, pies, brownies, cookies, rolls, and other desserts.

The plants are very large scale kitchens which purchase the ingredients such as butter, flour, shortening, eggs, sugar, flavoring, fruit filling, etc., in much the same way as the housewife would were she making the baked goods from scratch. Plants G and H are both major producers of these products with national distribution.

Tables 4 and 5 summarize the waste generation and waste strength of the effluents from the two bakery products plants. Waste strength is very high with BOD in the range of 2,100 to 4,300 mg/l. Unfortunately, Plant H would not provide production information, making it impossible to determine the average pollutants per unit of production for this plant.

Table 4. CATEGORY 2, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
G	52	23	14	14	0.082	0.30	11	11,000
H	No Production Information Provided							

Waste is generated from clean-up of spills and equipment and from the disposal of substandard ingredients and products. The major ingredients are very rich and high in BOD, suspended solids, and grease. Variations in frequency of product mix changes and house cleaning practices help to account for differences in effluent concentrations.

Table 5. CATEGORY 2, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
G	4,600	2,100	1,300	1,200	7.8	27	940
H	9,300	4,300	3,100	3,000	5.7	45	690
Average	7,000	3,200	2,200	2,100	6.8	36	820

Category 3 - Dressing, Sauces, and Spreads

Plant codes I and J are included in this category. Major products are salad dressings, mayonnaise, mustard and barbecue sauces. Typical ingredients include tomato paste, vegetable oil, spices, eggs, vinegar, mustard, and small quantities of dairy products. Generally, the ingredients are blended, bottled, cooked, and cooled. Clean-up of the blending and cooking vats contributes most of the waste load.

The two plants sampled were a very small batch type plant (J) and one of the nation's largest plants (I). As seen from Tables 6 and 7 corrolation was surprisingly good between the plants. Both exhibited very strong wastes with average BOD of 2,700 mg/l, however, waste generation in terms of production averaged a low 8 kg/kkg (16 lb/ton) of product. Wastewater volume averaged only 2,800 l/kkg (680 gal/ton) of product.

Table 6. CATEGORY 3, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
I	12	5.6	2.6	2.4	0.039	0.036	3.1	2,600
J	14	9.4	4.4	4.4	0.018	0.038	8.3	3,100
Average	13	7.5	3.5	3.4	0.028	0.037	5.7	2,800

Table 7. CATEGORY 3, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
I	4,900	2,300	1,000	960	16	15	1,300
J	4,500	3,000	1,400	1,400	5.8	12	2,700
Average	4,700	2,600	1,200	1,200	11	14	2,000

The overall low productivity factors for this category are due to the fact that equipment clean-up is the primary wastewater producing activity, and relatively small volumes of water are used. One misleading factor in the low productivity and wastewater generation factors is that water is a major weight component in the final product and most of the initial ingredients. This tends to make the production tonnages artificially high compared to other categories preparing low water content products. Final productivity factors would be substantially higher for this category if only product dry weight was considered.

Plant I has installed an automatic flow-proportional composite sampler with refrigerated storage. Samples are taken daily and analyzed for BOD and SS in the plant quality control laboratory. Plant management uses raw waste strength as a gauge of their in-plant efficiency in minimizing waste of valuable ingredients into the sewer. They informed our investigator that if the weight of BOD in the raw waste exceeds one percent of the production, weight they investigate to determine the reason. As shown in Table 6, the BOD during our sampling period averaged only 0.56 percent of the production weight. Incidentally, the BOD and SS results of the plant laboratory analyses for the sampling days corrolated very closely with the BOD and SS results of the NCA Laboratory analyses run on the frozen samples.

Category 4 - Meat Specialties

Plant codes K and L are included in this category. Major products are ham, sausages, stews, pickled meats, hash, and chile, plus frozen items such as pre-fried meat patties.

The meats have been slaughtered, dressed and packed elsewhere. Added ingredients are largely spices and preservatives. Substantial quantities of grease and oil are present in the waste flow from the cleaning of cooking vats, frying ovens, and other equipment which comes in contact with the meat.

The two plants sampled represented opposite ends of the meat specialties category in terms of amount of processing performed. Plant K is a very small operation preparing a limited number of products. Processes include grinding, mixing with additives, then canning and cooking or patty forming and freezing. Minimal amounts of water are used for clean-up activities. Plant L on the other hand is a large meat canning operation preparing a wide assortment of meat specialties. Processing is more extensive, product changes more frequent, and waste generation significantly higher than Plant K.

Tables 8 and 9 show the waste generation and strengths recorded for the two plants. We believe that Plant L is more typical of plants producing meat specialties, with BOD values of 16 kg/kkg (32 lbs/ton) of production and 1,100 mg/l concentration. Also, we believe the sampler used at Plant K may not have taken representative samples due to low flow volume in the sampler suction tube.

Table 8. CATEGORY 4, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
K	5.1	3.0	1.2	0.97	0.086	0.16	0.68	5,700
L	33	16	11	10	0.11	0.98	7.3	15,000
Average	19	9.5	6.1	5.5	0.098	0.57	4.0	10,000

Table 9. CATEGORY 4, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
K	900	530	210	170	15	28	120
K	2,300	1,100	720	670	6.7	67	490
Average	1,600	820	460	420	11	48	300

Category 5 - Canned Soups and Baby Foods

Plant codes M and N are included in this category. Canned soups and baby foods, are put in one category because the plants typically are large, and produce many product varieties which contain different vegetable, meat, starch, and fruit ingredients. Both plants perform significant raw product processing of vegetables, as reflected by the relatively high wastewater generation figures shown in Tables 10 and 11. In this respect they are more closely allied with straight commodity processors than with many other categories of the specialty foods industry. Major wastewater sources are plant clean-up; washing, trimming, blanching of raw vegetables; washing, peeling and coring of raw fruit; and cooking of meat. Generally, waste discharges will vary greatly in volume and strength, depending upon which varieties are being manufactured, and the relative quantities of raw commodities and pre-processed ingredients.

Table 10. CATEGORY 5, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg raw product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
M	15	8.5	4.3	3.1	0.068	0.19	-	15,000
N	27	15	11	8.4	0.29	0.75	2.4	29,000
Average	20	12	7.6	5.8	0.18	0.47		22,000

Table 11. CATEGORY 5, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
M	1,000	590	290	210	4.1	12	—
N	940	520	360	290	10	26	82
Average	970	560	320	250	7.0	19	—

Category 6 - Tomato-Cheese-Starch Combinations (Italian Specialties)

Plant codes O, P, Q and R are included in this category. Major products are canned and frozen spaghetti, lasagne, ravioli, frozen pizza, and other italian specialties made with tomato, starch, and cheese base. These plants were placed in one category because they typically have the three principal ingredients listed, all of which are pre-processed elsewhere. The wastes are generated primarily from spills and clean-up of blending vats and cooking kettles.

As seen from Tables 12 and 13 this category showed poor corrolation in waste generation. We believe this wide diversity is due to selection of three plants which are vastly different in their operations due to size, product style, and percent of total plant capacity being used at the time of sampling.

Plant R is the smallest operation covered in this study. Processing is done largely by hand. Virtually no water is used except for end of the day clean-up of equipment. As shown in the tables, wastewater generation was extremely low (1,820 l/kkg or 440 gal/ton product). This minimal clean-up flow provided little dilution, thus the high concentrations. However, the wastewater volume was so low that even the higher strength of the waste could not significantly effect the productivity factor. The 2.6 kg COD/kkg product factor was the lowest of all 26 plants investigated.

Plant O is a new plant operating at only a fraction of its design capacity. With increased production to optimum levels, the use of water for clean-up purposes is expected to become more efficient in terms of volume per unit production and cause the present high productivity factors and

Table 12. CATEGORY 6, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil	Volume (l/kkg)
O	39	19	14	13	0.79	0.59		80,000
P	-	3.3	-	-	-	0.12		9,800
Q	8.8	5.2	3.4	3.1	0.052	0.15	4.7	26,000
R	2.6	1.1	0.65	0.59	0.011	0.061		1,800
Average	17	7.2	6.0	5.6	0.28	0.23		29,000

Table 13. CATEGORY 6, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and oil
O	500	240	180	150	10	7.6	
P	-	340	-	-	-	11.8	
Q	340	200	130	120	2.0	5.6	180
R	1,500	690	360	330	6.0	34	
Average	780	370	220	200	6.0	15	

wastewater generation to drop significantly. This plant also prepares institutional salads. Significant amounts of wastewater are generated by the washing of lettuce and blanching of other salad ingredients.

Plant P is a very large plant which produces canned tomato-cheese-starch products. These canned products contain larger volumes of water than do similar frozen items. High product water content generates artificially high production weights and thus lowers substantially the effluent productivity factors.

To summarize Category 6 we believe that none of the plants sampled could be called a "typical" situation. It is entirely possible, however, that the pollutant generation levels shown in Table 12 result in reasonable average values for this category in spite of the wide ranges.

Category 7 - Sauced Vegetables

Only Plant S whose major product is frozen vegetables with and without cheese or butter sauce was sampled in Category 7. This category represents plants whose wastes are largely generated by the washing, peeling, cutting, blanching, and cooking or freezing of raw vegetables. The addition of butter sauce, tomato sauce, spices, etc. may technically place this plant under the specialty food category, however, we believe the waste load is similar to that of a straight vegetable processor, with added waste load from spillage and clean-up of sauce equipment.

Plant S generates exceptionally high wastewater volume due to inefficient water use in the washing, cutting, cooling and transporting of the produce. The plant is about twenty-five years old and was designed at the time that water conservation and wastewater volume reduction were not considered important. Little modernization of equipment has been implemented, and the plant owners will soon be faced with the choice of large expenditures to reduce volumes discharged to the city sewer, or shut-down. The large volume provides dilution of pollutant concentrations and the plant effluent has a low BOD concentration of 300 mg/l.

As can be seen from Tables 14 and 15. the sauce room clean-up wastewater is high in strength, being comprised of cheese, margarine and shortening; but it is insignificant in volume (less than 1 percent of the total wastewater flow). The sauce room waste accounts for about 15 percent of the total plant COD and BOD loads, 7 percent of the SS load, 27 percent of the total phosphorus load (phosphorus containing detergents used for sauce room clean-up), and 4 percent of TKN.

Table 14. CATEGORY 7, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code S	Constituent (kg/kkg finished product)						
	COD	BOD	SS	VSS	Total P	TKN	Volume (l/kkg)
24-hour plant raw wastewater	45	25	21	16	0.33	1.1	85,000
Sauce room clean-up wastewater	6.4	3.5	1.4	1.3	0.090	0.047	490

On the basis of this one plant, it appears that the rapid growth in the sale of sauced vegetables will increase the pollution load generated by the vegetable processing industry.

Table 15. CATEGORY 7, AVERAGE WASTEWATER CHARACTERISTICS

Plant code S	Concentration (mg/l)					
	COD	BOD	SS	VSS	Total P	TKN
24-hour raw wastewater	560	310	250	200	4.4	13
Sauce room clean-up wastewater	14,000	8,000	3,300	3,100	230	100

Category 8 - Sweet Syrups, Jams and Jellies

Plant codes T and U fall into this category. Major products are syrups, fruit toppings, jams, jellies, and preserves. Typically, the ingredients include fruit, sugar, chocolate, nuts, cocoanut, and flavorings. Most ingredients are pre-processed elsewhere. The plants blend various proportions of ingredients, cook and package the products.

Plant U processed only jams, jellies, and spreads. Plant T processed a variety of sweetened products plus jello, chocolate, cocoanut and instant rice. In spite of its variety of products, Plant T was placed in this category because the instant rice processing water is separately disposed and not included in Tables 16 and 17, and the chocolate, cocoanut and jello are very dry processes which contribute less wastewater than does the syrup operation.

As seen from the tables the wastes are strong in dissolved organic strength, but relatively low in pollutant load per unit weight of production. Major wastewater generation is from clean-up of mixing vats and cookers during changes in product runs and at the end of each day. Apparently, clean-up operations were efficient as indicated by low wastewater volumes for both plants.

Table 16. CATEGORY 8, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil	Volume (l/kkg)
T	5.4	3.0	1.3	1.1	0.076	0.057	0.62	2,700
U	12	7.2	0.68	0.60	0.019	0.030	-	2,000
Average	8.7	5.1	1.0	0.85	0.048	0.044	-	2,400

Table 17. CATEGORY 8, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil
T	2,000	1,100	470	410	28	21	230
U	6,100	3,600	340	300	9.6	15	-
Average	4,000	2,400	400	360	19	18	-

Category 9 - Chinese and Mexican Foods

Included in this category are plant codes V, W and X. Major products are chinese specialties such as chop suey, chow mein, and fried rice; and mexican specialties such as thick vegetable sauces, hot peppers and dip mix.

These plants correlated well because the product of all three plants is canned and high in vegetable content.

A substantial portion of the raw vegetables are processed at the plants while all other ingredients are pre-prepared elsewhere. Major waste flows originate from washing and blanching of vegetables, and from clean-up of mixing and cooking vats. Tables 18 and 19 show waste generation and strength. BOD generation averages 7 kg/kkg (14 lbs/ton) of production and 570 mg/l.

Table 18. CATEGORY 9, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg finished product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil	Volume (l/kkg)
V	12	6.3	2.4	2.2	0.084	0.36	1.2	14,000
W	12	6.7	4.0	3.8	0.041	0.27	4.7	18,000
X	12	7.8	1.9	1.2	0.29	0.21	-	8,900
Average	12	6.9	2.8	2.4	0.14	0.28	3.0	14,000

Table 19. CATEGORY 9, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil
V	830	450	170	160	6.0	26	85
W	670	370	220	210	2.3	15	260
X	1,200	900	210	140	34	22	-
Average	900	570	200	170	14	21	170

Category 10 - Breaded Frozen Products

Included in this category are plant codes Y and Z. Plant Y breads mushrooms, onions, and pre-processed perch after minimal washing. Plant Z prepares fish and shellfish that have been cleaned and dressed at a seafood processing plant. Generally, the seafood is thawed, washed, dried, dipped in batter, breaded and frozen. The breaded seafood is not fried. The major wastewater sources are plant clean-up, washing and rinsing of raw product, and thawing of frozen raw seafood in the case of Plant Z.

Tables 20 and 21 show the wastewater generation and strengths of the effluent from the two plants. Plant Z utilizes huge volumes of water to thaw and frequently wash the product. As a result, waste strength is a relatively low 400 mg/l BOD. Plant Y is primarily a producer of breaded onion rings. The batter is very rich and clean-up of equipment and spills results in a wastewater with an average BOD of 4,500 mg/l. In direct contrast to Plant Z, Plant Y operation generates very little wastewater but produces the strongest waste of all plants investigated.

Table 20. CATEGORY 10, AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION

Plant code	Constituent (kg/kkg raw product)							
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil	Volume (l/kkg)
Y	40	15	23	23	0.12	0.33	1.2	3,300
Z	66	37	30	29	0.58	4.8	-	92,000
Average	53	26	26	26	0.35	2.6	-	48,000

Table 21. CATEGORY 10, AVERAGE WASTEWATER CHARACTERISTICS

Plant code	Concentration (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	Grease and Oil
Y	12,000	4,500	7,100	7,100	37	100	360
Z	720	400	330	320	6.3	52	-
Average	6,400	2,400	3,700	3,700	22	76	-

These plants illustrate the differences between two plants with similar major process techniques (i.e., raw product cleaning, cutting, battering, breading, freezing) but with different water usage patterns; one being a very wet operation and the other very dry.

STANDARD RAW WASTE LOADS

Table 22 below summarizes average wastewater productivity factors for all categories in terms of kilograms of pollutant per thousand kilograms of finished product. Using COD as a measure of organic strength, Table 22 shows that category 10 (breaded frozen products) and category 2 (frozen bakery products) produce approximately 50 kg of COD per 1,000 kg of production (100 lbs/ton). The lowest category in terms of COD production is number 8 (sweet syrups, jams and jellies) in which the two plants sampled produced an average of only 9 kg of COD per 1,000 kg of production (18 lbs/ton). Values of BOD's generally ran about 50 percent of COD values in the samples analyzed.

Average values for other waste constituents shown in Table 22 generally indicate that the industry produces suspended solids (SS) which are highly organic (VSS), the wastes are often deficient in nutrients (Total P and N) which must be added for satisfactory biological treatment, that grease and oil are significant ingredients where substantial frying is done, and finally, that wastewater volumes vary greatly.

TABLE 22. AVERAGE POLLUTANTS CONTAINED IN WASTEWATER PER UNIT OF PRODUCTION, BY CATEGORY

(kg/1,000 kg)

Category	Average productivity factors (kg/kkg product)							
	COD	BOD	SS	VSS	Total P	TKN	G&O	Volume (l/kkg)
1	34	17	14	14	0.19	0.44	15	12,000
2	52	23	14	14	0.082	0.30	11	11,000
3	13	7.5	3.5	3.4	0.028	0.037	5.7	2,800
4	19	9.9	6.1	5.5	0.098	0.57	4.0	10,000
5	20	12	7.6	5.8	0.18	0.47	2.4	22,000
6	17	7.2	6.0	5.6	0.28	0.23	4.7	29,000
7	45	25	21	16	0.33	1.1	-	85,000
8	8.7	5.1	1.0	0.85	0.048	0.044	0.62	2,400
9	12	6.9	2.8	2.4	0.14	0.28	3.0	14,000
10	53	26	26	26	0.35	2.6	-	48,000

Table 23 on the following page summarizes average raw wastewater constituent concentrations for all categories. With few exceptions the average results reflect typical food processing wastes which are very high in COD and

Table 23. AVERAGE WASTEWATER CHARACTERISTICS BY CATEGORY

Category	Constituents (mg/l)						
	COD	BOD	SS	VSS	Total P	TKN	G&O
1	3,900	1,900	1,500	1,500	21	45	2,000
2	7,000	3,200	2,200	2,100	6.8	36	820
3	4,700	2,600	1,200	1,200	11	14	2,000
4	1,600	820	460	420	11	48	300
5	970	560	320	250	7.0	19	82
6	780	370	220	200	6.0	15	180
7	560	310	250	200	4.4	13	-
8	4,000	2,400	400	360	19	18	230
9	900	570	200	170	14	21	170
10	6,400	2,400	3,700	3,700	22	76	360

BOD concentrations, and organic suspended solids. In general, the wastes are amenable to discharge into municipal systems for joint treatment. In certain instances, pretreatment may be required for removal of grease and oil to prevent deposition in the municipal collection system. Where the specialty food processing plant provides final treatment and disposal, the wastes can be successfully treated with properly designed biological treatment processes.

It is important to note the wide differences (more than 10:1) in waste strength between categories of the specialty food industry as shown in Table 23. This wide difference in waste strength is due to a variety of reasons, the most significant of which are summarized in the following paragraphs.

- Richness of product ingredients. All food processing plants undergo extensive clean-up of equipment, floors, spillages, etc. The principal waste components of the wash water are the ingredients used in product manufacture. Where these ingredients are high in fats, carbohydrates, sugar, etc. the resultant waste is correspondingly strong. As an example, the categories showing the highest generation of organic wastes were frozen breaded products, which use a rich egg batter, and frozen bakery desserts which use large quantities of butter, eggs, and sugar.

- Number and type of processes performed. The plant process line may consist of many steps (cooking, blending, etc.) or very few. The individual process steps may contribute heavily to wastewater generation (blanching, washing, etc.) or very little. It was beyond the scope of this project to investigate wastes generated by individual process steps, however, even casual observation revealed the significance of this aspect.

- Number of different products and frequency of changes in product. As a rule when the type of product is changed all equipment in the process line is thoroughly cleaned. Therefore, plants which have relatively short runs of many different products generate more clean-up waste than do plants which run the same product for many days.

- Moisture content of ingredients and the final product. In this report pollution generation factors are calculated per unit weight of product. A major shortcoming of this approach is that the moisture of ingredients and products varies widely. For example, a canned spaghetti plant will produce less pollution per unit weight of production than a frozen pizza plant even though both are primarily a starch and tomato product. The canned spaghetti product has a much higher moisture content - therefore weighs more - and shows lower pollution productivity per unit weight of production.

- Management desire to reduce waste generation. Without question, a major factor in waste generation from any plant is the presence or absence of in-plant waste management programs designed to minimize waste disposal to the sewer.

- Other factors. A multitude of other factors may have a significant effect upon wastewater generation from a particular plant. These include, plant size, number of shifts, percentage of production capacity in use, cost of water supply and wastewater disposal, degree to which ingredients have been pretreated elsewhere, and economic ability of the plant to modernize equipment.

CURRENT TREATMENT TECHNOLOGY

The specialty food plants investigated exhibited a wide spectrum of wastewater treatment facilities from no treatment to extensive biological and physical-chemical systems. While evaluation of waste treatment systems was outside the scope of the project, a brief description of study team observations is provided.

Of the 26 plants investigated, 6 provided the equivalent of secondary treatment using biological systems in conjunction with other unit processes. The most extensive treatment facility observed is described in the case study for plant A (See appendix) and is reported to achieve in excess of 99 percent BOD reduction on raw waste with average BOD levels of 4,000 mg/l. The treatment facility has a design capacity of 350,000 gpd and is estimated by the owner to have a replacement value of approximately 3 million dollars. Other excellent secondary and tertiary treatment facilities were observed at Plants F, T and N. Plant D utilizes a land disposal system which has successfully operated for over 20 years.

Twenty-one of the 26 plants investigated discharged into municipal systems. Plants O and H provide activated sludge pre-treatment in order to reduce BOD levels 90 percent or more prior to discharge into the municipal sewer. Each is a large plant located in a small community. Plant V provides only screening on its' waste, but is reported to have a long term arrangement with the small community where it is located whereby the company pays approximately 85 percent of all capital and operating costs for municipal sewage treatment facilities.

Of the other 18 plants investigated, 4 provided no pretreatment, 2 provided grease traps only, and the remainder provided various degrees of screening, settling, or flotation prior to discharge to sewers. Several clarification operations utilized chemical treatment for pH adjustment and to promote coagulation and emulsification.

Table 24 summarizes the treatment at each plant investigated. There is no corrolation between category and degree or type of treatment.

Table 24. SPECIALTY FOOD PLANT WASTEWATER TREATMENT OPERATIONS

Treatment	Plants utilizing
. None	J, R, U, Y
. Collation baskets in drains (only)	E
. Grease trap (only)	F, K
. Screening	A, C, M, N, P, Q, S, T, V, W, Z
. Settling	A, B, C, D, F, G, H, I, L, N, T, X
. Coagulation	B, N, W
. Trickling filtration	A, N
. Activated sludge	
. Conventional	A, H
. Extended aeration	O, T
. Lagooning	
. Anaerobic	A
. Aerobic	P
. Aerated	F, N, P
. Dissolved air flotation	A, B, F, N, W
. Chlorination	A, F, N, P
. Sand filtration	F
. Land disposal (partial or total)	D, N, P

PAUNCH MANURE AS A FEED SUPPLEMENT IN CHANNEL CATFISH FARMING

by

S. C. Yin*

INTRODUCTION

One of the most serious problems faced by the meat-packing industry in attempting to comply with the increasingly more stringent pollution control regulations is the finding of an acceptable means to dispose of paunch manure from slaughtered cattle. The feasibility of drying paunch manure and incorporating it as a feed supplement for the commercial production of channel catfish was reported earlier (1, 2). By so doing, it would relieve the meat-packer from having to deal with this material as a probelm waste and transform it into a useful by-product. Following those preliminary feasibility studies, the Environmental Protection Agency awarded a grant to the Oklahoma State University for investigation on a scale simulating commercial enterprises to determine whether channel catfish could be grown on specially formulated feeds containing various substitution rates of dried paunch manure at growth rates (in one growing season) which would compare favorably with control fish given standard commercial catfish feed. This paper gives a summary of the findings of this completed project which was designated EPA Grant No. R-800746 (12060 HVQ). The final report on this project is in its final stages of preparation for printing, and should be available for distribution before long.

MATERIALS AND METHODS

Experimental Feeds

Two tons of dried paunch manure was donated by Beefland International, Inc. This meat-packing company, located at Council Bluffs, Iowa, was the recipient of another EPA grant which dealt with the technology and economics of

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drying paunch and blood. That completed project was reported by Baumann (3). This dried paunch was transported to a commercial feed manufacturer who contracted to supply the standard feeds and to formulate the experimental feeds for this project.

Table 1 shows the composition of the feeds used. The feeds were formulated in such a manner that all of them were essentially isonitrogenous (that is, equal in protein nitrogen content) and isocaloric (that is, equal in caloric value per unit weight). The sinking feeds were for the pond-reared fish and the floating feeds were for the caged fish. The original plan was to use feeds containing 20% and 30% paunch in both pond and cage cultures. Unfortunately, the plant which produced the floating pellets was located near a residential area. Dried paunch, which is practically odorless, produced a highly objectionable odor when remoistened during the manufacturing process. For this reason, the plant manager, fearing complaints from the nearby residents, refused to proceed further after finishing the batch containing 10% paunch. Anyone who has experienced the odor of fresh, wet paunch manure can easily sympathize with that decision. Unless this undesirable quality of paunch can be overcome, it may become an important factor in limiting its adoption by the feed industry for incorporation into feed of any kind.

Table 1. Composition (%) of Commercial Catfish Feeds, Sinking Feeds Containing by Weight 10-30% Paunch, and a Floating Feed Containing 10% Paunch

Ingredient	Floating feeds		Sinking feeds			
	Commercial	10%	Commercial	10%	20%	30%
Protein, Kjeldahl	38.6	38.7	32.2	34.9	33.5	33.1
Fat, ether extract	3.3	3.1	4.6	3.7	3.7	3.7
Fiber	5.8	5.1	7.9	8.3	10.2	10.7
Calcium	1.22	1.32	0.42	0.53	0.57	0.67
Phosphorus	0.93	1.13	0.98	0.85	0.75	0.73
Calories, KC/G	4.16	4.25	4.15	4.28	4.34	4.32

Fish Cultures

The layout of the ponds constructed for this project is shown in Figure 1. The size of the ponds used for pond cultures was 0.1 hectare each, and the cage culture ponds were 0.4 hectare each. Ponds 6 and 10 were control ponds for water quality monitoring, in which there were no fish stocked, and no feed of any kind was added to these two ponds during the course of the experiment. The cages used were constructed of aluminum frame and vinyl-coated wire mesh, each measuring 0.91m tall, 0.91m wide, and 1.37m long. They were buoyed with styrofoam so that a submerged depth of 0.81m with a water volume of $1.0m^3$ was obtained. These cages were tethered to a pier in each of the two cage culture ponds.

The size and number of fingerlings chosen to stock the ponds and cages were planned to simulate average commercial yield (kg/ha) while obtaining an "ideal" market size fish within a 168-day growing season. In considering these objectives, a number of authoritative publications with varying viewpoints (4, 5, 6, 7, 8, 9) was consulted before the following decisions were made:

(a) In the pond cultures, each 0.1-ha pond was stocked with 260 fingerlings of 70g each. This stocking density (2600/ha) was considered maximum commensurate with the basic objective of a yield of about 1408 kg and a final average weight of 568 g. Assuming a mortality rate of 4%, the number of fish stocked in each pond was ten more than the number expected to survive the investigative period.

(b) Each of the three cages in each of the 0.4-ha ponds was stocked with 345 fingerlings of the same size as used in the pond cultures. This stocking density (2587/ha) was selected not only to be consistent with commercial practice as recommended by top researchers in the field, but also to duplicate the densities in the pond cultures, so that the waste loading from the fish and from uneaten feed in both types of culture ponds would be expected to be equal. Thus, comparison of the effects on water quality between the two cultural methods would be more meaningful.

The daily ration of feed given to the fish in all ponds was based on an average of three percent of the body weight. For this purpose, samples of fish from each pond and each cage were taken every 28 days and the fish were anesthetized for length and weight measurements.

Water Quality Analyses

One justifiable concern of utilizing paunch as a fish feed constituent is its potential as a water pollutant. Since fresh paunch has a high biochemical oxygen demand (BOD), over eighty percent of which was found in the water soluble fraction (1, 2), if feed containing dried paunch is not

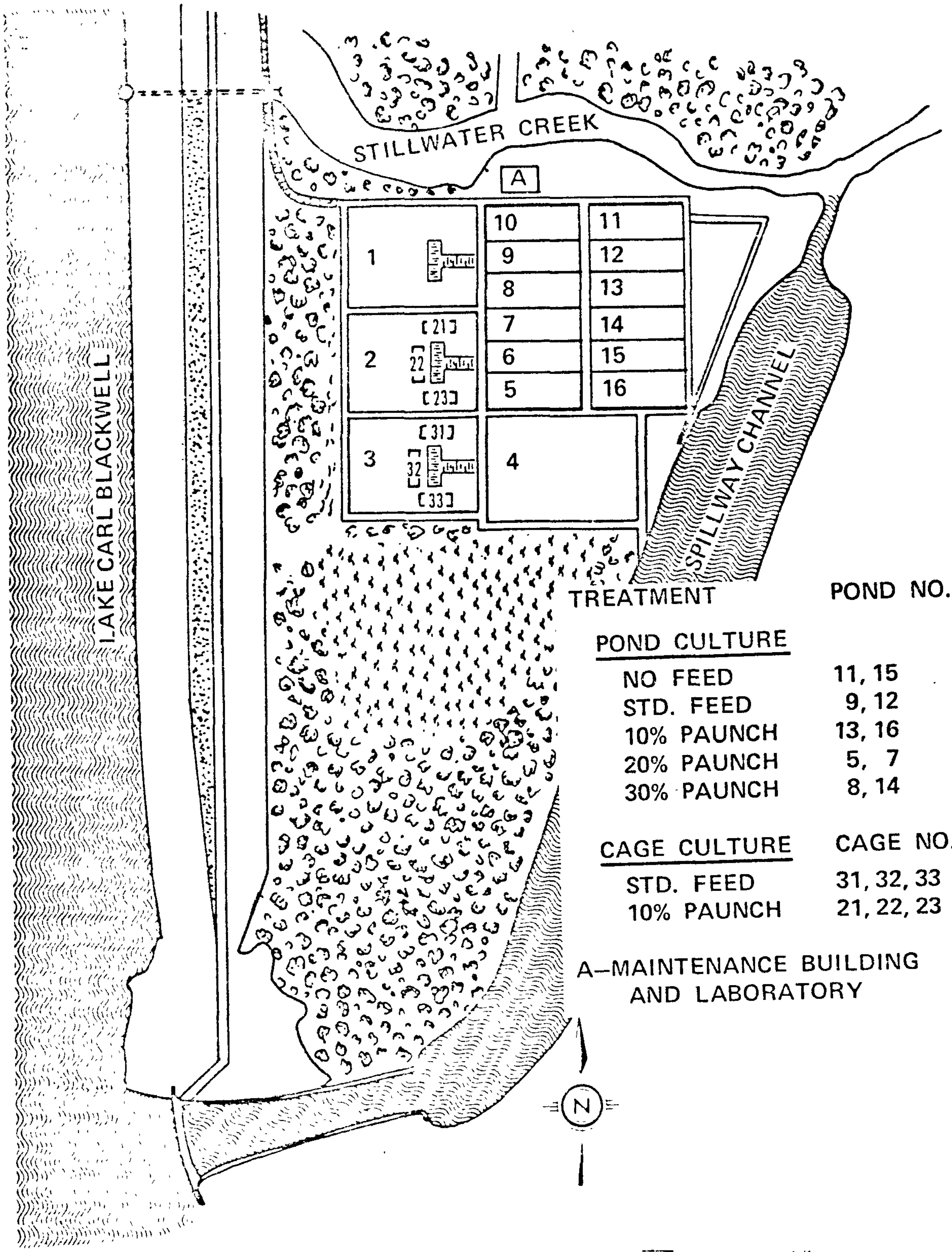

Figure 1. Experimental fish ponds used in pond (5-16) and cage culture (2 and 3) experiments. The tabular inset describes the experimental design. The cages used in ponds 2 and 3 are shown with [ ].

eaten by the fish within a reasonably short time after the feed is introduced into the water, the paunch in the feed could very well become a serious water pollutant. Therefore, it was decided to monitor the water quality of the ponds during the course of the investigation to see if this fear is indeed a reality and leads to a problem which would preclude the use of paunch for this purpose.

Because of the shortage of funds and manpower, it was not possible to monitor all of the ponds. The ponds selected for water quality monitoring were the following:

(a) Ponds 6 and 10, which were the two control ponds in which no fish were stocked and where no feed of any type was added to the water during the whole 168-day period.

(b) Ponds 2 and 3, which were the cage culture ponds. The fish in pond 2 received feed containing 10% paunch, while those in pond 3 received standard commercial feed.

(c) Ponds 9 and 12, which were the replicate ponds in the pond culture where the fish received standard commercial feed.

(d) Ponds 8 and 14, which were the replicate ponds in the pond culture where the fish received feed containing the highest proportion of paunch--30%.

This part of the investigation--the water quality studies--was a cooperative effort between Oklahoma State University and EPA's Robert S. Kerr Environmental Research Laboratory. A total of seventeen parameters was included in the analyses. These were pH, dissolved oxygen, temperature, carbon dioxide, biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, ammonia, total Kjeldahl nitrogen, nitrite, nitrate, total phosphate, orthophosphate, total solids, total suspended solids, volatile suspended solids, and fecal coliforms. Samples were collected weekly by O.S.U. personnel who also measured the first four parameters listed above at the site of the ponds. Each sample was pooled from three separate samples that were taken at different times during the daylight hours of the sampling day. Once every four weeks, however, both pooled daytime and nighttime samples were taken. For those analyses that were not performed at the site of the ponds, the samples were iced and transported to the Kerr Laboratory in Ada, Oklahoma, where the analyses were done.

RESULTS AND DISCUSSION

The details of all the data obtained in this investigation and the statistical analyses of these data will not be presented here in the short time available. Those who are interested in these details will be able to study them in the final project report which will soon be available. Only the salient points of the findings will be given in this presentation.

Table 2 shows the yields of the pond-reared fish at the end of the 168-day growing season which was terminated on November 2, 1972. Yield is defined as the biomass of fish present at the time of harvest; i.e., when the pond was drained. Ponds 11 and 15 were the ponds in which the fish were not

Table 2. Yield of Channel Catfish on November 2 from 0.1 ha Ponds and Amount of Feed Added During the 168-day Growing Season[a]

Treatment Pond	Yield/ponds kg	Amount (kg) Feed added
Standard feed		
9[b]	147.60	201.88
12	110.42	215.45
Avg.	129.01	208.66
Feed with 10% paunch		
13	123.96	211.90
16	132.73	223.02
Avg.	128.35	217.46
Feed with 20% paunch		
5	120.25	216.62
7	126.50	190.95
Avg.	123.38	203.79
Feed with 30% paunch		
8	104.16	178.72
14	109.91	187.02
Avg.	107.04	182.87
No supplemental feed		
11	16.78	0
15	21.85	0
Avg.	19.32	0

[a]Yield times 10 = yield/ha

[b]A 13% loss of fish due to poaching accounts for the low yield.

given any supplemental feed but lived only on whatever natural food they were able to find in the pond. The average yield of these two ponds was only 15.7% of the average yield of the other eight ponds where supplemental food was given. Average yields for ponds 9 and 12 (standard feed), for ponds 13 and 16 (10% paunch), and for ponds 5 and 7 (20% paunch) were quite similar, as were the average amount of feed added. The average yield of ponds 8 and 14 (30% paunch), however, was significantly lower. But it was also noteworthy that the amount of feed added, which was based on the average weight of the fish sampled every 28 days, was also significantly lower than those added to the other ponds. Because slower growing fish would, therefore, be fed less food, it is possible that yield merely reflects the total quantity rather than the quality of the food eaten.

Table 3 shows the mean condition factor, mean length, and mean weight of the fish receiving different treatments. Again, the means for the fish in the pond cultures where standard feed, feed with 10% paunch, and feed with 20% paunch were used were essentially equal, whereas those for the fish which were given feed containing 30% paunch were significantly lower. In the cage cultures, the three means for the fish given feed containing 10% paunch were significantly lower than those given standard commercial feed, and the means of the fish in both of these cage cultures were significantly lower than those in the pond cultures. Fish confined in cages are unable to supplement their diet with natural food present in the pond. Hence, deficiencies in the feed ingredients are apt to be more pronounced than for pond-reared fish. Also, for this same reason, it is expected that fish in pond cultures given the same kind and quantity of food as fish reared in cages will show a faster and greater growth rate.

However, in spite of a slower growth rate shown by the caged fish as compared to the pond-cultured fish, the caged fish in both ponds (standard feed and 10% paunch feed) showed better feed conversion than the pond-cultured fish, regardless of the type of feed, as shown in Table 4. The "S" conversion factor is obtained by dividing the weight in kilograms of feed added by the weight gain in kilograms, while the "C" conversion factor is obtained by dividing the weight in kilograms of feed added by the adjusted weight gain, which is the weight gain in kilograms minus the weight gain in kilograms expected if the fish had not been given any supplemental feed. This last weight gain, of course, is obtained from the weight gain shown by the fish in the control ponds 11 and 15 which lived only on the natural food they could find in the ponds. The average weight gain in these two ponds was 2.37 kg per pond. Thus, the smaller the conversion factor, the better is the feed conversion. Also, since the "S" factor includes weight gain due to natural foods, and since caged fish are practically totally dependent on supplemental food, in comparing feed conversion between pond-reared fish and cage-reared fish, it would be more accurate to compare the "C" factor of the former with the "S" factor of the latter.

Table 5 shows the comparative costs of producing catfish using standard commercial feeds and feeds containing various levels of paunch. The

Table 3. Mean Condition Factor (K_{TL}), Length, and Weight of Pond-Reared (TRTS 1-5) and Cage-Reared (TRTS 6 + 7) Channel Catfish on May 18 and November 2

TRT No.	Feed, Pond and Cage No. in ( )		May 18	November 2
1	None (11 + 15)	K_{TL}	0.66	0.67
		Length (mm)	212.6	227.0
		Mass (g)	65.2	80.4
2	Std. sinking (9 + 12)	K_{TL}	0.66	0.94
		Length (mm)	218.9	385.6
		Mass (g)	71.2	547.4
3	10% paunch (13 + 16)	K_{TL}	0.67	0.86
		Length (mm)	212.8	388.4
		Mass (g)	66.4	507.4
4	20% paunch (5 + 7)	K_{TL}	0.70	0.87
		Length	216.4	384.2
		Mass (g)	71.4	502.7
5	30% paunch (8 + 14)	K_{TL}	0.67	0.84
		Length (mm)	219.7	367.2
		Mass (g)	72.5	419.0
6	Std. floating (31, 32, 33)	K_{TL}	0.66	0.97
		Length (mm)	202.0	335.5
		Mass (g)	57.7	360.2
7	10% paunch (21, 22, 23)	K_{TL}	0.68	0.93
		Length (mm)	227.0	321.7
		Mass (g)	82.8	313.2

Table 4. Channel Catfish Conversion Factors of Fish Reared in Ponds Given a Standard Commercial Feed or Feeds Containing 10, 20, and 30% Paunch, and Conversion Factors of Cage-Reared Fish Given a Standard Feed or Feed with 10% Paunch

Treatment pond	Feed added (kg)	Weight gain (kg)		Conversion factor	
		Total	Adjusted	S	C
		PONDS			
Std. feed					
Pond 9	201.88	128.10	125.73	1.58	1.60
Pond 12	215.45	92.87	90.50	2.32	2.38
TRT Avg.	208.66	110.48	108.12	1.89	1.93
10% paunch					
Pond 13	211.90	105.76	103.39	2.00	2.05
Pond 16	223.02	116.38	114.01	1.92	1.96
TRT Avg.	217.46	111.07	108.70	1.92	2.00
20% paunch					
Pond 5	216.62	101.69	99.32	2.13	2.18
Pond 7	190.52	106.94	104.57	1.79	1.82
TRT Avg.	203.57	104.32	101.94	1.78	2.00
30% paunch					
Pond 8	178.72	84.66	82.29	2.11	2.17
Pond 14	187.02	91.71	89.32	2.04	2.09
TRT Avg.	182.87	88.18	85.82	2.07	2.13
		CAGES			
Std. feed					
Cage 32	153.53	94.72	-	1.62	-
Cage 33	147.08	139.08	-	1.06	-
TRT Avg.	150.30	116.90	-	1.28	-
10% paunch					
Cage 22	124.87	84.80	-	1.47	-
Cage 23	118.04	75.74	-	1.56	-
TRT Avg.	121.45	80.27	-	1.51	-

Table 5. Comparative Feed Costs to Produce Channel Catfish Using the Standard Feeds and Feeds with Various Levels of Paunch

Culture System feed type	Cost of feed $/kg	Conversion factor S	Conversion factor C	Cost of feed $/kg S	Cost of feed $/kg C
Pond Culture-Sinking Feed					
Standard commercial	0.106	1.89	1.93	0.20	0.20
Feed with 10% paunch	0.104	1.92	2.00	0.20	0.21
Feed with 20% paunch	0.115	1.78	2.00	0.20	0.23
Feed with 30% paunch	0.137	2.07	2.13	0.28	0.29
Cage Culture-Floating Feed					
Standard commercial	0.176	1.28	-	0.22	-
Feed with 10% paunch	0.178	1.51	-	0.27	-

comparisons were based on prices existing at the time the study was initiated, i.e., March 1972. Cost of dehydrated paunch was estimated to be $22.05 per metric ton, f.o.b., Omaha, Nebraska. For the sinking feeds used in pond cultures, the only experimental feed containing paunch that did not cost more than the standard commercial feed to produce the same weight of fish was the 10% paunch-containing feed. Feeds containing higher percentages of paunch cost more because to make the feeds isonitrogenous (i.e., having the same protein content as the standard commercial feed) more higher priced, high protein constituents such as fish and soybean meals have to be added to make up for the protein deficiency of paunch. In the cage cultures, the cost to produce one kilogram of fish with floating feed containing 10% paunch was considerably higher than the cost using standard commercial feed. Unless the saving to the meat-packer in not having to treat the paunch as a waste is taken into consideration, it would not be economical to raise channel catfish by incorporating more than 20% paunch into the feed in pond culture, and any at all in cage culture. Nevertheless, with more stringent waste discharge regulations facing the meat industry, this saving may become an important consideration that should not be overlooked in considering the cost.

The data obtained in the water quality studies revealed that the sinking feed containing 30% paunch and the floating feed containing 20% paunch did not have any significant adverse effects on the water quality as compared to standard commercial feed. Moreover, although the water quality of all the ponds in which fish were kept in this investigation had deteriorated to some degree by the end of the 168-day period, the deterioration in none of the parameters measured was sufficiently great to have caused concern. In all ponds, fresh water was added as needed to maintain a constant water level. Statistical analyses of the data showed that under the experimental conditions described which were designed to simulate commercial production, the water quality of all the ponds--both pond and cage cultures--had not deteriorated to any appreciable degree in this one growing season. In this study, it was demonstrated that incorporation of as high as 30% dried paunch in sinking feed and 10% in floating feed for the production of channel catfish will not cause any greater water pollution than the use of standard commercial feeds.

CONCLUSIONS

It is feasible to use dehydrated paunch as a feed constitutent in formulated feeds for pond-rearing channel catfish. Levels of 10 to 20% paunch can be used without producing a significant reduction in growth as compared to fish reared on a typical commercial feed. Economically, levels of paunch up to 20% may be used without increasing the feed costs per kg of fish flesh produced. Thus, paunch is economical as a feed constituent in formulated feeds for pond-rearing of channel catfish up to a 20% level. For cage culture, however, paunch at 10% substitution level would not produce a desirable economic return, and only smaller amounts may be used. The fish harvest obtained in the present study averaged 1219 kg/ha. At this density none of the water quality parameters limited growth or production. There was no evidence that at production levels typical of average commercial catfish farming that metabolic wastes have a negative feedback on fish growth or production.

Under the experimental conditions of the present study which endeavored to simulate typical catfish farming techniques, fish culture did not cause appreciable water quality deterioration in one growing season. Moreover, there was no significant difference in water quality between ponds using a typical commercial feed and a feed containing dehydrated paunch. At similar densities, there was no difference in water quality between ponds using cage- and pond-rearing techniques.

REFERENCES

1. Yin, S. C., R. C. Summerfelt, and A. K. Andrews. 1972. Dried cattle paunch manure as a feed supplement for channel catfish, p. 75-82. In Proc. 23rd. Okla. Ind. Waste and Advance Waste Conf., April 3-4, 1972, Oklahoma State University, Stillwater, Oklahoma.

2. Yin, S. C. and J. L. Witherow. 1972. Cattle paunch contents as fish feed supplement: feasibility studies, p. 401-408. In Proc. 3rd. Nat. Symp. on Food Processing Wastes, Mar. 28-30, 1972, New Orleans, Louisiana (EPA Pub. No. EPA-R2-72-018).

3. Baumann, D. J. 1971. Elimination of water pollution by packinghouse animal paunch and blood. Water Pollution Control Research Series. EPA Pub. No. 12060 FDS 11/71.

4. Bureau of Commercial Fisheries. 1970. A program of research for the catfish farming industry. U. S. Dept. Commerce, Economic Development Adm., Tech. Assist. Proj. XIII. 216 p.

5. Bureau of Sport Fisheries and Wildlife. 1970. Report to the fish farmers. U. S. Dept. Interior, Bureau of Sport Fisheries and Wildlife, Resource Pub. No. 83, 124 p.

6. Meyer, F. P. 1969. Where do we stand?, p. 8-11. In Proc. 1969 Fish Farming Conf., Texas Agr. Ext. Serv., Texas A&M Univ., College Station, Texas.

7. Collins, R. A. 1970. Cage culture of catfish: research and private enterprise. Catfish Farmer 2(4):12-17.

8. Lewis, W. M. 1970. Suggestions for raising channel catfish in floating cages. Unpublished multilith report of Fisheries Research Laboratory, Southern Illinois Univ., Carbondale. 5 p.

9. Schmittou, H. R. 1970. Developments in the culture of channel catfish, *Ictalurus punctatus* (Rafinesque), in cages suspended in ponds. Proc. S. E. Assoc. Game & Fish Comm. 23(1969): 226-244.

PRETREATMENT OF VEGETABLE OIL REFINERY WASTE WATER

by

Alex Grinkevich*

INTRODUCTION

The production of a finished product of edible oils requires the use of processes which progressively remove incremental amounts of impurities and undesirable oil constituents from the crude oil until it has reached the clear, bright, odorless high quality cooking or salad oil or the pure white solid shortening that the American consumer enjoys.

For years the technology of the edible oil industry was directed to achieving a high quality consumer product by removing these impurities from the oil and achieving a high level of cleanliness in the product container, shipping and storage tanks, the plant areas which the processes occur, etc., etc. Almost without exception when a new gain in product purity or plant cleanliness was achieved, the undesired constituent was transferred eventually to a waste water stream and was discharged from the plant, thus presenting a clean-up problem downstream at a waste water treatment plant or a river or other surface water. For years this waste was some one elses problem; however, recent Federal legislation has required that the discharger control and abate the nuisances generated by his discharge. Hence, at a rather late date the edible oil industry has turned its technology and attention to waste water. Like others, this industry found it knew very little about waste water.

OUTLINE OF THE PROBLEM

In the edible oil industry, not surprisingly, the largest single problem is oil removal from the waste water system. If the free and emulsified oils are removed the BOD and suspended solids are reduced almost proportionately to the oil reduction.

Consider the problem:

(1) A modern oil refinery will have a product throughput ranging from 1/2 million to 1-1/2 million pounds of finished product per day.
(2) During this processing, the oil will pass through several individual processes such as (1) the first refining (2) the second refining (3) deodorizing (4) winterizing (5) hydrogenation and (6) packaging or loading of bulk shipment vehicles. Thus, to produce one (1) million pounds of finished product, the oil will be sent through a minimum of 6 processess which means that 6 million pounds of oil are handled to produce a million pounds. Actually, the product is stored in intermediate storage tanks in its way through the refinery so that more realistically it is handled and pumped more than 15 to 20 times. Thus, production of one (1) million pounds of finished oil will require handling about 20 million pounds of oil through the incremental processes.

From the above, one would expect some leaks, spills, clean-ups, drainage of pipes to make repairs, etc., all of which will find

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its way to the waste water stream. If you have a handling efficiency of 99.44% the losses to waste water would be 112,000 # oil, clearly unacceptable. What is acceptable to the inlet of a municipal treatment plant is 100 mg/l FOG which at 300 GPM of waste water amounts to 346 # oil/day which is a loss of .001173% or an efficiency of 99.8827%!

(3) In the refining, deodorizing and acidulation of soapstock, direct contact of water with the oil is inherent in the process itself so that when the products are purified a direct transfer of the impurities is made to the waste water steam together with an additional amount of oil which goes over to the waste water in the form of oil-water emulsions.

(4) The quantity of wastes which wind up in the waste water are directly related to the free fatty acid content which is in the available crude oil. This factor is outside the control of the refinery manager. He must process the available oil. The free fatty acid concentration can vary widely.

(5) In addition to the oil that is transferred to the waste water, a large amount of water soluble highly complex organic materials, originally present in the raw oil, leave the raw oil and wind up in the waste water stream. This is particularly true of waste water from the acidulation of soapstock which creates a waste having characterisitics of 4,000-90,000 mg/l BOD and 200-10,000 mg/l hexane extractables or fats, oils and grease, which will be hereafter designated F.O.G.

Depending on the design of the individual refinery the total water stream could vary from 100 gpm to 4,500 gpm. We have one refinery rated at 1 million #/day, that was built in the early 1900's on the bank of a very large river. The refinery was built to use once through river water. It represents the 4,500 gpm figure. We are very busy installing cooling towers, repiping to achieve maximum reuse of water and expect to reduce the water discharge to approximately 200-300 gpm. I suspect that with optimization this can and will be reduced further but the waste concentration will be spectacular. An achievable level of water use for a complete refinery employing conventional processes, including acidulation of soapstock, appears to be about 200 gpm for 30,000 # oil/hr. This works out to 0.28 gal. of water per pound of refined oil.

Typical edible oil refinery waste water would have characteristics in the following range:

BOD	500-6,700 mg/l
FOG	300-4,200 mg/l
SS	541-5,851 mg/l

The range is wide because of the factors previously mentioned, variability due to accidental spills, leaks which reflect state of repair, dilution, free fatty acid content of the incoming raw oil, etc.

Let me describe a system recently installed and started-up in a mid-west refinery which refines animal and vegetable fats to make solid shortening. This plant also refines soy and cottonseed oil to produce bottled salad oil. Since animal oils are used, the plant comes under

Meat Inspection Department of Department of Agriculture (M.I.D.). Consequently, a clean-up crew of 10 people are constantly scrubbing down equipment, floors, concrete aprons, the paved tank farm, etc. Recent figures show plant consumption of special commercial cleaning compounds at approximately 6,500 #/month. This is above counting the 50% caustic used for clean-up. Some product is shipped in tank cars so the operation of washing Railroad tank cars is present. Plant processes include caustic refining, deodorizing, winterizing, bleaching, hydrogenation, acidulation of soapstock, manufacturing of emulsifiers, packaging, and bulk shipment by tank, truck and tank car. From this you can see that the waste water will represent a rather complex mixture of emulsions, soaps, detergents, emulsifiers that is constantly changing as plant operations change. The plant, when built circa 1940, had installed on the final outfall line a gravity grease skim basin 20 feet wide x 20 feet long and of 7 feet depth. Waste water after this skimming contained FOG levels ranging 500-5000 mg/l and waste water flow varied from 150 to 350 gpm.

SYSTEM OBJECTIVES

Several alternate systems were reviewed before ultimate selection was made. Objectives were two fold. (1) Water quality objective was an FOG level of 50 mg/l since the local sanitation district already had an ordinance requiring 100 mg/l. It was established that reducing the FOG would achieve proportionate reductions in BOD and S.S. (2) Recovery of oil from the waste water of quality that would product a saleable by product.

THE SYSTEM EMPLOYED

A block flow diagram of the system installed is depicted on Figure (1). In figure (1) you will notice that all the plant waste water is discharged into an existing basin which was originally installed when the plant was built. Originally this water passed thru an under flow weir and was discharged to the city manhole to the right of figure (1). In the installation of the additional pre-treatment facilities this basin was converted to become a pumping basin to feed the new gravity circular oil-water separator shown in figure (1). This separator is a 40,000 gal. capacity and at a 500 gal./min. flow rate provides approximately 80 minutes of retention time. It has a top sweep boom and a bottom sweep boom to handle both the floatable oil and any settleable solids that might be delivered to the vessel. At the inlet of the pump sump, we have a pH recorder controller and the ability to add acid to insure that the pH throughout the system is kept below 4. It is important that any soaps that might be in the waste water be acidified before they get to the oil water gravity separator, inasmuch as soap is miscible with water and will not separate by gravity from water. Discharge from the Rheem oil-water separator is then fed to a 3 vessel filter unit which is installed to take the final oil reduction in the waste water down to the acceptable limit of 100 mg/l and our design target of 50 mg/l. After passing through the filter unit the clear water discharge is directed to the final portion of the old, original skim basin at which point caustic soda is added to correct the pH back to the acceptable limits of 4.5 to 9 before discharge to the city sewer manhole.

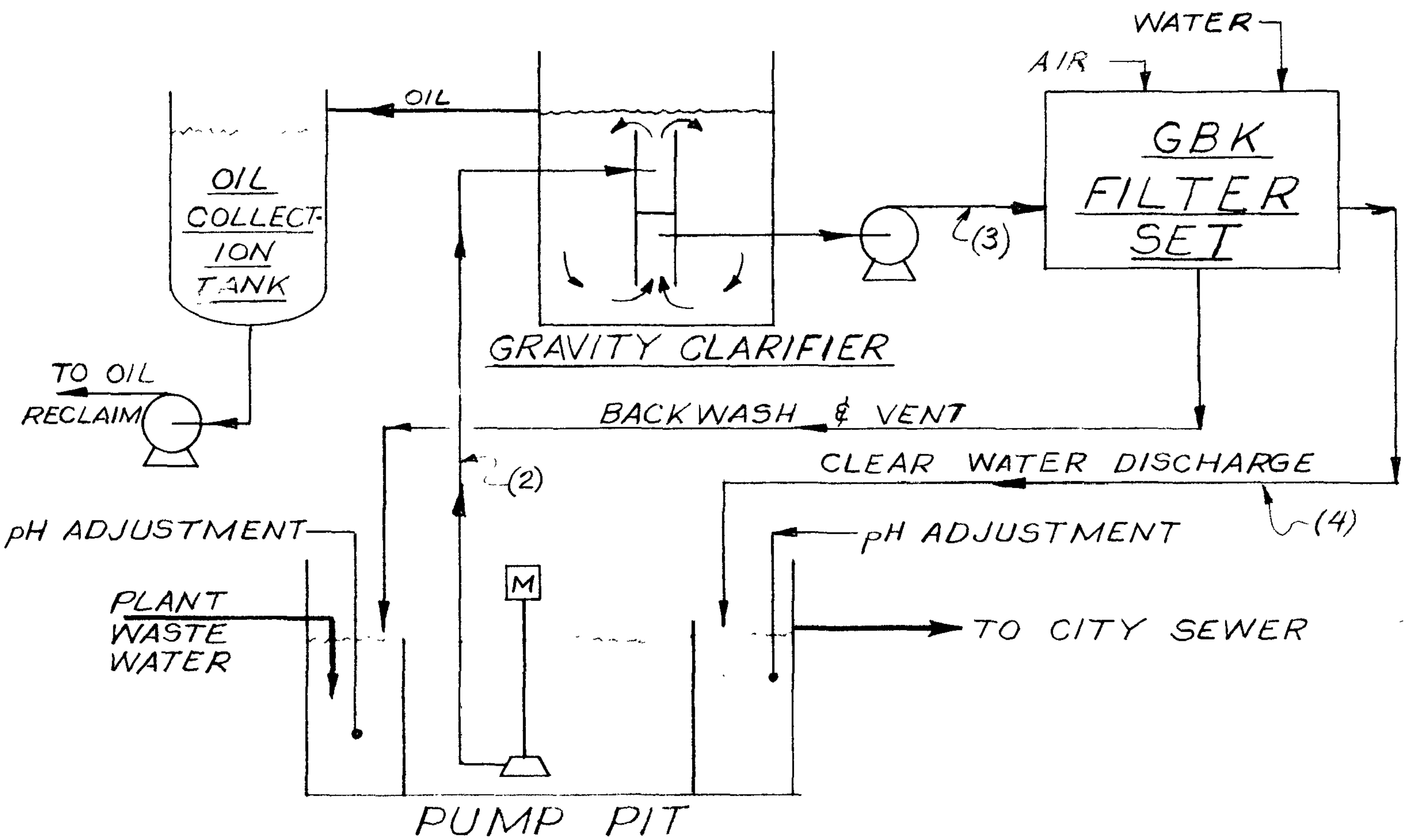

FIG 1
BLOCK FLOW DIAGRAM

(2) (3) & (4) ARE SAMPLE POINTS OF TABLE I

As you look at figure (1) you can see that what we have done is taken sequential reductions in oil level across each part of the system. The old skim basin which serves as a sump pump, in itself, still does collect large quantities of free oil that on occasion come down from the plant discharge. These are easily floatable and almost immediately pop to the surface of the pump basin and remain there building a pad of oil that is eventually skimmed and pumped back to the oil reclaim operation. The initial reduction in oil content that occurs in this basin is then followed by a further reduction in the oil water gravity separator. The quiescent laminar flow that is available and the 80 minute detention time, plus the fact that the water is an acid condition, and that most of the soaps have been broken, allows for natural gravity separation to occur between the oil and water phase. Even so, the discharge from the oil water separator still has an oil level completely unacceptable for discharge direct to the sewer. These oil levels can range from 300 to 800 ppm at this point in the system and a further reduction is required. This reduction is accomplished through the filter units that are shown.

THE ADSORPTION FILTERS

Please refer to figure (2) which is a schematic diagram of the filters. The deep bed filter has always been recognized as effective for removal of solids from liquids. It has also been known that a granular type filter medium used in a deep bed filter can effectively remove minute quantities of oil from a water stream. However, the major draw back for using a filtration method for the separation of oil from water is that, until recently, there was no means by which the filter media could be reused after it was once saturated with oil from the waste water stream. Several years ago, a patent was issued for a method in which the filter media bed was cleaned by introducing steam into the media passing it through the bed in the direction counter-current to the liquid flow. For the petroleum industry this method has been used for cleaning deep bed filter media and has proved to be satisfactory. An attempt was made to apply this steam cleaning process to the waste water from an edible oil refinery and it was unsuccessful. The problem encountered was that, after several backwashings using steam to clean the media bed, the temperature of the steam started to polymerize the residual oils that were on the filter media, and was actually steam cooking the media to form a cemented mass which eventually became impossible to remove. In order to over come this problem, a method using chemical regeneration was developed and is now part of the process used to regenerate the filter media. Patents for this process have been applied for by GBK Enterprises, developers of the process, have been approved but have not yet been issued.

Referring to figure (2) let's go through the filtration and the back-wash process. You can see that the waste water flows to the filter from the top down, entering the filter from the left. Passes through a distributor pipe, through the mixed bed media, all of which is supported by a very dense media support bed. The water then flows through the bottom distributor pipe and is discharged as clear water.

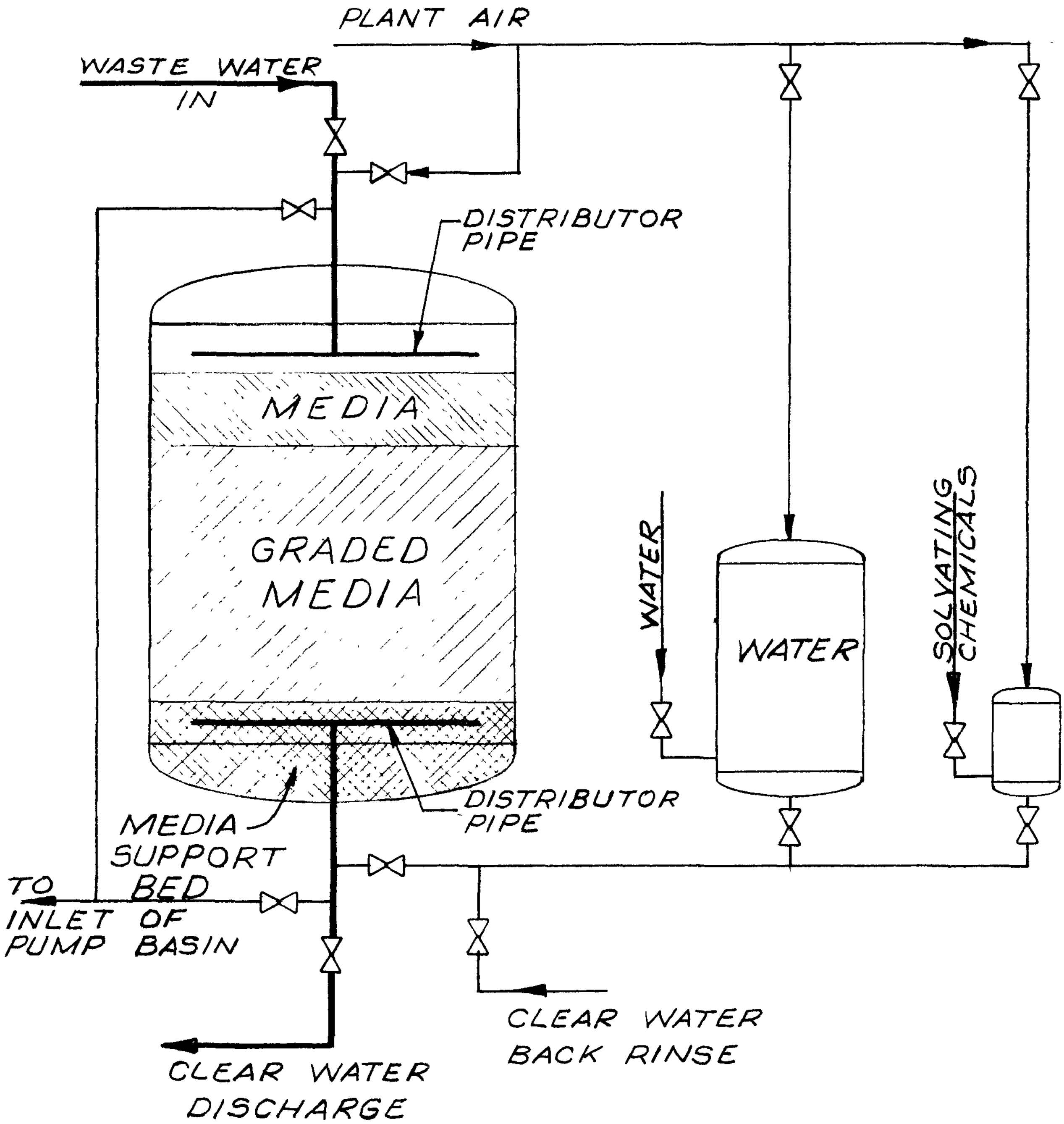

FIG 2

* GBK FILTER SCHEMATIC

* PATENT APPLIED FOR BY GBK ENTERPRISES, PLACENTIA, CA. AND APPROVED.

As the filtering process continues, the oil is stripped from the water and adsorbed on to the surface of the filter media with the clear water passing through the balance of the bed out to discharge. The media at the top of the filter is the first to become coated with adsorbed oil. As the filter run continues, the oil penetrates deeper and deeper through the media bed. If the filtering is continued long enough, eventually the oil will completely coat all the media that is in the filter and will start to break through the bottom of the media and pass out with the clear water discharge. When this happens the filter is then acting as a coalescer and the water discharge will be clear and bright, but with small droplets of oil floating on the surface. This obviously is not the intended method of filter operation, rather the filter run should be interrupted at some point that retains the total adsorbed oil within the filter bed. Normal design allows a 100% safety margin for this and we attempt to have the filter bed saturated with oil only about 1/2 the way down. This then allows for variations in oil content of the incoming waste water. At the end of the filter run, the valves on the water inlet and the water outlet are shut off and a fresh filter is put into service. The filter that has now been saturated is put through a backwash cycle which is as follows:

Step 1: Drains the water from the filter from the top down by opening the drain valve off to the inlet of the pump basin and putting plant air on the top to force this water through the bed out to the discharge.

Step 2: Shut off the drain from the bottom of the filter. Open up the water valve on the bottom of the water tank and on the bottom of the solvating chemical tank. Put air pressure on the top of both tanks and displace both the water and the solvating chemical into the filter bed. This will cover up the top of the filter media. The vent valve at the top is opened. Agitating air is allowed to continue in via the pipe system and the water tank to the bottom of the filter media coming up through the media agitating the media with the solvating chemical for a period of approximately 5 minutes.

Step 3: Shut off the agitating air, open the drain valve at the bottom of the filter, put the plant air on the top of the filter and force the mixture of oil and solvating chemical down through the main valve to be discharged back to the front end of the system where it can be acidified for eventual recovery of the oil.

Step 4: Open the vent valve at the top of the filter. Start backwash using clear water rinse up through the filter bed at the rate of approximately 14 gals./min. per square foot. Continue for a period of approximately 5 or 6 minutes. This provides a clear rinsing backwash which removes all the residual soap and solvating chemical discharging it to the front end of the system. This rinse also removes any solid material which might have been trapped in the filter media.

The filler has now been regenerated; the media is clean and ready to be placed back in service as the occasion demands.

Let's refer back to figure (1). Note that the backwash line from the filter unit is discharged to the front end of the pump basin. Since in our case the solvating chemical used during the backwashing cycle has been caustic soda, we have formed a sodium soap in the filter during the backwashing. When this sodium soap is drained and placed to the front end of the system, the soap is then re-acidified to break out whatever oil is in the soap. Most of this oil floats out and is collected immediately at the surface of the pump basin. Some of it will pass on through and be collected in the oil-water gravity separator and only a very small amount of it will eventually be circulated back to the filter. From this you can see the total oil recovery is not only achievable but is done in a manner that uses no chemicals that are not already used in the processing of vegetable oils. There has been no contamination from polymers, alum, lime, etc., all of which have been known to interfer with the acidulation recovery process.

PERFORMANCE DATA

Please refer to Table (1). Table (1) shows the results of the system operation with samples taken at the sampling points depicted in Figure (1). We have the hexane extraction value on water samples composited over a 24 hour period. Samples were collected on the waste water from the pits, on the waste water from the gravity clarifier and on the water from the GBK Filter. This data was collected between July 18 and August 3, 1973 with a single filter vessel installed. When the filter vessel required backwashing it was taken off the line, put through the backwashing cycle and then put back on the line. During this two (2) week test period the system was completely manned 24 hours a day by Engineering personnel and Engineering assistants. From the data you can see that the average value for hexane extraction leaving the pump pit during this test period was 1,325 mg/l. From the gravity clarifier the F.O.G. averaged 314 mg/l and from the filter unit F.O.G. average was 54 mg/l. The average F.O.G. reduction between the pit and the outlet of the Rheem Separator was 1,011 mg/l. The average F.O.G. reduction through the filter unit was 260 mg/l. This works out to a 78% reduction through the gravity clarifier separator and a 22% reduction through the filter unit. You will note that with the exception of July 26 all values were under 100 mg/l from the filter unit. The average being 54 mg/l which was very close to the original objective.

Please refer to Table II. Table II shows data collected during the start-up of the three (3) filter vessel installation in December of 1973. Once again the values show hexane extractions in mg/l for 24 hour composite samples collected across the system in the various sampling points as shown in Figure (1). Here with the whole system in operation, but with plant operators manning the system, the following data was generated. You can see that the average performance during the period showed the water going to the clarifier at 1,336 mg/l. The water to the filters at 424 mg/l if we exclude the rather questionable data for the 14th and 15th, or a value of 734 mg/l if we include the questionable 14th and 15th data. Water from the

TABLE I

HEXANE EXTRACTIONS DURING ENGINEERING TEST JULY - AUG. 1973

MG/L

	FLOW GPM	FROM PIT (2)	FROM RHEEM (3)	FROM GBK (4)	TEMP. of	REMARKS
July 18, Wed.	--	178	160	12	---	Deodorizer Pit Clean
19, Thurs.	--	214	179	34	---	
20, Fri.	--	961	313	35	---	
21, Sat.	170	3,051	144	46	100	
22, Sun.	125	672	271	70	104	
23, Mon.	125	525	252	42	112	
24, Tues.	125	588	232	58	107	
25, Wed.	150	1,330	688	42	129	
26, Thurs.	150	2,450	745	224	114	$2\frac{1}{2}$ Ft. of Fat in Deodorizer Basin - High Fat Loading in Blow Down.
27, Fri.	109	4,930	748	69	116	
28, Sat.	45	2,227	306	75	105	Skimming Complete and Basin Flocced.
29, Sun.	44	324	183	19	123	
30, Mon.	112	1,575	206	52	122	
31, Tues.	115	1,400	222	38	119	
Aug. 1, Wed.	116	1,810	275	40	115	
2, Thurs.	80	790	306	34	125	
3, Fri.	36	71	92	26	152	
Average	107	1,325	314	54		
Mg/l F.O.G. Reduction			1,011	260		
% F.O.G. Reduction			78	22		

TABLE II
HEXANE EXTRACTABLES MG/L IN 24 HOURS
COMPOSITE SAMPLES COLLECTED ACROSS THE SYSTEM

Date 1973	Water To Clarifier (2)	Water To GBK Filters (3)	Water From GBK Filters (4)
Dec. 10-11	--	505	79
11-12	1,291	417	49
12-13	2,644	476	59
13-14	584	212	51
14-15	*1,008	*2,288	*393
15-16	1,156	514	25
Average	1,336	*Excl. 424 *Incl. 734	*Excl. 52.6 *Incl. 109

* Data suspect; readings at (3) are higher than at (2). Mixing or mislabeled samples when compositing.

filter unit showed a value of 52.6 when the questionable data of the 14th and 15th was excluded and a value of 109 mg/l if the questionable data was included.

SUMMARY

In summary, the system described achieves the original objectives as well as additional benefits as follows:

(1) Oil recovery is made into a saleable by product without contamination from flocculating agents, polymers, etc.

(2) Hexane extraction levels are reduced to below the legal requirement of 100 mg/l commonly set in municipal sewer ordinances.

(3) Reductions in suspended solids, and B.O.D. almost proportionate to the F.O.G. are achieved.

(4) Reductions of waste water surcharges between $10 and $12,000 per month have been achieved, which amounts to $120,000 - $144,000 per year savings.

(5) The recovered oil is currently selling at approximately 14¢/#. Oil recovery is expected to approximate about 1.5 million pounds per year with a value currently estimated at $108,000 per year.

(6) Total gross savings will be between $228,000 and $252,000 per year.

You will note that the data collected during the two (2) periods is surprisingly close.

If you have any questions I will try to answer them.

BIODEGRADABILITY OF FATTY OILS: A CASE STUDY**

by

Dr. Thomas K. Nedved* and Dr. C. Fred Gurnham*

The stated objective of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The U.S. Environmental Protection Agency was charged by Congress to administer this Act, which included research and related programs, grants for construction of treatment works, standards and enforcement, permits and licenses, and other broad provisions.

One major U.S.E.P.A. task was to establish effluent limitations for "point sources" of discharges, using the "best practicable control technology currently available" by July 1, 1977, and the "best available technology economically achievable" by July 1, 1983. The ultimate goal of the Congress was "that the discharge of pollutants into the navigable waters be eliminated by 1985."

The regulations promulgated are required to "identify, in terms of amounts of constituents and chemical, physical, and biological characteristics of pollutants, the degree of effluent reduction attainable." They are also to specify the factors taken into account in identifying the two statutory technology levels noted above and in determining the control measures applicable to point sources within specific industrial categories.

One pollutant which has been the subject of a great deal of controversy and concern has been what "Standard Methods" calls "oil and grease" or simply "grease." Recommended Federal standards for this parameter in the food processing and other industry categories have been or are being developed. For example, in various subcategories of the meat products industry, a 10 mg/l limit is called for, even though this concentration is too low to measure with any reliability.

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* Gurnham and Associates, Inc., Chicago, Illinois.

** This study was in part supported by Borden, Inc.

The Federal Congress has determined that the U.S.E.P.A. should "encourage cooperative activities by the States....(and)....the enactment of improved and, so far as practicable, uniform State laws relating to the prevention, reduction, and elimination of pollution...." One of the more aggressive States, Illinois, in March, 1972, adopted perhaps the most comprehensive effluent standards ever promulgated. The standards prescribed limitations on the concentrations and properties of some 23 contaminants associated with wastewater and industrial waste discharges. The effluent limit for oil, defined as "hexane solubles or equivalent," is 15 mg/l, and the public and food processing water supply limit for oil is 0.1 mg/l. The latter limit is in the process of being eliminated, by a proposed amendment to the regulations. These figures are supplementary to the subjective general standard of "freedom from visible oil."

Because sanitary districts and other municipal and industrial treatment facilities must comply with Federal and State standards, additional local ordinances have also been promulgated. For example, the Metropolitan Sanitary District of Greater Chicago adopted a Sewage and Waste Control Ordinance to "provide for the abatement and prevention of pollution by regulating and controlling the quantity and quality of sewage and industrial wastes admitted to or discharged into the sewerage systems and waters under the jurisdiction of ....(the MSDGC)." The maximum accepted concentration of "fats, oils or greases" (hexane solubles) has been set at 100 mg/l.

The present paper is based on studies at three plants of Borden, Inc., located within the jurisdiction of the MSDGC. The Kilbourn Street ice cream plant uses cream, condensed skim milk, sweetening sirups and flavoring oils, gelatin, and nuts and fruits, to manufacture ice cream and ice cream products. Wyler Foods Company manufactures chicken and beef bouillon soup products and flavored sugar drink mixes. Cracker Jack Company manufactures a well-known caramel corn-peanut product and marshmallows. These plants were experiencing difficulties meeting the MSDGC requirements of 100 mg/l.

The MSDGC position is that, because its secondary treated effluent on occasion exceeds the Illinois Environmental Protection Agency oil limit of 15 mg/l for discharge to waterways, and because historic data indicate an average removal of 85 percent through its treatment plants, a limit of 100 mg/l is necessary for wastes entering the sewer. This position, although rational, is debatable, and the studies were planned to supply supportive evidence.

BACKGROUND ON FATTY OILS

Many of the problems surrounding the whole subject of "oil and grease" can be attributed to the following basic difficulties:

(a) the non-specific nature of the "oil and grease" standard analytical procedures;

(b) the large number and diverse nature of materials detected by the standard procedures;

(c) the sensitivity and variability inherent in the sampling and analytical procedures; and

(d) the complex mechanisms and interactions involved in the removal of these materials from the wastewater.

In addition to the above problems, which are characteristic of all oils and greases, we believe that the true "oils" should be distinguishable into two major fractions: (a) those of hydrocarbon structure, commonly of petroleum origin, characterized as "nonpolar," and (b) fatty oils, which are glycerides or esters and their related compounds, normally of animal or vegetable origin, and characterized as "polar." All oily waste materials are objectionable when they exist in free form or as floating films. The hydrocarbons are further objectionable, even when dissolved or dispersed, because of their persistence and lack of biodegradability. The claim has been made, and is further documented by these studies, that less stringent limitations would be realistic for fatty oils than the conventional limits which were intended to control refractory mineral oils.

Analytical Background

The analytical reference traditionally employed and cited in the water pollution control field is "Standard Methods For The Examination of Water and Wastewater," prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation. This is currently in its 13th edition (1971).

"Standard Methods" is divided into six parts; of interest in this study are "Physical and Chemical Examination of Natural and Treated Waters in the Absence of Gross Pollution" and "Physical, Chemical and Bioassay Examination of Polluted Waters, Wastewaters, Effluents, Bottom Sediments, and Sludges." Waters included in the first category are surface water, ground water, softened water, cooling or circulating water, process water, boiler water, and boiler feed water. In the second category are wastewaters of both domestic and industrial origin, treatment plant effluents, and polluted waters.

The 10th edition (1955) of Standard Methods describes a direct extraction technique for determining "oil and grease" in natural and treated waters in the absence of gross pollution, using a 1000-ml sample; and a Soxhlet extraction technique for determining "grease" in sewage, treatment plant effluents, polluted waters, and industrial wastes, using a sample containing from 50 to 150 mg of "grease." For industrial wastes high in "grease," a significantly less accurate (tentative) semi-wet extraction method was suggested. All three methods used petroleum ether as the extracting solvent.

The 11th edition (1960) added a section on Hydrocarbon and Fatty Matter Content of Grease, and changed the extracting solvent to n-hexane (not "hexanes") in the procedures for sewage and industrial wastes. Petroleum ether was retained as the extracting solvent in the water section. No explanation was presented for these changes.

The 13th edition (1971) is essentially the same in respect to oils and grease as the 11th except that an alternative extraction solvent, trichlorotrifluoroethane, can be used in all procedures. The semi-wet extraction method is retained as a tentative procedure which gives reproducible results but does not have the precision and accuracy of the Soxhlet extraction technique.

The editors of Standard Methods caution that "In the determination of grease, an absolute quantity of a specific substance is not measured. Rather, groups of substances with similar physical characteristics are determined quantitatively, based on their mutual solubility in the solvent used. Grease may therefore be said to include fatty acids, soaps, fats, waxes, oils and any other material which is extracted by the solvent from an acidified sample and which is not volatilized during evaporation of the solvent. It is important that this limitation be clearly understood. Unlike some constituents - which represent distinct chemical elements, ions, compounds or groups of compounds - greases are in effect defined by the method used for their determination."

Continuing from Standard Methods:

"The methods presented here have been found suitable for biological lipids and long-chain mineral hydrocarbons, when these occur at the concentrations which are usual in domestic wastewaters. However, samples which contain certain industrial wastes may require modification of the methods (1,2) due to the presence of either excessive concentrations of natural greases or synthetic or modified compounds which are not well recovered by the standard procedures....The (Soxhlet extraction) method is entirely empirical, and duplicate results can be obtained only by strict adherence to all details. By definition, any material recovered is called grease and any filtrable organic-soluble substances, such as elemental sulfur and certain organic dyes, will be extracted as grease. The rate and time of extraction in the Soxhlet apparatus must be exactly as directed because of varying solubilities of different greases in the solvents. In addition, the length of time required for drying and cooling the extracted grease cannot be varied. There may be a gradual increase in weight, presumably due to the absorption of oxygen, or a gradual loss of weight due to volatilization."

Analytical Refinements

Lisanti (3) studied the effect of using petroleum ether for the oil and grease determination procedure in the natural and treated waters section of Standard Methods compared to the grease Soxhlet extraction procedure in the polluted waters section using n-hexane. His investigations indicated that the hexane-extractable material in dairy wastewaters is approximately ten times the petroleum ether result. He suggested use of the petroleum ether direct extraction procedure to determine the "oil and grease" content of dairy wastes. Lisanti also ran treatability studies on domestic sewage and dairy wastewaters and concluded that the hexane-extractable matter contained in dairy wastes was readily biodegradable and, therefore, should not be categorized as oil and grease.

Several investigators have utilized more sophisticated analytical techniques to define the characteristic fractions of sewage and to measure changes during treatment. Farrington and Quinn (4) reported on the petroleum hydrocarbon and fatty acid concentrations in effluents from three secondary treatment plants in Rhode Island, using solvent extraction and thin layer, gas, and column chromatography. The data varied from 0.73 to 43.05 mg/l (11.8 arithmetic average) for fatty acids and from "non-detected" to 16.2 mg/l (5.9 average) for petroleum hydrocarbons. The fatty acids were partitioned into 14 carbon-atom/0 double-bond, 16/0, 16/1, 18/0, 18/1, and 18/2 acids, with 16/0, 18/0, and 18/1 predominating, which indicates oils and fats of animal and vegetable origin.

Walther (5) at Stevenage, England, determined that 32 percent of the total organic carbon in raw sewage was fatty acids and esters, by reversed phase paper or column chromatography. He further showed that 99 percent of this material was removed by biological filtration (trickling filter).

Loehr and de Navarra (6) studied grease removal at a contact stabilization activated sludge plant at Topeka, Kansas, using wet extraction and thin layer chromatography. These investigators determined that: fatty acids were the dominant lipid class in influent wastewater, followed by hydrocarbons, triglycerides, and compound lipids; no alteration of lipid types was apparent in the primary clarifiers although 45 percent of the total grease was removed; compound lipids, a minor component of bacterial lipids, increased as the degree of treatment increased; and hydrocarbons were the dominant lipid class in effluent wastewater, followed by compound lipids and fatty acids with an average observed grease removal of 84 percent and a maximum of 98 percent.

Oils in Sewage Treatment

With the continuing development of stricter standards and regulations for the protection of our environment, many regulatory agencies have imposed limits on the quantity of oil and grease which is permitted to be discharged to a sewerage system or to a receiving water body. These materials have been alleged to cause problems in sewers and sewage treatment plants: by coagulating and plugging transmission lines and pumps; by coating surfaces of tanks, diffuser plates, and by film formation on air bubbles, thus reducing oxygen transfer efficiency; by clogging mechanical equipment, thus increasing operation and maintenance requirements; by forming grease balls on secondary settling tanks; by combining with primary and waste activated sludge, causing difficulties in settling, thickening, and dewatering operations; and by creating scums which interfere with anaerobic digester operation. They also cause pollution problems in receiving streams by exerting BOD, forming slicks, and otherwise interfering with both the natural biology and the recreational usage of the waters.

Because the oil and grease test procedures are so non-specific, a more rigorous way to determine what happens to fatty oils in a sewage treatment plant would be to tag them with carbon-14 and to follow their fate. This technique was beyond the scope of our studies, but we suggest its merit to future investigators. We postulate that possible dispositions of oily materials are:

(a) some hexane-extractable material (HEM) physically separates from the wastewater and is removed during primary treatment as skimmings or as settled solids;

(b) some HEM is adsorbed on the biological floc and is removed with the waste activated sludge;

(c) some HEM is degraded to non-HEM or to CO_2 and H_2O;

(d) some HEM is converted to cellular mass, containing both HEM and non-HEM;

(e) some HEM is created from non-HEM material; and

(f) some HEM passes through the treatment unchanged.

It is also reasonable and most important to point out that raw municipal wastewaters contain relatively non-biodegradable HEM in addition to the hydrocarbons, such as complex aromatic compounds and chlorine, sulfur, and nitrogen derivatives of hydrocarbons. These substances in large part pass through the treatment system and register as polar HEM in the effluent.

OBJECTIVES OF PRESENT STUDY

In an attempt to shed additional light on some of the above issues, investigations comparing the biodegradability and disposition of hexane-extractable materials present in three industrial wastewaters and in influent sewage of the MSDGC were conducted for Borden, Inc., by Gurnham and Associates, Inc., with the assistance of Professor Roger Minear, then of Illinois Institute of Technology.

The original objectives of these studies were:

(a) to use Standard Methods procedures to determine the hydrocarbon fractions and the total hexane-extractable materials present in MSDGC untreated sewage and in equalized industrial wastewater samples. The industrial samples were diluted to match the COD of the sewage and were fortified with nutrient salts to match the COD:N:P ratios of the MSDGC sewage.

(b) to trace the degradation and conversion of the HEM fractions when subjected to biological treatment, using batch reactor techniques;

(c) to compare the HEM and hydrocarbon concentrations and distributions in the treated effluents.

The above objectives were expanded in the third phase of the study to include the following:

(d) to provide a measure of the accuracy and precision of the analytical procedures and techniques by designing a mass-balance experiment;

(e) to check potential areas of HEM and hydrocarbon loss (error) and variability (sensitivity) in the analyses; and

(f) to more accurately differentiate between the phases of HEM and hydrocarbon present initially, during treatment and conversion, and in the treated effluent.

EXPERIMENTAL PROCEDURES

Grab samples of raw sewage and return activated sludge were obtained from the MSDGC sewage treatment plant serving each particular industrial facility under investigation. Composite samples of the industrial wastewater discharges were obtained during the peak period of clean-up operations to assure representation of the broadest spectrum of wastes. Approximately one gallon of wastewater was obtained from the plant discharge stream every 10 minutes over a 3-hour period.

This program resulted in a 15-gallon composite sample representing the greatest concentration and diversity of contaminants. For the purposes of this study, such a sample was preferred to a truly proportional all-day composite. At the analytical laboratories of the Environmental Engineering Department at Illinois Institute of Technology, preliminary analyses were conducted for chemical oxygen demand, nitrogen, and phosphorus.

Three polyethylene cylindrical tanks of 40-liter capacity, with covers, were used as reactors. Aeration and mixing was provided with fritted glass sparger plates, using filtered laboratory compressed air. The reactors were located in a walk-in cooler maintained at a temperature of 20°C. The biological reactors were charged with sewage and with diluted wastewaters either in combination with sewage or with a stronger concentration of diluted wastewater. The reactors were seeded with activated sludge which had been aerated for 24 hours. Sampling and analysis commenced immediately.

The reactors were sampled before sludge addition (seeding) and at various intervals up to 48 hours. Each reactor mixed-liquor sample was analyzed for total suspended solids, volatile suspended solids, pH, and dissolved oxygen uptake rate. A 1200-ml portion was centrifuged and the supernatant liquor was analyzed for COD, 5-day biological oxygen demand, HEM by liquid extraction procedure, and hydrocarbons in the HEM. The centrifuged solids were filtered and analyzed for HEM by Soxhlet extraction procedure, and for hydrocarbons. In the third study, the centrifuged solids were filtered, washed with cold hexane, and analyzed for HEM by Soxhlet extraction procedure, and for hydrocarbons. The hexane wash also was analyzed for HEM and hydrocarbons.

DISCUSSION OF RESULTS

The complete analytical results of this study are too voluminous to be presented for publication, but the following observations are of interest.

Hydrocarbon in Hexane-Extractable Material. The three sewage HEM's contained 17, 34, and 18 percent hydrocarbon. Corresponding figures for the food plant wastewaters were 14, 20, and 31 percent. The averages of these figures, for sewage versus food wastewater, are substantially identical: 23 and 22 percent.

Degradation of Non-hydrocarbon HEM. The non-hydrocarbon HEM in the food wastewaters degraded to a greater extent than that in the sewage, as follows: Ice cream plant, 94 percent versus 82 for the sewage (the initial concentration was nearly double that of sewage, but the final concentration was lower). Soup and soft drinks, substantially complete degradation in both plant waste and sewage.

Snack foods, 77 percent versus 57, in 48 hours.

Degradation of Hydrocarbons. The hydrocarbon fraction degraded significantly less rapidly than the non-hydrocarbon HEM, in all samples. The hydrocarbon in food wastes degraded more rapidly than its counterpart in sewage, as follows: Ice cream plant, 78 percent versus 61. Soup and soft drinks, approximately the same as sewage, 57 percent versus 54. Snack foods, 41 percent versus 23, in 48 hours.

HEM in Final Solids. A major portion of the HEM remaining in the mixed liquor after treatment is associated with the solids: Sewage, 38 and 72 percent. Ice cream plant (2 tests), 49 and 50 percent. Soup and soft drinks (2 tests), 60 and 63 percent. Snack foods, major portion associated with the solids. A large part of the HEM associated with the sludge solids is hydrocarbon, in comparison with the hydrocarbon fraction in the raw waste; this reflects the slower degradation rate of hydrocarbon: Sewage, variable, 35 and 25 percent in the two weak sewages, almost 100 percent in the strong sample. Ice cream plant, 59 and 41 percent. Soup and soft drinks, almost 100 percent. Snack foods, 48 percent.

The third, on snack food wastewaters, was run in more detail, leading to the following additional results:

HEM as Fraction of COD. In the raw sewage sample, one percent of the liquid-phase COD was HEM, compared to 0.06 percent in the snack food raw waste.

Distribution of HEM and Hydrocarbon. Extremely small concentrations of HEM and of hydrocarbons, approaching minimum detectable limits for the respective analytical procedures, were found in the raw sample filtrates, the centrifuged and filtered supernatants, and the hexane washes except the 48-hour sample. These items can reasonably be eliminated from the mass balance estimates. Large but random differences occurred in the attempted mass balances, which therefore require individual study and cannot be summarized at this time.

CONCLUSIONS

The data presented demonstrate that non-hydrocarbon hexane-extractable material (HEM) of animal and vegetable origin, such as is present in food processing wastewaters, is substantially removed when subjected to biological treatment.

The HEM in each of the three food plant wastewaters studied is more readily degraded than the HEM in municipal sewage.

The hydrocarbon fraction in the HEM degrades less readily than the non-hydrocarbon fraction; but the food waste hydrocarbons degrade more readily than the sewage hydrocarbons.

A major part of the HEM remaining after treatment is associated with the solids portion of the mixed liquor, strongly suggesting a conversion of initial HEM to a biologically associated form. It was not possible, however, to explore the distribution and interconversion of HEM between nonviable solids (dead cells and other organic or inorganic matter) and viable solids (live, functioning bacterial cells); nor, in the latter, to distinguish between adsorbed and component HEM.

RECOMMENDATIONS

The Federal Environmental Protection Agency (U.S.E.P.A.) has taken the position that a secondary sewage treatment plant can be expected to achieve substantial removal of "compatible" pollutants, and it is therefore not appropriate to require industrial users to achieve "best practicable control technology currently available" for this group of materials. U.S.E.P.A. has further stated (7) that fats, oils, and greases of animal or vegetable origin may be classified as "compatible pollutants." In consideration of all of the above, the following recommendations are proposed.

(a) The differentiation between non-hydrocarbon hexane-extractable material, recognized to be a compatible pollutant, and hydrocarbon hexane-extractable material, a non-compatible pollutant, should be officially and uniformly recognized by all concerned regulatory agencies and determined by the procedures outlined in the current edition of Standard Methods.

(b) State environmental protection agencies' water pollution regulations should be amended to interpret "oil" contaminants as any free, floating, and visible oil plus dissolved and suspended <u>hydrocarbons</u> as determined by the Standard Methods procedure.

(c) Municipal regulatory agencies' regulations for discharges to public sewer systems should be amended to interpret "fats, oils, or greases" as those materials determined by the Standard Methods hydrocarbon analysis.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the laboratory assistance of Professor Roger Minear (now at the University of Tennessee) and others of Illinois Institute of Technology staff and graduate students. The project was in part supported by Borden, Inc., and special assistance was provided by Louis Janik, Corporate Environmental Coordinator.

REFERENCES

1. Chanin, G., Chow, E. H., Alexander, R. B., and Powers, J. F. Scum analysis: a new solution to a difficult problem. Water and Wastes Engg., 5, No. 6, 49 (1968).

2. Taras, M. J., and Blum, K. A. Determination of emulsifying oil in industrial wastewater, JWPCF, 40, R404 (1968).

3. Lisanti, A. F. Regulating the discharge of oils and greases in dairy wastewater. Unpublished paper, April 1973.

4. Farrington, J. W., and Quinn, J. G. Petroleum hydrocarbons and fatty acids in wastewater effluents. JWPCF, 45, 704 (1973).

5. Walter, L. Composition of sewage and sewage effluents - II. Water & Sewage Works, 108, 478 (1961).

6. Loehr, R. C., and de Navarra, C.T., Jr. Grease removal at a municipal treatment facility. JWPCF, 41, R142 (1969).

7. U. S. Environmental Protection Agency. Pretreatment of Pollutants Introduced into Publicly Owned Treatment Works. Oct. 1973. (See also 40 CFR 128.121).

ECONOMIC EFFECTS OF TREATING FRUIT AND VEGETABLE PROCESSING LIQUID WASTE

by

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ABSTRACT

A fruit and vegetable processing industry survey is the source of data on liquid waste generation, treatment and costs, and the economic impacts of waste management. Factors responsible for some of the wide variations in wastewater flows and pollutional loads are identified. The costs of processor-operated liquid waste treatment, of disposal to land and to municipal treatment, and of in-plant pollution abatement are reported. Large economies of scale are found in all of these data. The pollution control costs (in addition to current costs) that can be borne by processors are estimated. Estimates of the number of plants expected to be closed because of pollution control costs are discussed. The economic consequences of closing food processing plants are calculated. Factors affecting the economic impacts of pollution control in the industry are listed.

SUMMARY

This is a report on a survey of food processing liquid wastes generation, treatment, and costs; and of the economic impacts of their control.

The surveyed industry (canned, frozen, pickled, and dehydrated fruits and vegetables) is characterized by many small and some large plants, short operating seasons per year, a variety of plant locations, and many raw commodities.

The wastewater quantities and pollutional loads per unit of production vary enormously among the industry's plants. Factors responsible for the variations include the processed commodity, product style, percentage of the plant capacity utilized, and the method of conveying the product and solid wastes.

The costs of processor-operated liquid waste treatment and of disposal to irrigation and to city treatment are highly variable. Changes in in-plant operations to reduce water flows and abate pollution also vary widely in cost.

Economies of scale are shown in all of the treatment and disposal data.

The additional pollution control costs that can be borne by processors vary among plants and are inversely proportional to the plant's current and expected control costs. The smaller the plant, the less favorable is the comparison between feasible additional costs and the estimated costs of liquid waste control by any method.

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Estimates of the number of plants expected to be closed because of pollution control costs vary between 296 and 468, depending on the required BOD and suspended solids removal.

Assuming that about 430 plants will close because of pollution control costs, economic losses are estimated to include 27,000 jobs on average and 31,000 additional part-time jobs, outlets for 14,000 farmers, and $600 to $900 million in local economic activity.

Factors with inescapable effects on the economic impacts of pollution control include plant size, commodity, product style, plant location, and length of operating season.

INTRODUCTION

A questionnaire survey of liquid wastes generation and costs of the economic impacts of their control undertaken by the National Canners Association, American Frozen Food Institute, and cooperating processors is the basis of this report. The survey covered canned, frozen, pickled, and dehydrated fruits and vegetables. Data from more than 200 plants, processing about one-third of the industry's production, are summarized.

The surveyed industry operated about 2200 plants and processed about 30 million tons of raw products in 1968 (1; references in parentheses). Plants ranged in production from about 500 tons to 700,000 tons of raw commodity per year, and averaged about 14,000 tons. An estimated two-thirds of the plants processed 7500 tons or less. Average peak employment varied from 42 in the smallest plants to 4000 in the largest. About two-thirds of the plants were within 0.3 miles of a residential area and a majority of them operated for six months or less per year.

The industry is thus characterized by a large number of small businesses; it is highly competitive, operating on a relatively low profit margin. The before tax profit on sales for canning and freezing was 1.8% in the 1969-70 year and 48% of the industry's companies had no profit (2).

Because raw foods must be rendered clean and wholesome for human consumption, and because food plants must be sanitary at all times, large volumes of clean water are used and discharged as waste. Food processing wastewaters are highly putrescible and cannot be stored for later treatment. Unavoidable variations in wastewater strength and volume cause treatment difficulties and the variations are many-fold among months of the operating season and periods of the operating day. Treatment facilities must therefore be designed for an unsteady-state basis.

RAW WASTE LOADS

Table 1 summarizes the quantities of wastewater, biochemical oxygen demand (BOD) and suspended solids (SS) of untreated waste effluents from processing plants. The reported waste loads varied many-fold among plants processing the same commodity, confirming conclusions from other studies. An example of this variability is shown in Figure 1, distributions of the generation of BOD from peeled and from unpeeled tomatoes. Peeling resulted in more BOD on average, but the two distributions overlap broadly. Curves for other commodities and for the generation of wastewater and of suspended solids have a similar shape, with some plants generating several times as much waste as the average. Data on several commodities have been analyzed to identify some reasons for the variations.

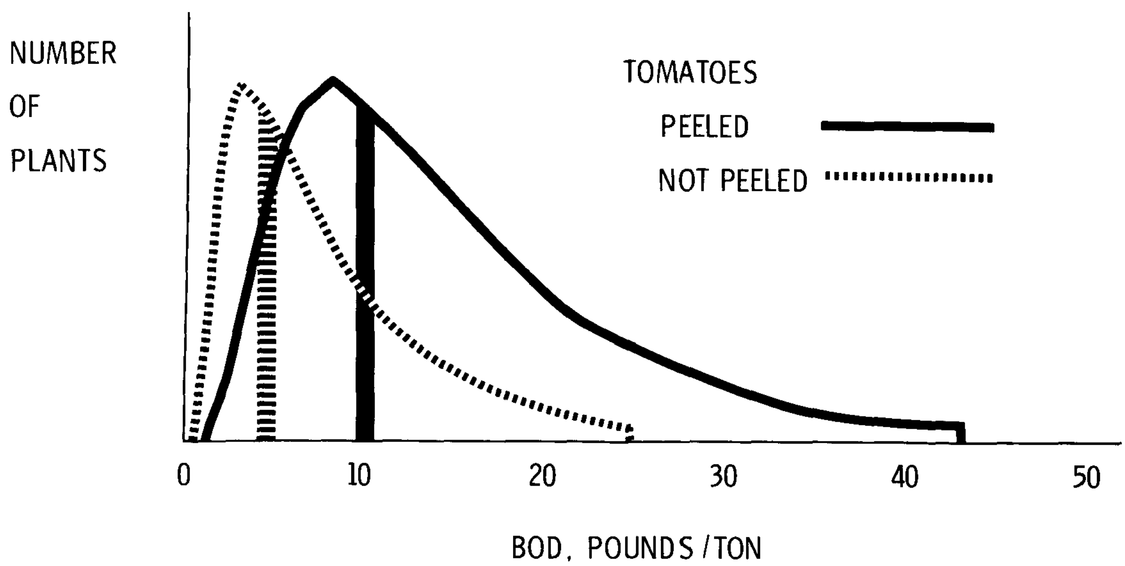

Figure 1. Variability in the generation of BOD from tomato processing.

Product style was related to the amount of water discharged in processing at least some commodities; for example, whole potatoes used more water than other styles; pulped fruits used less than average; sliced snap beans used more than other styles; and corn-on-cob used less than cream style or whole kernel corn. Less water was discharged per ton of product as the plant's capacity was more fully utilized or as the proportion of water reused in the plant increased. More water was discharged with increasing degrees of transportation of the product in water between processing steps. Conveying solid waste in water instead of "dry" increased the waste flow more often than not.

Table 1. Discharged Wastewater and Pollutional Loads

	Wastewater, 1000 gal/ton					BOD, pounds/ton					SS, pounds/ton				
Commodity	n	x	G	min.	max.	n	x	G	min.	max.	n	x	G	min.	max.
apple	19	3.1	1.9	.2	17	9	14	13	6	30	6	3.0	3.1	1.0	9.1
apricot	11	4.9	4.1	1.1	14	8	48	44	18	105					
asparagus	10	6.7	5.8	1.8	18										
dry bean	27	9.6	6.8	.9	44	6	75	61	15	239					
snap bean	49	4.8	4.0	1.1	14	15	16	9	1	72	14	5.4	4.1	.8	21
beet	7	4.2	3.3	.8	13	5	36	28	4	179	5	11	10	3.6	29
berry	10	3.0	2.7	.9	7.5										
cauliflower	5	5.8	5.1	1.5	18										
carrot	19	3.9	3.3	1.0	11	8	28	25	8	72	6	19	13	1.8	86
cherry	11	4.9	4.1	1.3	13	5	20	15	2	94					
citrus	8	2.3	2.1	.8	5.6										
corn	31	1.7	1.4	.4	5.1	16	21	18	6	55	10	9.7	9.0	4.0	20
grape	6	3.0	1.8	.2	18										
lima	10	6.8	5.8	1.8	17										
pea	40	4.7	4.0	1.2	13	18	36	32	12	88	10	12	10	2.6	41
peach	21	3.1	2.8	1.1	6.9	13	44	39	13	118	8	7.5	6.5	2.0	21
pear	15	4.0	3.7	1.6	8.8	6	31	28	10	78	8	7.0	6.1	1.8	20
pepper	12	4.6	4.4	1.6	12										
potato	21	4.7	4.0	1.3	12	11	50	45	17	118	9	43	27	2.6	297
pumpkin	11	2.9	2.1	.4	11	5	32	28	9	87					
sauerkraut	11	1.4	.8	.1	6.8										
spinach, gr	21	7.0	5.9	1.7	21	6	12	8	1	85					
squash	6	7.4	7.0	3.2	15										
sweet potato	9	4.8	4.0	.9	18										
tomato	47	1.7	1.3	.3	5.2	23	9	7	2	28	20	8.8	4.9	.3	72
turnip	6	7.3	6.6	2.5	18										

n = sample size;
x = arithmetic average
G = geometric average
min. and max = calculated 95% limits

The generation of BOD was influenced by product style. For example, the BOD load from tomatoes was largely determined by the proportion peeled. BOD generation declined as the proportion of pulped style increased for several commodities. Transporting the product in water was very highly correlated with BOD generation for snap beans and was generally related for other commodities. Conveying solid residuals in water increased BOD for some commodities. The generation of suspended solids was influenced by about the same factors as those affecting BOD.

All of these effects of processing operations on waste generation were expected.

An estimated 100 billion gallons of wastewater were discharged by all the plants together. They reused about 200 billion and the amount that would have been needed with no second use was about 300 billion. By these estimates, the industry reused two-thirds of its water, thus conserving an important resource but at the same time increasing the pollutional strength of its waste streams.

The total amount of BOD generated (before any treatment except screening) was estimated at about 800 million pounds and suspended solids generation was about 500 million pounds. The concentration of BOD in the wastewater before treatment was therefore 960 parts per million (ppm). If there had been no reuse of water, the concentration would have been 320 ppm. Corresponding figures for suspended solids were 600 ppm actual and 200 ppm without reuse of water. Without reuse the concentrations would be comparable to those of domestic wastewater.

COSTS OF LIQUID WASTE CONTROL

The costs of liquid waste control compiled from the survey are divided among four systems:

1) treatment by lagoons, aeration, or other systems for reducing the strength of the wastewater;
2) disposal by irrigation, including pre-irrigation treatment costs;
3) disposal to municipal sewage plants, including pre-treatment costs; and
4) in-plant changes to reduce wastewater flows or the generation of BOD or suspended solids.

Both existing systems and near-future systems for which cost and efficiency estimates were available were compiled. Summarized cost estimates are presented in Figures 2 through 5, necessarily using different bases for different systems. The costs of "treatment" depend critically on the percent of BOD and suspended solids removed but removals are unknown, irrelevant, or only partly relevant for irrigation and city disposal; both waste flow and BOD-SS reductions are important in in-plant abatement systems. Except for the percent removal in Figure 2, all the data in Figures 2 through 5 are plotted against logarithmic scales to accommodate the wide range of numbers.

Treatment Costs

Estimated costs for plants operating their own treatment systems are given in Figure 2, where the plant size is plotted against the percent removal of BOD and suspended solids combined. Contour lines show smoothed averaged costs per ton of raw product. These are geometric averages (smaller than arithmetic averages would be because the data are skewed). They are also conservative when compared to reductions required by regulations because the percent removals entered here are averages. A plant with a listed removal that coincided with a regulation would be in violation half the time. Other evidence shows that the costs of treatment rise more steeply going both upward and to the left than indicated by the simplified analysis drawn on for Figure 2.

Larger plants had higher absolute costs but their increase was not proportional to the increase in size, so that smaller plants had much higher costs per ton of product. Economies of scale like this showed up repeatedly in the survey.

As for nearly all the data in this survey, the costs of company operated treatment plants were highly variable. Trends of the kind indicated by the lines on Figure 2 were clear, but some plant costs were considerably higher and others considerably lower than expected. The reasons for a few of these differences are known, but in general they are unexplained.

Irrigation costs

Estimates of irrigation costs are in Figure 3, with wastewater flows plotted against plant size in tons and contour lines for the cost in dollars per raw ton. The water flows are conservative estimates of the peak flows per month. Economies of scale are again large.

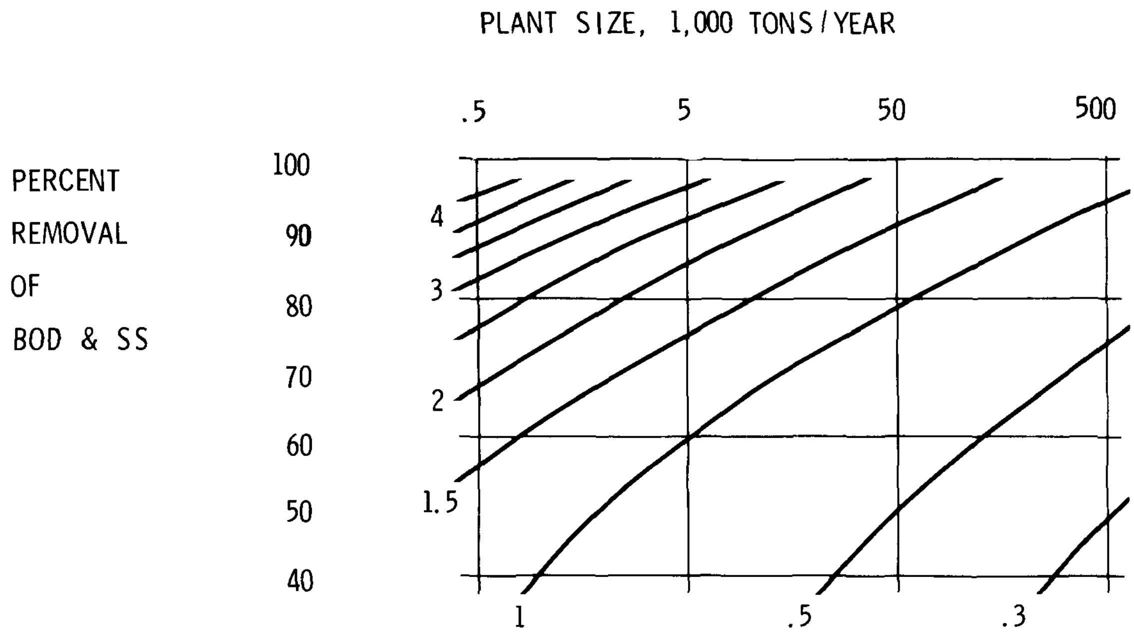

Figure 2. Costs of company-operated treatment systems, $/ton.

Contour lines show dollars per ton of raw product: Geometric average costs from (a) one-eighth of 1972 capital cost plus (b) operation and maintenance costs.

Pre-treatment of the wastewater before irrigation varied from screening only (most plants) to fairly elaborate treatment. The pre-treatment costs were included as part of the irrigation costs since they must have been required or else found advantageous to the processor.

City Disposal Costs

City treatment plant disposal costs are estimated in Figure 4; waste-water flows are plotted against plant size in tons, and dollar per ton costs are shown by contour lines. Economies of scale are again evident. The degrees of pre-treatment of wastewater disposed of at municipal plants varied widely and the pre-treatment costs were included with city costs for the same reason as for irrigation pre-treatment.

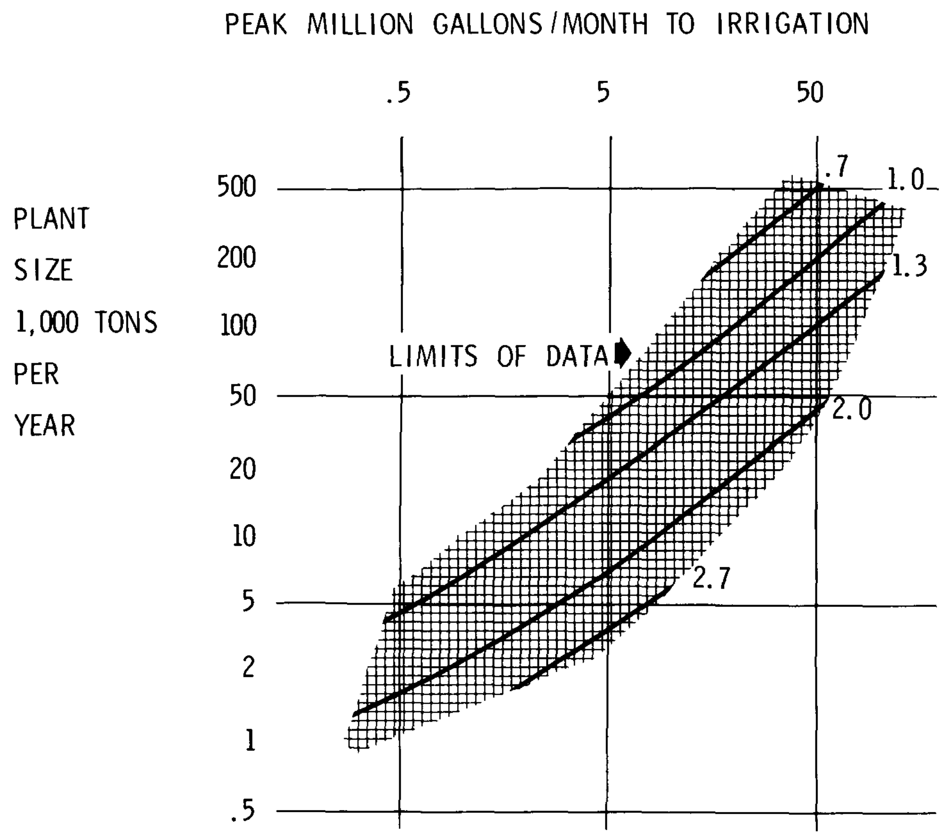

Figure 3. Costs of irrigation disposal, $/ton.

Contour lines show dollars per ton of raw product: Geometric average costs from (a) one-eighth of 1972 capital cost plus (b) operation and maintenance costs.

In-plant Abatement Costs

The estimated costs of reducing wastewater flows and the quantities of BOD and SS generated by changes in in-plant operation are presented in two ways, in Figure 5 and Table 2. The variability of these costs is shown in Figure 5, where degrees of abatement are plotted against cost. The former is in units of a million gallons wastewater plus 10,000 pounds BOD and suspended solids reduction. The costs were extremely variable, with differences of 100-fold among plants of the same size to achieve the same degree of abatement. Wide variability still remained when the 25% of plants with the most extreme costs or degrees of abatement were omitted, resulting in the inner area of Figure 5 (which surrounds the plotted points of the remaining plants). The costs of in-plant changes to abate liquid waste are listed in Table 2 for a series of plant sizes and for different degrees of wastewater and of BOD plus SS reductions. The figures in the table are the average costs of from one to nine plants. They show with some inconsistency economies of scale and increased costs for increased returns. The in-plant abatement costs in this report are incomplete. For example, many companies did not give the costs of extensive water re-use systems.

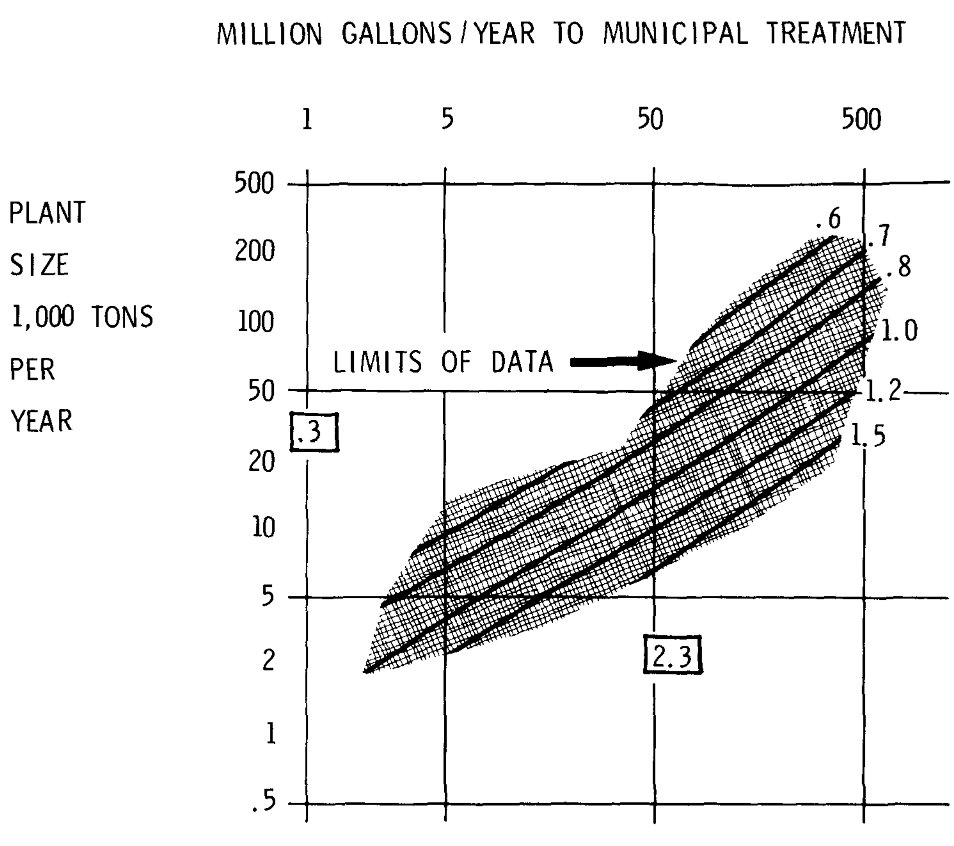

Figure 4. Costs of disposal to municipal treatment, $/ton.

Contour lines and squares show dollars per ton of raw product: Geometric average costs from (a) one-eighth of 1972 capital costs plus (b) operation and maintenance costs (both for pretreatment) plus (c) sewer charges.

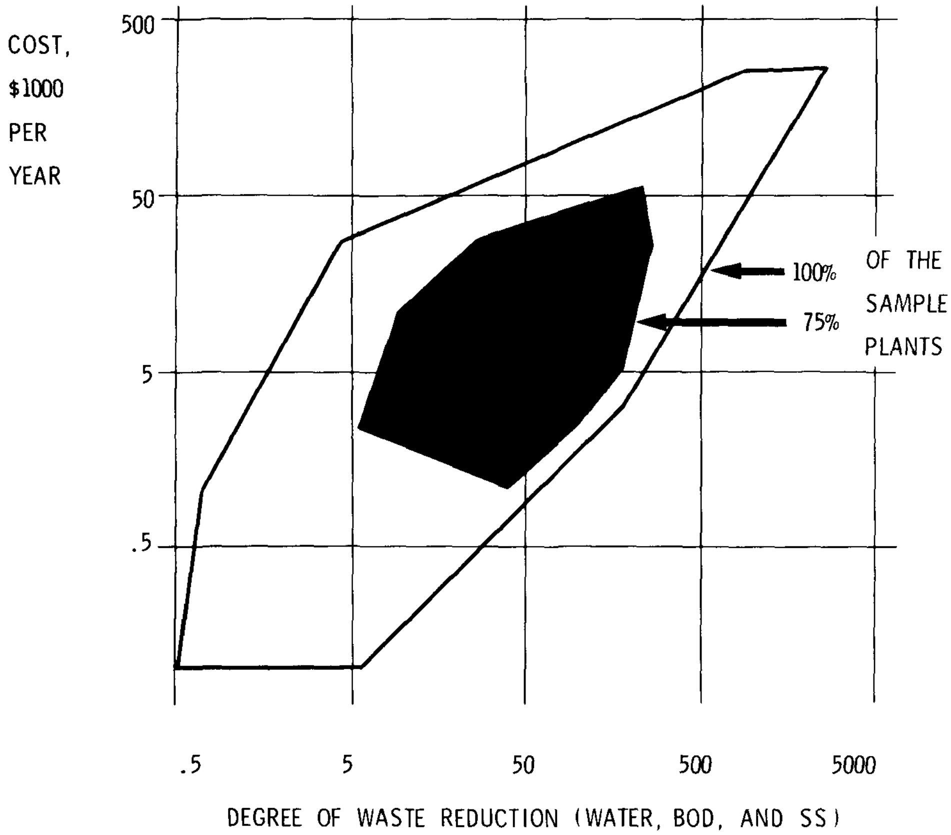

Figure 5. Variability of costs of in-plant changes to reduce pollution.

The reported in-plant changes mostly reduced waste flows or BOD and SS by small percentages, far too little to meet any likely regulations.

Economies of scale were also conspicuous in the costs of specific in-plant changes which reduce liquid effluents and pollutional loads. For example, the capital costs of new peeling methods which reduce BOD and SS generation increased only 2.5-fold with a 10-fold increase in plant size; and the capital costs of cooling towers went up 3-fold with a 10-fold plant size increase.

Table 2. Average Costs of In-Plant Pollution Abatement*

% discharge flow reduced		0-10		More than 10	
% BOD + SS reduced		0-10	More than 10	0-10	More than 10
Plant size, 1000 tons per year	1-19	(-.08)	.92	.41	.82
	20-49	.14	.60	.28	.24
	50-99	.11	.06	.12	.27
	100-169	.08	.02	.04	.17
	170 +	.02	.42	.10	.22

*Tabled figures are dollars per ton of raw product

Current and Anticipated Costs

The estimated current costs of pollution control to the industry total about $50 million per year and the total expected in the next few years is about $90 million per year. These estimates include an annual charge for capital (12.5% of the capital costs expressed in 1972 dollars) and yearly operations and maintenance costs. They are detailed as follows, in millions: for company-operated treatment, $12 current and $24 expected; for irrigation disposal, $14 current and $20 expected; for city treatment, $15 current and $27 expected; and for in-plant controls, $8 recent and $19 expected. The capital costs (in millions of 1972 dollars) for company operated treatment systems are estimated at $50 current and $115 expected; for irrigation disposal, at $69 current and $100 expected. The expected costs (generally for 1974-75) do not include the effects of new federal limitations.

CRITICAL POLLUTION CONTROL COSTS

The survey determined what pollution control cost (in addition to current expenditures) would cause a plant to go out of business, assuming no price increase. This additional cost is named in this report, the "critical pollution control cost". Its geometric average was about $1 per ton of raw commodity processed and about two-thirds of the critical costs were between $.25 and $3.6 per ton. Twenty-eight percent of the plants reported that they could stand no additional control costs. The critical costs varied many-fold among plants of the same size. Part of the reason for the variation was the level of current and expected pollution control expenses. Plants with higher current costs and those with higher expected costs both estimated lower critical costs. The distribution plotted in Figure 6 is of critical costs in dollars per ton versus the cumulative percent of plants.

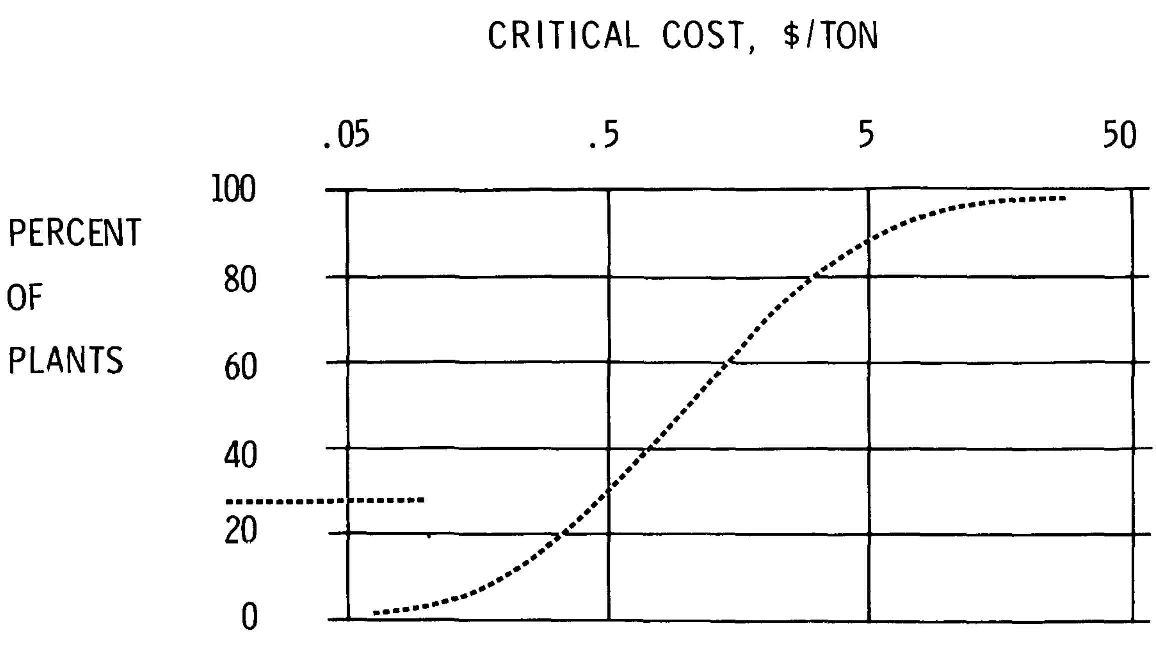

Figure 6. Distribution of critical costs of pollution control: Percent of plants with given limiting cost or less.

With data as variable as are the costs and critical cost estimates in this study, conclusions based on averages cannot be precise. Accepting $1 per raw ton as the critical pollution control cost anyway, Figures 2, 3, and 4 suggest how much abatement could be had at the breaking point for plants of different sizes, ignoring current expenditures. To operate their own treatment systems (Figure 2) plants processing 1000 tons per year could afford 40% BOD plus suspended solids removal at the critical cost. Five thousand ton plants could afford about 60% removal on average; 50,000 ton plants, about 80%. Larger plants and those with higher than average critical costs could afford higher removals, assuming they were situated where building a treatment system was feasible.

Irrigation (Figure 3) would cost more than $1/ton for plants up to about the 50,000 ton size. Even the smallest plants could presumably afford irrigation if their critical cost were $3.6/ton. However, processors are restricted in the use of irrigation disposal in other ways besides costs; for example, the soil type, topography, and nature of the groundwater must be suitable. A large majority of the states and territories impose controls on irrigation; some require "secondary treatment" prior to land disposal and many have restrictions on BOD, pH, solids, and/or other wastewater constituents. The costs in Figure 3 are from plants that have found irrigation disposal feasible; they do not reflect the costs that would be needed for arbitrarily chosen plants.

City disposal costs (Figure 4) exceed $1/ton for many plants but do not rise very much higher. Evidently most plants can afford city treatment more readily than the other forms of disposal, especially at current levels of sewer charges. However, city treatment is not available to many processors and where municipal facilities are built new, expanded, or upgraded, the pay-back policy for federal subsidies will increase sewer charges. Some very large expected increases were reported. Of the plants submitting data on current and announced future sewer charges, one out of four expected triple or greater and half expected double or greater costs.

Conclusions from the use of in-plant changes to abate pollution are much more difficult to arrive at because of the extreme variability of the data. Table 2 shows costs below $1/ton for in-plant control, but only small quantities of pollutants were reduced on average. Furthermore, the data do not adequately reflect the increasing costs of abatement as the amount of it already achieved increases. Most of the flow and strength reductions reported were small percentages of the totals. Costs may also be expected to go up when operating changes for abating pollution require further modification to maintain sanitation and meet noise control regulations.

ESTIMATED PLANT CLOSINGS

An earlier study for the EPA (3), based on highly generalized control costs and levels, concluded that 100 plants in the industry would go out of business because of pollution controls alone and that 300 more would close down sooner than otherwise because of these costs. The following estimates of the number of plants that will be closed because of pollution control costs are based on data from the current industry survey.

The estimated numbers of plants of each size, given below, are modifications of estimates in reference (1) to account for the smaller segment of the industry in the current survey:

Plant size 1000 tons	.5	1	2	5	10	20	50	100	200	500
Estim. no. of plants	150	400	500	400	300	200	100	70	20	10

Twenty-five percent of the plants were estimated to operate their own treatment systems; 31% to use irrigation disposal; and 50% to discharge to city treatment.

The number of closed plants that operate their own treatment systems was estimated in two ways. Table 3 lists the number of plants whose estimated treatment costs (Figure 2) would exceed their critical costs (Figure 6), using the first method of estimation. Current expenditures were taken into account.

Table 3. Plants with Own Treatment Closed by Pollution Control Costs (Method One).

Plant size 1000 tons		.5	1	2	5	10	20	50	100	200	500	Total
Re-quired	60%	3	6	7	4	2	2					25
percent	80	8	18	22	16	10	6	2	2			85
removal of BOD	90	13	32	37	26	17	10	4	3	1		144
plus SS	95	17	43	50	34	24	15	7	4	1		197

The number of closed plants using the second method of estimation included plants disposing of wastewater to irrigation and to city treatment as well as plants with their own treatment systems; see Table 4. By the second method of estimation about the same number of plants with their own treatment would be closed down regardless of the required percent removal of BOD and suspended solids. These estimates were based on costs of treatment or disposal and an assumed competitive cost incurred by large plants; they reflect economies of scale but do not involve the subjective critical costs.

Table 4. Plants Closed by Pollution Control Costs (Method Two).

Plant size 1000 tons	.5	1	2	5	10	20	50	100	200	500	Total
No. closed treatment	21	42	41	25	14	5	2	1			151
No. closed irrigation	7	12	12	7	4	2	1	1			46
No. closed city	22	56	68	48	22	6	2	1			225

The estimated total number of plants closed because of costs of pollution controls is between 296 and 468, depending on the required BOD and suspended solids removal. They are mostly small plants and tend to be located in or near small communities. Assuming that about 430 plants would be closed, the social impacts would include the loss of about 27,000 jobs on average and 31,000 additional part-time jobs; $140 million per year in wages; outlets for 14,000 farmers and $160 million in payments to farmers; and the generation of between $600 and $900 million in local economic activity.

Some of the survey questionnaires asked if there was a possibility that the plant would go out of business because of pollution control costs. About one-third of the responses were "yes", including affirmative answers from all sizes of plants, very small to very large.

INDUSTRY SEGMENTS FOR EPA EFFLUENT GUIDELINES

In setting effluent guidelines under the 1972 Water Quality Act Amendments, the Environmental Protection Agency (EPA) is to give separate consideration to different segments of an industry according to the degree of economic impact of the controls on each segment. Plant age, commodity and style, plant size, plant location, and operating season are discussed in this section as bases for such segmentation of the fruit and vegetable processing industry.

Plant Age

Plant age is listed as a consideration in the 1972 Act and may have significant effects, especially on the costs of abating pollution. The data on plant ages in this survey have not been developed, partly because most plants are a conglomeration of old and new equipment regardless of the time they have been on the same site. In data from the solid waste survey (1), plant age and location were clearly correlated. The older the plant, the less was the distance to the nearest residential development, no doubt because of the expansion of cities, towns and suburbs. The effects of plant age would therefore be associated with the effects of location, discussed below. Preparation procedures and equipment might also reflect plant age, but data on this relationship have not been analyzed.

Commodity and Style

That different commodities generate different quantities of wastewater and pollutants has been recognized by EPA in previous and current studies leading to effluent guides. The extremely wide variations among plants processing the same commodity are equally significant. As discussed in Section III, the product style was responsible for differences in generated waste loads. Enough significance has been found to show that the EPA must take style into account in order to apply effluent limits without severely uneven economic impacts.

The quality of the raw product (for example, its proportion of culls and the maturity and size of individual units) also affect the generation of waste. These factors vary among regions, years, and days within the same year; they are strongly influenced by weather. However, there are no standard measures of raw product quality for many commodities and an allowance for variability may have to substitute for the industry segmentation based on these factors.

Preparation procedures and types of equipment also influence the generation of wastes. Among the restrictions on processors in choosing what procedures and equipment to use are sanitation requirements, product style and quality requirements, and cost requirements for introducing changes. It seems doubtful that the EPA could practically or legally require the use of particular procedures or equipment, but the effluent limits could differ depending on the existing situation in different plants.

Plant Size

Plant size is a major factor in the economic impact of pollution controls. This fact could be incorporated by not applying the EPA effluent limits at all to plants below a particular size and by applying them on a sliding scale to plants above this size. The plant size cut-off used in the following illustrative data is 7500 tons of raw product per year.

Justifications for the proposed cut-off include:

(A) Much of the record-keeping, checking and testing by the EPA, state agencies, and small plants would be eliminated; about two-thirds of the industry's plants are smaller than 7500 tons per year. Only a small fraction of the industry's generated wastes would be excused from the EPA limits; these plants generate an estimated 12% of the industry's total BOD and suspended solids and 14% of the liquid waste flow.

(B) The wastes from small plants would not be released without control. About half the small plants discharge to city treatment systems; nearly all the rest have their own treatment, including irrigation. Discharges would be subject to limitations depending on the quality requirements of receiving waters and on prohibitions against creating a nuisance; these requirements would over-ride EPA limits in any case.

(C) The smaller the plant, the higher are the relative costs of irrigation, other company-operated treatment, disposal to city systems, and in-plant pollution abatement. The same effluent limit applied to all plants would therefore affect small plants more severely than large plants. This industry is highly competitive and operates on a small profit margin. The economic analyses in reference (3) show clearly the problems created for small plants by economies of scale: smaller plants would need higher price increases than larger plants to achieve the same level of pollution control; the price differences would force the smaller plants out of competition; and in addition, capital for expanded controls would less often be available to smaller plants.

(D) A large majority of the plants estimated to be closed by pollution control costs are smaller than the cut-off size. Even with the suggested cut-off in the application of EPA limits, some of these small plants are expected to close. Many of them are estimated to be unable to meet the city disposal costs, for example, and the justifications for cutting off EPA limits could also apply to relieving small plants from re-paying the federal grants used to build or improve city sewage works. In addition, small plants would still be subject to the alternative controls under (B) above.

The justification for a sliding scale effluent limit for plants larger than, say, 7500 tons of raw product per year are like those above under (B), (C), and (D). Since the relative costs of pollution control increase in inverse proportion to plant size, so will the impacts of a constant EPA effluent limit.

Location

Liquid waste treatment requires land. For irrigation disposal, the land must be not only available, but also suitable in several characteristics. A city treatment plant must be within reasonable reach if this method of disposal is to be used. For treatment or disposal at a distance from the processing plant, the costs of rights of way, piping and pumping must be financially bearable. Treatment and disposal systems are affected by climate.

In addition to the land cost and climatic differentials associated with plant location, the EPA should consider the relative effects of a closed plant on its local economy. Processing plants may employ a large percentage of the local work force and provide a vital outlet to local farmers.

Operating Season

Treatment systems must be scaled for peak flows and organic loads; city sewer charges may be based on peak demand. Processing nearly all fruits and vegetables is highly seasonal. On average, the plants in this survey operated during about eight months of the year and processed 75% of their raw tonnage in four months. The operations beyond the main seasonal items are commonly repacks of partly processed commodities or other processing that generate small effluents and waste loads. Even during the heavy season there are many-fold fluctuations in day to day processing tonnage. The proportion of the plant capacity utilized in processing a commodity commonly averaged about 70 to 80%. The excess capacity is needed for peak days during the season and for bumper crops that may occur any year. The immediate availability of most raw commodities depends on the weather and most of them cannot be stored to even out the flow of deliveries to processing.

The differences in operating seasons among processing plants depend on commodity, region, and other factors. The seasons for the same commodity and same region vary from year to year as do the percentage utilizations of plant capacity. Because of variables like these, the classifications of seasonality required by the EPA to avoid disproportionate economic impacts on different plants may have to be somewhat arbitrary.

REFERENCES

1. Katsuyama, A. M., Olson, N. A., Quirk, R. L., and Mercer, W. A., 1973. Solid Waste Management in the Food Processing Industry. NCA under Contract No. PH 86-68-138, Environmental Protection Agency. Distributed by National Technical Information Service, PB-219 019.

2. Internal Revenue Service. Almanac of Business and Industrial Financial Ratios (Issued annually).

3. Agri Division, Dunlap and Associates, Inc. 1971. Economic Impact of Environmental Controls on the Fruit and Vegetable Canning and Freezing Industries. For the Council on Environmental Quality (P-585).

INVESTIGATIONS OF FISHERY BYPRODUCTS UTILIZATION: RUMINANT FEEDING AND FLY LARVA PROTEIN PRODUCTION*

by

John H. Green**, Susan Cuppett*** and Harry J. Eby****

INTRODUCTION

As technicians learn how to collect and handle waste solids or sludges, methods must be found to dispose of this waste material. We feel that endeavors to find uses for solid/sludge byproducts is one of the ways to alleviate the economic burden of pollution abatement. This is particularly true in the smaller, often seasonally operated food producing/processing industries where expensive disposal equipment would be a great economic burden.

Methods of solid/sludge disposal, such as incineration, landfill, composting, and pyrolysis either present an economic burden to the smaller business operator in terms of expensive equipment and hauling costs or, in the case of the coastal based fisheries, are not always practical because of the location of nearby high real estate valued resort areas or because of tide-water land, rocky outcroppings or other terrestrial conditions which are not usable as disposal sites. In the case of agronomic solid/sludge wastes, with which part of this report is concerned, we are faced with the disposal of massive amounts of carbohydrate material of low economic value and presenting the potential of expensive equipment or treatment if physical or chemical methods of disposal are to be considered. In addition, such disposal destroys a natural resource.

Our objectives, therefore, are to find uses for solid/sludge wastes that are practical, do not require expensive equipment, can be seasonally operated, and are applicable to the characteristics of the waste under consideration. This latter is most important. The utilization of the waste must take its characteristics into consideration. Not every fishery, agronomic, or animal waste is instantly a potential feed or fertilizer.

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*Funded by the U. S. Department of Commerce, NOAA, NMFS, and by the U. S. Department of Agriculture, ARS.
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In the case of fishery wastes, the amount and quality of the protein, the amount of lipid material present, and the chemical and physical characteristics of the waste must be considered. Making a fish meal out of a fishery waste may not always be a wise choice. For example, fish solubles, a case in point for this report, has the characteristic of being extremely hydroscopic. Any attempt to dry this material to be sold in bulk as a fish meal would be impractical because the material would regain water, cake, and eventually undergo microbial decomposition. Hence, fish solubles are condensed to only 50% solids, acidified, and stored or shipped under anaerobic conditions in steel tanks. Fish solubles are desired and used in small quantities in poultry feeds because they contain an unknown growth factor (UGF). However, its protein quality (amino acid profile) is not as good as that of the high-quality parent product, fish meal (menhaden or other species), and the fat content of fish solubles is too high to be considered for abundant uses in animal feeds. The fisheries people have known about these and other characteristics of fish solubles for many years, hence they are aware that making a fish meal out of a fishery waste is not the answer to everything. Characteristics of fish solubles are described in reports (4,8,9).

In the case of agronomic wastes, such as vegetable/fruit peelings or animal wastes, we have collecting, hauling, and stabilization costs to consider versus the costs of existing commodities, such as cereal feeds and chemical fertilizers. In the situation dealt with in part of this report in which animal wastes are being considered for reuse as animal feeds, we have health considerations--the potential recycling and/or concentrating: animal diseases; pesticides found in the original feeds or used in the animal barns; and antibiotics used to treat the herds or flocks of animals.

Our endeavors as presented in this report and our report of the last conference (5) are efforts to find suitable byproduct utilization at a minimum of processing. We have taken a biological, or rather a microbiological, route in our quest for possible solutions. About our only innovation presented here is that we have chosen alternatives which are perhaps a little different than alternatives that have been considered in the past.

There is another consideration that this report takes into account. Most organizations or industries are interested in finding solutions for their particular pollution problems and uses for their recoverable byproducts. This report presents research done on combinations of byproducts from different industries for the mutual benefit of both. We believe in the philosophy that in this present day and age of modern technology and resulting monstrous wastes to consider for disposal, the old concept of combining wastes for mutual benefit has its merits. We have been looking for new uses for the fishery byproduct, menhaden fish solubles, bearing in mind that what uses we find for this slurry-like material could be applied to some other fishery slurries and "wet" solid wastes. The primary market for fish solubles is in poultry feeds and the demand for this application is based in part on the UGF. The protein of fish solubles contains all known natural amino acids; however, the quantity of essential amino acids needed for monogastric nutrition is only good, not excellent. Hence fish solubles does not rate as a high-quality protein, like fish meal, to be used as primary protein source in poultry feeding.

In addition, the residual fish oil of "stickwater" is condensed with the production of fish solubles and results in an elevated fat content (approximately 10%) not desired in feeds. Poultry feeders and others use a limited amount of fish oil as an energy source in feeds, but too much fish oil in diets result in a fishy flavor in poultry or other meats (7). Hence the fat content also limits the use of fish solubles.

The prices of fish meal and even fish solubles have recently been abnormally high due to the world shortage of fish meal and soybean meal. However, prices are beginning to return to normal which means that fish solubles will be selling at a price nearly breakeven with its cost of production, storage, and shipment. Should the UGF in fish solubles be identified, and poultry experts and researchers have been trying to do this for years, the poultry feed market for this byproduct will suffer. For this reason, we have been looking for new uses for fish solubles, which might also be applicable to other fishery wastes. Although this report is specific for the utilization of certain fishery and agronomic byproducts, we hope the concepts presented here will have application to other food processing wastes, to other agronomic wastes, and perhaps even to other industrial or municipal wastes.

RUMINANT

One potential use for fish solubles, or other fishery wastes, investigated by the animal nutritionists at our Laboratory was ruminant feeding. Cattle can be fed a diet of cellulose and urea. However this is only a maintenance diet which results in low yields of meat or milk. Also, a diet too high in urea is toxic to the animal. Dr. W. M. Beeson's Animal Nutrition Group at Purdue University has been exploring the efficiency of adding various inexpensive protein substances as a "rumen stimulatory factor" or "urea supplement" in high urea diets to increase urea utilization in cattle (10). For this purpose, he has employed corn distillers dried solubles, dehydrated alfalfa meal, and fish solubles. These protein-containing substances added to high-urea diets stimulate the rumen microbes to better protein synthesis, hence better utilization of the total nitrogen in the diet. Low to medium quality protein will suffice because essential amino acids required in monogastric nutrition are not an important factor in ruminant microbe nutrition. The microbes in the rumen transform ingested materials into nutrients the animal can absorb and use.

The use of fish solubles as a "rumen stimulatory factor" have been under consideration by our Laboratory's Animal Nutrition Group for over 3 years. We also became impressed by the large volumes of caustic potato peel waste that would be generated by the new "dry" caustic peeling process. We had a wet, acid, proteinaceous, high-fat slurry to find a use for, the vegetable and fruit industries have a wet, caustic carbohydrate waste for which to find uses. The combination of acid fish solubles with caustic vegetable/fruit peel waste offered an opportunity to neutralize (pH) both products, yielding a high salt (ionic) content of a carbohydrate-protein-fat material leading to a potential supplement for ruminants. At least one researcher (6) had explored "dry" caustic potato peel waste for cattle feed. We combined our experimental efforts and explored fish solubles as a "rumen stimulatory factor" both alone and in combination with "dry" caustic potato peel waste on lambs.

Our Laboratory's animal nutritionists decided to use fish solubles and a mixture of fish solubles and caustic potato peel waste in ruminant liquid feed supplements. Liquid feed supplements, a combination of vitamins, minerals, high energy nutrients, sweeteners and nitrogen, are used nowadays in feed lots or dairy herds to supplement alfalfa, grass and cereal feeds.

The first two attempts to run the experiment on lambs had certain mishaps. A third experiment was reasonably successful in its completion. The results for the third experiment are as follows:

When fish solubles was added to complete diets for growing lambs (solubles equaled 0.3 to 0.6% of the complete ration), no significant differences were observed in growth rates, feed efficiency, digestibility of dietary dry matter, and protein or blood protein concentrations (third trial only). No UGF activity could be demonstrated from either the fish solubles and/or potato wastes. Based on these findings, it is concluded that fish solubles may be fed in limited amounts to growing ruminants without detrimental effects. As a substitute for non-protein nitrogen (i.e., urea) in ruminant diets, the cost of solubles (on an equivalent nitrogen basis) is prohibitive. However, as a means of utilizing wet fishery wastes, or other proteinaceous food processing wastes, ruminant feeding might serve a useful purpose. Some potential revenue from this use might help defray the costs of collection and transportation.

FLY LARVA PROTEIN PRODUCTION

In recent years the agricultural researchers at universities and the U. S. Department of Agriculture sections who are involved in animal husbandry have been experimenting with processes and methods to reuse animal droppings as animal feeds. Their concern is that many animals, expecially ruminants, are not efficient in their use of feeds and that animal droppings contain a high amount of unutilized nutrient material--waste or natural resources.

The Agricultural Research Service under the U. S. Department of Agriculture located at Beltsville, Maryland, is exploring several such feed/animal dropping recycling methods. These include composting and direct drying and pelletizing of the animal droppings. One of these methods is to grow fly larva by inoculating animal droppings with fly eggs of the common housefly

(*Musca domestica* L.). This is followed by several days of controlled rotation, aeration, and larva growth. The fly larva are harvested, dried, and ground into a protein, nutritious meal for animal feeds. The residue of composted animal droppings might also serve as animal, probably ruminant, feeds (1,2,3).

The advantage to this fly larva process is that the larva, which are grown and removed from the media are nearly void of pesticides and antibiotics which may have been in the animal droppings. This cuts down the possibility of recycling these and other unwanted materials. The fly larva, when dried, contains about 65% high-quality protein nutritionally equivalent to egg albumen. It has been shown to be excellent in chicken diets. The yields of fly larva protein are extremely low in terms of total raw product processed. Fly larva production is really the side product of the agricultural waste management system of composting animal waste. The revenue from the sale of high-quality protein for animal diets might help underwrite the cost of this pollution abatement. The sale of the residue, which is about 96-97% of the compost after removing the fly larva, would help defray other operational costs. Hopefully the total revenue would break even, perhaps yield a slight profit for the processor.

The residue contains less concentration of nitrogen than the concentration of nitrogen in the total compost prior to fly larva harvest. The residue has some value as fertilizer or even as a feed. If the nitrogen content could be increased, the residue would have even more value. In either fertilizer or feeds, the price is primarily set by the nitrogen or protein content. As materials undergo composting, the nitrogen and mineral concentrations increase due to loss of carbon primarily as carbon dioxide and to loss of water by both metabolism and by evaporation through heat generated during composting.

The experimental composting is done by adding weighed amounts of manure and other ingredients to a cement mixer and initially rotating the cement mixer to well blend all ingredients. The temperature of the compost can be controlled by aeration and ventilation. Both factors are controlled in these experiments by the amount of rotation of the cement mixers for aeration and by electric fans blowing into and around the cement mixers for ventilation, both are set on electric timers. After the raw manure has composted and mellowed for one day, a known quantity of fly eggs prepared in an entomology laboratory are inoculated into the compost mixture and allowed to develop into fly larva for five days. The fly larva which are photophobic are harvested by passing a thin layer of compost material on top of a screen which is below a set of lights. The fly larva crawl thru the screen to avoid the lights and are caught in pans below. The residue minus most of the fly larva is collected for other potential uses such as fertilizer or ruminant feeds. The harvested fly larva can be dried and ground into a meal, allowed to develop into pupae then made into a meal, or allowed to develop into flies and then prepared into a meal (1,2,3).

The original objective for adding fish solubles to the raw animal waste was to increase the nitrogen content of the residue and perhaps enhance composting. It was believed from prior research that the maximum yields for fly larva production had been approached (3). To our surprise, the growth of fly larva remarkably improved. It became evident that the presence of 2-1/2 to 5% fish solubles was affecting the growth of fly larva. The potential for increasing fly larva protein yields was intriguing.

The composting of cow manure is not easy. The texture of the cow manure makes it technically difficult; it acts like a pancake batter and gets anaerobic. One author, H. J. Eby, solved this important detail by adding a "texturizer" to break up the cow manure. In present experimental procedures, we are using 15% ground corn cobs. Future explorations could include both fiber and food milling wastes, wastes from other food processing such as chopped pea vines, peanut hulls, and, oh yes, shrimp and crab shell waste. The latter, of course, would contain nitrogen which might serve as an adjunct to the composting.

In our present experiment we are using 2.5% fish solubles which contains approximately 5% nitrogen. We have plans to explore wet wastes from a variety of fisheries as potential nitrogen sources.

For our first experimental approach we decided to explore the effects of fish solubles on the composting of cow manure without the presence of induced fly larva; therefore the fly egg inoculum was omitted. We felt it was important to see if fish solubles was having a noticeable affect on composting. It must be emphasized that what we really are doing is composting cow manure as part of an animal waste management system. Fly larva production is only the icing on the cake as a possible profitable revenue source. Smaller feed lots or dairy farms may be content with just composting. The harvest mechanism for fly larva is rather sophisticated. It would require both biological and engineering or mechanical technical ability to maintain it.

The results of our first phase are shown in Figures 1 and 2. Figure 1 shows the daily temperature readings of two composts. Readings were taken at 8 a.m. and 4 p.m., each working day and about noon on some days during weekends. The air temperature is the average of several readings taken outside of the composter (cement mixer). This particular experiment was done in February--and we had one cold night in which the air temperature dropped in the housing shed. It is normally assumed that the temperatures of the compost elevated above room temperature are due to microbial action. The higher the temperature, the more microbial activity, all other conditions being equal. Since the amount of aeration and ventilation for both composters was the same, the difference between control (no fish solubles) and experimental (2.5% fish solubles) appears to be due to greater activity in the latter.

Figure 2 shows the total plate counts and the total yeast/mold counts for mesophilic (35° C) and the thermophilic (55° C) microorganisms. In composting, we are purposely holding down the compost temperature in these experiments

Figure 1

Temperatures of the air and cow manure composts with and without 2.5% menhaden fish solubles, but no fly larva production. Aeration and ventilation controls (see text) were set the same as for fly larva production (see Figure 3) and were intended to keep the compost temperature below 45°C.

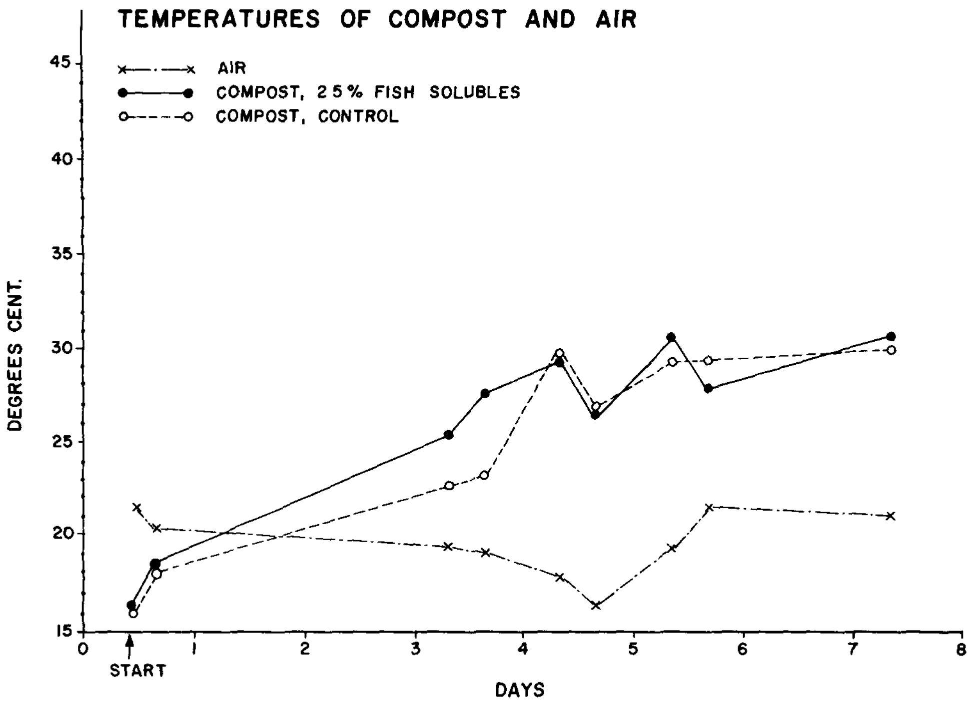
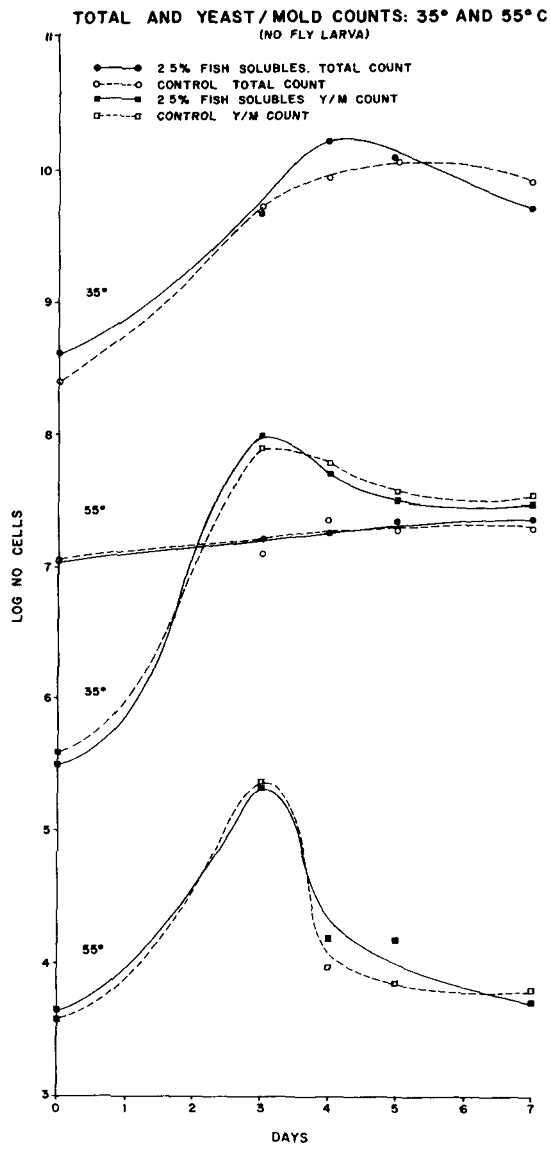


Figure 2

Mesophilic and thermophilic microbial counts on cow manure composts with and without 2.5% menhaden fish solubles, but no fly larva production.



by control of aeration and ventilation. Hence, thermophilic microorganisms did not make a great show. Another point should be emphasized. Yeast and mold cells have a greater biomass than bacteria cells. Hence yeast/mold cell counts that are lower than bacteria (total) counts do not always mean negative activity from these fungi.

In our second phase of these experiments we have included a fly egg inoculum for the production of fly larva. Results are shown in Figures 3 and 4. Figure 3 shows the temperature curves for an experiment run in March. Again the compost containing 2.5% fish solubles shows a higher temperature. In general the temperature curves are higher than when fly egg inoculum was omitted. The amount of controlled aeration and ventilation were the same as for phase one. Hence there is evidence of greater biological activity when fly larva inoculum is done. Figure 4 shows the microbial growth curves. Our theory of more cell population from compost containing fish solubles appears invalid. We have no rational explanation why the fish soluble total counts are lower. Additional runs verify the same general observation: in compost containing fish solubles, temperatures are higher, but microbial counts lower.

The thing that is most evident is that the combination of microbial activity and larva growth really speed up the bio-degradation of the cow manure. We are now quite convinced that this combination might be purposely fostered in large-scale or commercial composting as a means of speeding up the compost process. If the fly larva were not harvested, then a rotary drier at the end of the composter would dry the material for storage and shipment. The drying would also kill the fly larva and pupa. In this situation we would have a compost containing both single cell and fly larva protein which could serve as an animal feed.

We are quite convinced that we have stumbled onto something interesting: the fish solubles increases the fly larva growth and the fly larva increases the bio-degradation of the composting action.

Our future plans are to pursue this aspect further and to explore other fishery wastes. Our original objective is to provide a suitable means of disposing of "wet" solid/sludge wastes from the fisheries. This would be particularly advantageous for smaller and/or seasonally operated food (fish) processing plants. However, we seem to have found a practical system for efficient composting of cow, perhaps most animal manure.

SUMMARY

Our objectives are to find economical and practical methods to utilize wet solid/sludge fishery wastes. This report describes combining menhaden fish solubles, a byproduct of the fishmeal industry, with agronomic wastes to form useful products.

Figure 3

Temperatures of the air and cow manure composts with and without 2.5% menhaden fish solubles and with fly larva production. Aeration and ventilation controls (see text) were designed to keep the compost temperature from exceeding 43-45°C at which temperature fly larva would begin to die.

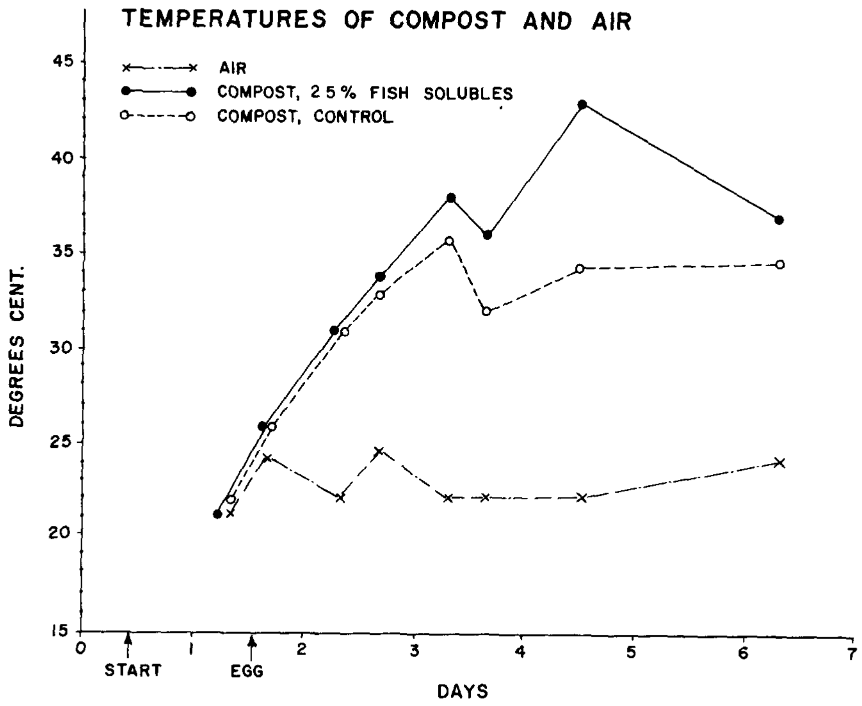
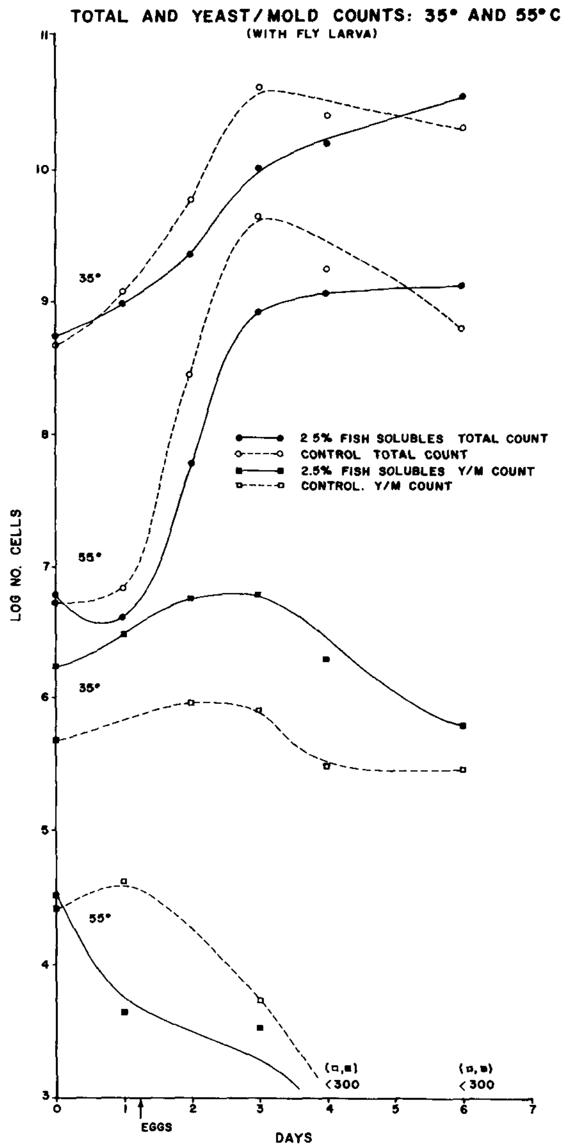


Figure 4

Mesophilic and thermophilic microbial counts on cow manure composts with and without 2.5% menhaden fish solubles and with fly larva production.



Ruminants fed a high urea diet usually require an inexpensive protein source to function as a "urea supplement" or "rumen stimulatory factor" to increase efficiency of nitrogen metabolism. Fish solubles and fish solubles combined with "dry" caustic potato peel waste were explored for this purpose using lambs as the test animal. Results indicated that fish solubles could be used in sheep diets, but no benefits were noted and this application of fish solubles would not be economically feasible. However, other wet solid/slurry food (fish) processing wastes should be tried for this utilization.

Fish solubles were used as a nitrogen supplement in experimental composting of cow manure. Fly eggs were purposely inoculated into the composting cow manure for the purpose of producing fly larva as a new source of protein for poultry diets. It was shown that fish solubles was a benefit to the cow manure composting with and without the presence of fly larva growth. The fly larva growth in the cow manure compost contributes to the biodegradation and fish solubles appear to increase this activity. Further exploration using other wet solid/sludge fishery wastes is planned.

Application of these methods of application of wet solid/slurry fishery wastes may be of interest to other food processing industries.

REFERENCES

1. Calvert, C. C., Martin, R. D., and Morgan, N. O. House Fly Pupae as Food for Poultry. J. Econ. Entomology 62(4): 938-939 (1969).

2. Calvert, C. C., Morgan, N. O., and Martin, R. D. House Fly Larvae: Biodegradation of Hen Excreta to Useful Products. Poultry Sci. 49(2): 588-589 (1970).

3. Calvert, C. C., Morgan, N. O., and Eby, H. J. Biodegraded Hen Manure and Adult House Flies: Their Nutritional Value to the Growing Chick. Proceedings of the International Symposium on Livestock Wastes published by the American Society of Agricultural Engineers, St. Joseph, Michigan 49085, pp 319-320 (1971).

4. Cuppett, S. L. and Soares, J. H. The Metabolizable energy values and digestibilities of menhaden fish meal, fish solubles and fish oil. Poultry Sci. 51(6): 2078-2083 (1972).

5. Green, J. H., Paskell, S. L., Goldmintz, D., and Schisler, L. C. New Methods Under Investigation for the Utilization of Fish Solubles, a Fishery Byproduct, as a Means of Pollution Abatement. Food Processing Waste Management published by the College of Agriculture and Life Sciences, Cornell University, Ithaca, New York 14850, pp 51-68.

6. Heinemann, W. W. and Dyer, I. A. Nutritive Value of Potato Slurry for Steers. Bulletin 757, Washington Agricultural Experiment Station, College of Agriculture, Washington State University, Pullman, Washington 99163.

7. Miller, D. and Robisch, P. Comparative Effect of Herring, Menhaden, and Safflower Oils on Broiler Tissues Fatty Acid Composition and Flavor. Poultry Sci 48(6): 2146-2157 (1969).

8. Soares, Jr., J. H., Miller, D., and Ambrose, M. E. Chemical Composition of Atlantic and Gulf Menhaden Fish Solubles. Feedstuffs 42(33): 65, 71 (1970).

9. Soares, Jr., J. H., Miller, D., Cuppett, S. L., and Bauersfeld, Jr., P. E. A Review of the Chemical and Nutritive Properties of Condensed Fish Solubles. Fishery Bulletin 71(1): 255-265 (1973)

10. Velloso, L., Perry, T. W., Peterson, R. C., and Beeson, W. M. Effect of Dehydrated Alfalfa Meal and of Fish Solubles on Growth and Nitrogen and Energy Balance of Lambs and Beef Cattle Fed a High Urea Liquid Supplement. J. Animal Sci. 32(4): 764-768 (1971).

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Environmental Protection Agency report number EPA-660/2-74-058
June 1974

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