1974

Investigation of the Anaerobic-Aerobic Treatment System Treating Potato Processing Wastes, Midwest Foods Corporation, Clark, South Dakota

William J. Trygstad

INVESTIGATION OF THE ANAEROBIC-AEROBIC TREATMENT SYSTEM
TREATING POTATO PROCESSING WASTES
MIDWEST FOODS CORPORATION
CLARK, SOUTH DAKOTA

INVESTIGATION OF THE ANAEROBIC-AEROBIC TREATMENT SYSTEM TREATING POTATO PROCESSING WASTES MIDWEST FOODS CORPORATION CLARK, SOUTH DAKOTA

by

WILLIAM J. TRYGSTAD

A thesis submitted
in partial fulfillment of the requirements for the
degree of Master of Science, Major in
Civil Engineering, South Dakota
State University

1974

INVESTIGATION OF THE ANAEROBIC-AEROBIC TREATMENT SYSTEM
TREATING POTATO PROCESSING WASTES
MIDWEST FOODS CORPORATION
CLARK, SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Major Adviser Date

Head, Civil Engineering Department Date

ACKNOWLEDGMENTS

The author expresses appreciation to Professor Dwayne A. Rollag and Dr. James N. Dornbush for their advice and suggestions made during the course of this investigation.

Appreciation is also extended to Wayne (Buster) Altfillisch and Joe Roe of Midwest Foods Corporation for their cooperation and assistance during the study. A special thanks is extended to Peggy Phipps for her assistance in the sampling program and for obtaining the flow measurements. A special thanks is also extended to Charles Tiltrum for performing the nitrate analyses.

This study was supported, in part, by an Environmental Protection Agency-Water Quality Office Traineeship Grant, No. 5T1-WP-272.

WJT

TABLE OF CONTENTS

Table of Contents (Continued)

Table of Contents (Continued)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The potato is one of the few foods provided by nature that is capable of nourishing the great populations of the world. The potato provides many nutrients essential to man, including carbohydrates, fats, proteins, iron, magnesium, vitamin C and the B-vitamins of niacin, thiamin, and riboflavin (1-218). Although potatoes are a nourishing food, per capita consumption in the United States has declined from a peak of 195 pounds per capita in 1910 to a low of 100 pounds per capita in 1952 (2). Since that time, consumption has shown an increase and was 117 pounds per capita in 1967 (3). An important factor in the per capita decline in potato consumption was the development of various substitute food products resulting from advances in food-processing technology. The increase in per capita consumption could be attributed to the development of specialty items such as frozen French fries, hash browns, and dehydrated potatoes (2).

The annual production of raw potatoes in the United States has exhibited a marked increase since 1951 when 9.75 million tons were produced. By 1966, the production had increased to greater than 15 million tons, or an increase of approximately 55 percent in 15 years (4). Utilizing a study in the Pacific Northwest, the Department of Interior has predicted that potato production will increase by 83 percent during the 20-year period from 1965 to 1985 (5).

The rapid increase in raw potato production has been accompanied by an even greater increase in the amount of processed potatoes. In 1946, only 4.6 percent of the annual potato production was processed into specialty items. By 1960, 32 percent of the total potato crop was being processed (6). Predictions for 1970 were that more than 50 percent of the raw potatoes would be processed into potato food products (2).

Approximately 36 percent of the potatoes processed in 1964 consisted of frozen potato products (1-340). Predictions by DuPont indicate that by 1976, over 3926 million pounds of frozen potato products will be produced. This would represent an increase of 170 percent over the 1966 production of 1460 million pounds (4). According to the Department of Interior, frozen and dehydrated potato production will increase by 250 percent from 1965 to 1985 (5).

From the sources cited above, it is apparent that the potato industry has undergone a major change during the past 25 years. To increase product acceptance, many new industrial processes have been developed. A considerable amount of wastes has been generated from many of these new processes. For example, only 30 to 45 pounds of frozen French fries are obtained from 100 pounds of raw potatoes (1-351). As a result, 55 to 70 pounds of solid waste are generated per 100 pounds of raw potatoes processed in addition to several wastewater streams associated with the various steps of production. State and Federal laws require that the disposal of these wastes be accomplished without harming the natural environment.

Various methods of treating these potato processing wastes have been utilized during the past 25 years. One of these methods has been anaerobic-aerated lagoon systems. However, very limited data is available regarding the effectiveness of anaerobic-aerated lagoons in treating potato wastes. Midwest Foods Corporation (formerly Fairfield Products, Incorporated), Clark, South Dakota, utilizes such a system to treat the wastewater generated from the production of frozen French fries. A previous study of this system by Hagin (7) in 1971 and 1972 yielded very little information regarding the adequacy of the treatment system because the treatment units were overloaded organically. Therefore, Hagin recommended additional studies when the units had recovered from the overloaded conditions.

Evidence of recovery was first noticed in March, 1973, and aerobic conditions prevailed in the stabilization pond at this time. The 1973-74 waste discharge permit issued by the South Dakota Board of Environmental Protection required Midwest Foods Corporation to monitor its waste discharges and loadings to the various treatment units. Considering the need for further studies as recommended by Hagin and others (4), the monitoring program represented an opportunity to determine the value of anaerobic ponds and flow-through aeration basins for the treatment of potato processing wastes at very little additional expense. Based on these factors, the studies described herein were authorized.

The objectives of this investigation of the anaerobic-aerated lagoon treatment system employed by Midwest Foods Corporation were to determine the following:

1. the condition of the treatment units prior to the 1973-74 processing season,

2. the quantity and quality of the raw wastes entering the treatment system in terms of the amount of potatoes processed,

3. the removal efficiencies obtained by the treatment units during the 1973-74 campaign, and

4. the overall suitability of the anaerobic lagoon-aerated lagoon-stabilization pond system for treating wastewater from Midwest Food's frozen French fry processing plant.

LITERATURE REVIEW

The performance of wastewater facilities treating potato-processing wastes reported in the literature should be included in evaluation of the adequacy of the wastewater treatment system at Midwest Foods Corporation. Also factors affecting the performance of the specific treatment units employed by Midwest Foods Corporation should be presented to aid in the discussion of the results obtained. The literature review that follows was conducted for these purposes as well as to allow a comparison of the characteristics of the wastewater from Midwest Foods with those of other potato-processing plants.

Potato Waste Characteristics

[The average composition of a white potato is presented in Table 1. From this table it can be seen that 77.5 percent of the whole potato is water and only 22.5 percent solid matter (8)]. [Also, the average carbohydrate content is 19.4 percent of the total weight, with an average of 2.0 percent protein. Because carbohydrates do not contain nitrogen, it is not clearly evident from Table 1 whether the protein nitrogen in the potato is present in quantities sufficient to prevent a nutrient deficiency in a wastewater containing only potato solids.]

Table 1 (1)(8)

Composition of an Ordinary White Potato

Item	Range (percent by weight)	Average (percent by weight)
Water	63.2-86.9	77.5
Total Solids	13.1-36.8	22.5
Protein	0.7-4.6	2.0
Fat	0.02-0.96	0.1
Total Carbohydrate	13.3-30.5	19.4
Crude Fiber	0.17-3.48	0.6
Ash	0.44-1.9	1.0

The wastes from processing potatoes consist mainly of potato solids and materials added during processing such as caustic peel solutions, oils and detergents (7). According to Guttormsen and Carlson (5) and Sproul, Keshavan, Hall and Barnes (9), an average of approximately 60 pounds of suspended solids and 50 pounds of biochemical oxygen demand (BOD_5) are produced per ton of raw potatoes processed. Dostal reported the average screened waste characteristics per ton of potatoes processed as 4200 gallons of water, 90 pounds of BOD_5, 210 pounds of chemical oxygen demand (COD), and 110 pounds of suspended solids (7). It is evident from a comparison of these values that the quantities of waste vary from plant to plant.

Table 2 includes a listing of the average waste characteristics for plants utilizing wet-caustic and dry-caustic peeling processes.

The values are typical for the process water composed of caustic potato peel, barrel-washer discharges, and cleanup water (11). From this table, it is obvious that the waste characteristics are dependent upon the type of peeling process utilized. By removing the caustic peeling waste from the wastewater stream and substituting dry-caustic for wet-caustic peeling only one-third the flow and two-thirds the BOD_5, COD, and suspended solids per ton of raw potatoes processed are produced. Also, the type of potato product and extent to which in-plant modifications for water conservation have been adopted will also influence the waste characteristics of a particular plant (6).

Table 2

Average Potato Processing Waste Characteristics

Parameter	Wet-Caustic Peeling (7)	Dry-Caustic Peeling (10)
Flow (gal/ton raw potatoes)	4500	1666
BOD_5 (mg/l)	1750	2879
(lbs/ton)	65.7	40
COD (mg/l)	2700	4512
(lbs/ton)	101.3	62.7
Suspended Solids (mg/l)	2600	4599
(lbs/ton)	97.6	63.9
pH	11.0	10.8

Flume silt-water is the second major waste stream derived from processing raw potatoes. The flume silt-water waste originates from washing the potatoes and using water to transport them in a flume (11). Flume silt-water is high in suspended solids but contains only a small amount of organic matter (5)(8). Grames and Kueneman (6) reported that 1200 gallons of flume and wash water are discharged per ton of raw potatoes processed. The flume silt-water had an average suspended solids concentration of 20,000 mg/l. The amount of solids present in the silt-water will vary with the type of soil in which the potato is grown and the moisture content of the soil during harvest (6). At the R. T. French Company in Shelley, Idaho, the silt-water average suspended solids concentration was 13,240 mg/l. A clarifier-thickener was utilized to remove the suspended solids and produced an average reduction of 72 percent. Following clarification, the dewatered silt solids were found to be very acceptable as landfill material (11).

Process Changes to Reduce Waste Characteristics

One method of reducing the strength of potato-processing wastes is to remove the caustic peeling wastes from the wastewater stream. It has been estimated that 80 percent of the plant BOD_5 originates from the peeling process (12). At a potato-processing plant in North Dakota, removal of the caustic peel resulted in an actual BOD_5 reduction of about 50 percent (13). Furthermore, the BOD_5 loading rate to the stabilization ponds was reduced to 90 pounds/acre/day.

Average waste characteristics may also be reduced by utilizing the dry-caustic peeling process in place of the conventional wet-caustic peeling process. Cyr (10) reported that peel loss, amount of caustic, and BOD_5 and suspended solids loadings were markedly reduced by utilization of the dry-caustic peeling process. Water usage was reduced to approximately one-fourth of that used in the wet-caustic peeling process. Furthermore, the pounds of BOD_5 discharged per ton of raw potatoes processed was approximately four and one-half times higher for the wet-caustic peeling process (10).

Water conservation, water recirculation and by-products recovery accounted for a reduction of over 50 percent in plant BOD_5, 30 percent in suspended solids and approximately 10 percent in water usage at a Maine potato processing plant (14). Removal of potato pieces from the waste stream will prevent an increase in BOD_5 due to leaching of organic matter from the potato solids (5)(9). It is estimated that one pound of dry potato solids will exert a BOD_5 of 0.45 pounds (1). Therefore, dry handling of all solid wastes will prevent leaching and reduce the BOD_5 loading to the treatment system.

Primary Treatment Methods

[Screening of the wastewater stream is essential to prevent plugging of pipes and damage to pumps by large pieces of potatoes.] It has been reported that screens finer than 20-mesh tended to blind although screens of 20-mesh removed approximately 25 percent of the suspended solids and 10 to 15 percent of the BOD_5 in the plant effluent (6). In another report, 35 percent of the suspended solids and 27 percent of the BOD_5 were removed using a 10-mesh screen (9). The investigators did not comment on the problem of screen clogging.

Due to the high concentration of settleable suspended solids present in potato wastes, sedimentation has proven to be an effective primary treatment method. Sedimentation units vary from simple settling ponds to sophisticated mechanical clarifiers (5). Grames and Kueneman (6) have reported BOD_5 removals of approximately 90 percent in a settling pond under quiescent conditions. However, the build-up of solids could necessitate dredging operations which are usually accompanied by obnoxious odors. These factors make the mechanical clarifier more desirable (7).

Mechanical clarifiers have produced varied results under various overflow rates. One mechanical clarifier receiving potato wastes at an overflow rate of 800 gallons/day/square foot achieved a 41 percent removal of BOD_5 and a 73 percent removal of suspended solids (5). Another mechanical clarifier with an overflow rate of 730 gallons/day/square foot obtained a 62 percent COD removal, 93 percent suspended solids removal and 95 percent settleable solids removal (5). This clarifier was preceded by grease removal facilities and three rotary screens with four-mesh cloth. Sproul, <u>et al</u>. (9) believe that BOD_5

removals between 50 and 70 percent and suspended solids removals as high as 80 percent may be obtained by primary sedimentation with overflow rates in the range of 600 to 1000 gallons/day/square foot.

Centrifugation has been proposed as a means of primary treatment but is not as economical and dependable as conventional clarification. In an attempt to improve primary clarification, chemical coagulants have been added. Significant improvements in removal efficiencies have not been obtained (5).

Solids obtained during primary clarification have proven to be nutritionally equivalent to barley (5). Proper rationing of potato solids in cattle feed has produced accelerated weight gains in cattle (5). In 1970, these potato solids with a 14-percent dry solids content were being sold for approximately $3.00 per ton (5).

Secondary Treatment Methods

The first studies of secondary treatment of potato processing wastes were conducted approximately ten years ago in Idaho (5). From these studies, design criteria for activated sludge, trickling filter, and stabilization pond treatment methods were developed. Additional investigations of anaerobic ponds and flow-through aeration basins were recommended due to the high costs associated with activated sludge and trickling filter operations. It was found that BOD_5 removals in excess of 90 percent were possible for the completely-mixed activated sludge process loaded up to 150 pounds of BOD_5/1000 cubic feet/day (5). In another investigation (14), it was found that at a mixed-liquor suspended solids (MLSS) concentration of 4000 mg/l and detention time of six-to-eight hours that BOD_5 reductions of 95 percent could be achieved by the completely-mixed activated sludge system at loadings above 300 pounds of BOD_5/1000 cubic feet/day. In this system it was unnecessary to adjust the pH of the influent. Excessive sludge production and nutrient addition are problems associated with activated sludge treatment units (5).

Performance data for full-scale trickling filter systems treating potato wastes could not be found. However, in a pilot-plant study utilizing trickling filters with artificial media, BOD_5 reductions of 75 percent were obtained at a loading of 400 pounds of BOD_5/1000 cubic feet/day (5). Nutrient addition was found advantageous but pH adjustments were not required. Anaerobic-filter pilot-scale studies in Idaho revealed BOD_5 removals of almost 70 percent at a loading of 60 pounds of BOD_5/1000 cubic feet/day (5).

In 1962, only three stabilization ponds were being used to treat potato processing wastes (5). The median loading and detention times for these ponds were 111 pounds of BOD_5/acre/day and 105 days, respectively. Treatment efficiencies were not reported. However, one pond was considered effective while another exhibited nuisance odors. One stabilization pond system for treating domestic and potato processing wastes was designed on the basis of 20 pounds of BOD_5/ acre/day but it was believed that loadings of 50 to 60 pounds of BOD_5/ acre/day could be handled successfully (13). However, data were not presented to substantiate this claim. The usual design criteria for stabilization ponds treating domestic wastewater is 20 pounds of BOD_5/ acre/day with retention times of 20-120 days (15-533).

Aerated lagoon treatment has also been studied. An experimental lagoon in North Dakota with a detention time of 14 days obtained 85 percent BOD_5 reductions at temperatures close to 0^oC (5). In an aerated lagoon pilot study, BOD_5 removals of 80 percent were obtained at a detention time of 7.8 days and temperature of 7^oC (5). Investigations by the R. T. French Company indicated that 70 to 80 percent of the BOD_5 may be removed by aerated lagoon treatment (11). Further studies utilizing pilot lagoons at the J. R. Simplot Company plant in Idaho revealed that primary clarification followed by aerobic lagoon treatment removed 90 percent or more of the BOD_5 (4). Chemical additions, pH control, and nutrient additions were not required to obtain these high removal efficiencies. A maximum loading rate of ten pounds of BOD_5/1000 cubic feet/day is recommended for an aerated basin (16).

Anaerobic ponds have been utilized for potato processing wastes but little published information is available regarding the efficiency of these units. At least three ponds were in use in 1962 and nuisance odors were associated with one of these (5). Hagin (7) reported negative BOD_5, COD and suspended solids removals from an anaerobic pond loaded at 13.8 to 29.2 pounds of BOD_5/1000 cubic feet/day with an average loading of 20.2 pounds of BOD_5/1000 cubic feet/day. A completely-mixed anaerobic pond loaded at eight pounds of BOD_5/1000 cubic feet/day obtained an average BOD_5 removal of 70 percent (5). In pilot-plant studies involving primary clarifiers in series with an anaerobic-aerobic lagoon system, BOD_5 removals greater than 90 percent were obtained without nutrient addition or pH adjustment (4).

Anaerobic-Aerobic Lagoon Systems

In 1966, Dostal (17) conducted a pilot-plant study at the J. R. Simplot Company waste treatment plant in Burley, Idaho. The treatment system consisted of screening followed by primary clarification and anaerobic-aerobic lagoons in series. The anaerobic lagoon was covered with styrofoam to retard heat loss and control odors. During the pilot-plant studies, the anaerobic and aerobic lagoons were subjected to various BOD_5 and hydraulic loadings as summarized in Table 3.

Dostal concluded that a BOD_5 removal of at least 90 percent could be obtained by primary clarification plus subsequent treatment by the economically feasible method of anaerobic-aerated lagoons operated in series without pH control or inorganic nutrient addition. Also, anaerobic lagoons should be covered to control heat loss and odors.

Table 3 (17)

BOD_5 Loadings, Hydraulic Loadings, Detention Times, and Pilot-Plant Efficiencies

	Hydraulic Loading (gpm)	Detention Time (days)	BOD_5 Loading ($lbs/1000ft^3/day$)	Reductions-% S.S.	COD_5	BOD_5
Anaerobic Pond	4.0	8.8	11	82	33	25
Aerobic Pond	4.0	8.8	8	-230	49	88
Overall				74	73	95
Anaerobic Pond	7.0	5	22	33	15	12
Aerobic Pond	7.0	5	20	-75	58	87
Overall				66	82	94
Anaerobic Pond	15.0	2.4	46	52	15	12
Aerobic Pond	15.0	2.4	40	-226	28	64
Overall				51	68	81

The report recommended secondary clarification following the aerated lagoon for removal of suspended solids. Foaming could create operational problems in an improperly designed aerated lagoon according to the report.

Investigations by Hagin (7) in 1971-72 involved the newly constructed treatment system employed by Fairfield Products, Incorporated, Clark, South Dakota. The treatment system included a 64-mesh screen, anaerobic lagoon, aerated lagoon and stabilization pond. As a result of the study, Hagin concluded that the entire lagoon system was being organically overloaded and, as a result, was operating under anaerobic conditions during the entire study. The anaerobic lagoon obtained negative BOD_5, COD and suspended solids removals due to overloading, low temperatures in the lagoon, and discharge of soil to the lagoon from the mud pit. Also, the anaerobic lagoon, having been recently constructed, may not have contained the proper anaerobic micro-organisms to effectively treat the potato wastes. The aerated basin could not be analyzed as such due to its anaerobic condition, but was in a period of transition from a mixed anaerobic basin to an aerated basin due to the installation of six 25-horsepower surface aerators. Due to water usage practices in the plant, the stabilization pond received an excessive hydraulic loading. Also, due to the poor removal efficiencies obtained in the previous treatment units, the stabilization pond received an extremely high organic loading of 250 pounds of BOD_5/acre/day.

Theory of Anaerobic-Aerobic Pond Treatment

Anaerobic Lagoon

Generally, high temperature, high strength wastes are particularly amenable to anaerobic treatment (18). Stabilization of organic matter by anaerobic treatment is basically a two-stage process (19). In the first stage, complex materials are converted to simpler organic end products, such as fatty organic acids. Facultative and anaerobic bacteria accomplish this conversion and are commonly called acid formers.

Very little BOD_5 and COD reduction occurs in this stage. In the second stage, methane-forming, strictly anaerobic microorganisms convert the organic acids to gaseous end products, primarily methane and carbon dioxide. It is through the release of methane, which is relatively insoluble in water, that the BOD_5 and COD reductions are obtained (19). Detention times recommended for the two-stage stabilization are in the range of three to 30 days (20).

The balance between the production of organic acids and conversion of these acids to methane is a delicate one. Increased loading will result in the formation of more organic acids than the methane bacteria can digest. As a result, the increased organic acid concentration will cause a pH reduction. The average loading criteria developed by most states is 12 to 15 pounds of BOD_5/1000 cubic feet/day (20). Anaerobic lagoons in Iowa operating in this range have received an 85 percent average BOD_5 removal. However, one anaerobic lagoon used for treating packing wastes removed 72 percent of the applied BOD_5 at a loading rate of 60 pounds of BOD_5/1000 cubic feet/day with a 3.4 day detention time (20).

The pH of an anaerobic lagoon should be maintained between 6.6 and 7.6 for optimum operation (19). Methane-forming bacteria are very sensitive to pH changes and operate best at a pH of 7.0 to 7.2. When the pH in the lagoon is outside the optimum range, methane fermentation will become retarded. As a result, the organic acid concentration in the lagoon will increase because the acidogenic bacteria are less sensitive to pH extremes. The net result is a decrease in BOD_5 removal (19). An alkalinity of approximately 2000 mg/l will maintain a proper pH in the lagoon (18).

Temperatures in excess of $60^{o}F$ and preferably in the area of $90^{o}F$ should be maintained in an anaerobic lagoon (18). If the lagoon temperature drops below $55^{o}F$ or $60^{o}F$, biological activity is sharply curtailed and the lagoon functions primarily as a settling pond. Insulative covers, short detention times and pond depths to 20 feet will reduce temperature losses (20).

Toxic materials present in the waste will also affect the performance of an anaerobic lagoon. Methane fermentation may be inhibited by toxic ions. Ions found to exhibit toxic effects include alkali and alkaline-earth cations, heavy metal ions, ammonia, sulfide and certain organic compounds (18)(19).

Anaerobic lagoons are capable of large organic matter reductions. The effluent from these units is odorous and unstable, thus further treatment must be provided before the waste can be discharged to a receiving body of water. This treatment is usually provided by an aerobic process (18).

Aerated Lagoon

Aerated lagoons have evolved due to the need to speed up natural purification processes by artificially inducing oxygen into aerobic stabilization ponds. Aerated lagoons have been classified into three types. One type is the completely-mixed aerated lagoon in which the essential function is waste conversion and the incoming solids and biological solids do not settle out (21-543)(22). A second type is the aerated oxidation pond in which aeration equipment is added to an overloaded oxidation pond (22). The third is a facultative aerated lagoon in which heavier solids settle in the lagoon while suspended and soluble organics are biologically treated in the aerobic liquid portion. Anaerobic decomposition stabilizes the heavier organic solids that settle in the lagoon (22)(23).

Detention time, temperature and oxygen are all important factors affecting the performance of an aerated lagoon. The recommended minimum concentration of dissolved oxygen to be maintained in an aerated lagoon is 1.5 mg/l (16). The rate of biological oxidation in an aerated lagoon is dependent on temperature. According to Thimsen (16), an increase of $10^{o}C$ will double the reaction rate. The detention time required for a certain BOD_5 removal is inversely proportional to the reaction rate coefficient. As a result, winter temperature conditions are used to determine the detention time for the lagoon and summer conditions are used to determine the oxygenation capacity of the aeration equipment (16). Typical detention times for aerated lagoons treating domestic wastes vary from three to six days (21). To minimize heat losses, Sawyer recommends liquid depths of 15 to 17 feet (7).

Mixing also exerts an important influence on the biological reaction rate in completely-mixed or facultative aerated lagoons (22). In fact, experimental evidence has been presented that mixing may be more critical than aeration considerations for the proper operation of an aerated lagoon (22). Slow moving impellers are more efficient mixing devices than either the fast moving, small impellers or gas diffusion (22).

Stabilization Ponds

Stabilization ponds are the most common method of organic waste treatment where sufficient land is available (23). These ponds are flat-bottomed, earthen basins usually ranging in liquid depth from two to five feet (15). Stabilization basins may be either impounding or flow-through ponds with the basic aerobic types being classified as aerobic or facultative (23).

Aerobic stabilization ponds contain a variety of bacteria and algae in suspension with aerobic conditions throughout the pond (21). The algae and bacteria operate through a symbiotic relationship to stabilize oxidizable organic matter. Two types of aerobic stabilization ponds are common (21). One utilizes a depth of six to 18 inches and attempts to maximize the production of algae, whereas, the second utilizes a depth up to five feet to maximize the amount of oxygen produced. Purushothaman (24) has found that dissolved oxygen concentrations in ponds from three to five feet deep follow a diurnal pattern. The study concluded that an increase in dissolved oxygen resulted from an increase in the intensity of sunlight and achieved a maximum concentration at about 2 p.m. Maximum concentrations of 31.8 mg/l and 24.0 mg/l were observed in the effluent from three and five foot ponds, respectively (24). In both types of aerobic stabilization ponds, both algae and surface wind action add oxygen to the pond. Design factors for flow-through aerobic ponds with a depth of six to 12 inches include a detention time of two to six days and a BOD_5 loading of 100 to 200 pounds/acre/day (23). Expected BOD_5 removals at these loading rates are 80 to 95 percent.

The second type of aerobic stabilization basin is the facultative pond. Three zones exist in this type of a pond. They are (1) an aerobic surface zone where bacteria and algae exist symbiotically, (2) an anaerobic bottom in which settled solids are decomposed anaerobically, and (3) an intermediate zone in which facultative bacteria decompose the organic matter. Odors are minimized by maintaining the aerobic surface zone (21)(23). These ponds are usually two to five feet deep with a detention time of seven to 30 days (23). BOD_5 removals of 75 to 85 percent can be obtained at loadings in the range of 20 to 50 pounds/acre/day (23).

Climatic conditions affect the performance of aerobic stabilization ponds (15). During warm, sunny weather, decomposition and photosynthetic processes will flourish and result in BOD_5 reductions of greater than 95 percent. During cold weather, under ice cover, biological activity is reduced and BOD_5 reductions are generally reduced to about 50 percent.

DESCRIPTION OF THE PROCESSING PLANT AND TREATMENT FACILITIES

Processing Plant

Raw potatoes for the Midwest Foods Corporation are derived from an area within 40 to 50 miles of Clark, South Dakota. The raw potatoes are harvested and hauled to an unheated warehouse at the plant site and stored until processing which generally begins in late August and usually ends the following May.

Figure 1 includes a flow-diagram of the processing operations. The production line, approximately 600 feet in length, is basically a "straight through" process. Initially, the raw potatoes are transported to the mudpit by water in a flume. Dirt is removed from the potatoes as they move along in the flume. This material is composed of large amounts of soil and small quantities of organic matter (8). The soil that settles in the mudpit forms one of the waste streams. This soil is pumped periodically to the receiving pit and through a Parshall flume before flowing by gravity to the anaerobic lagoon. Most of the water used during the fluming operation is recycled to flume additional potatoes to the processing line.

The potatoes are then conveyed over a scale and into a preheat tank in which they are heated. The heated potatoes are then immersed in a hot caustic solution which loosens and partially dissolves the skin. Following this caustic treatment, the potatoes are peeled by

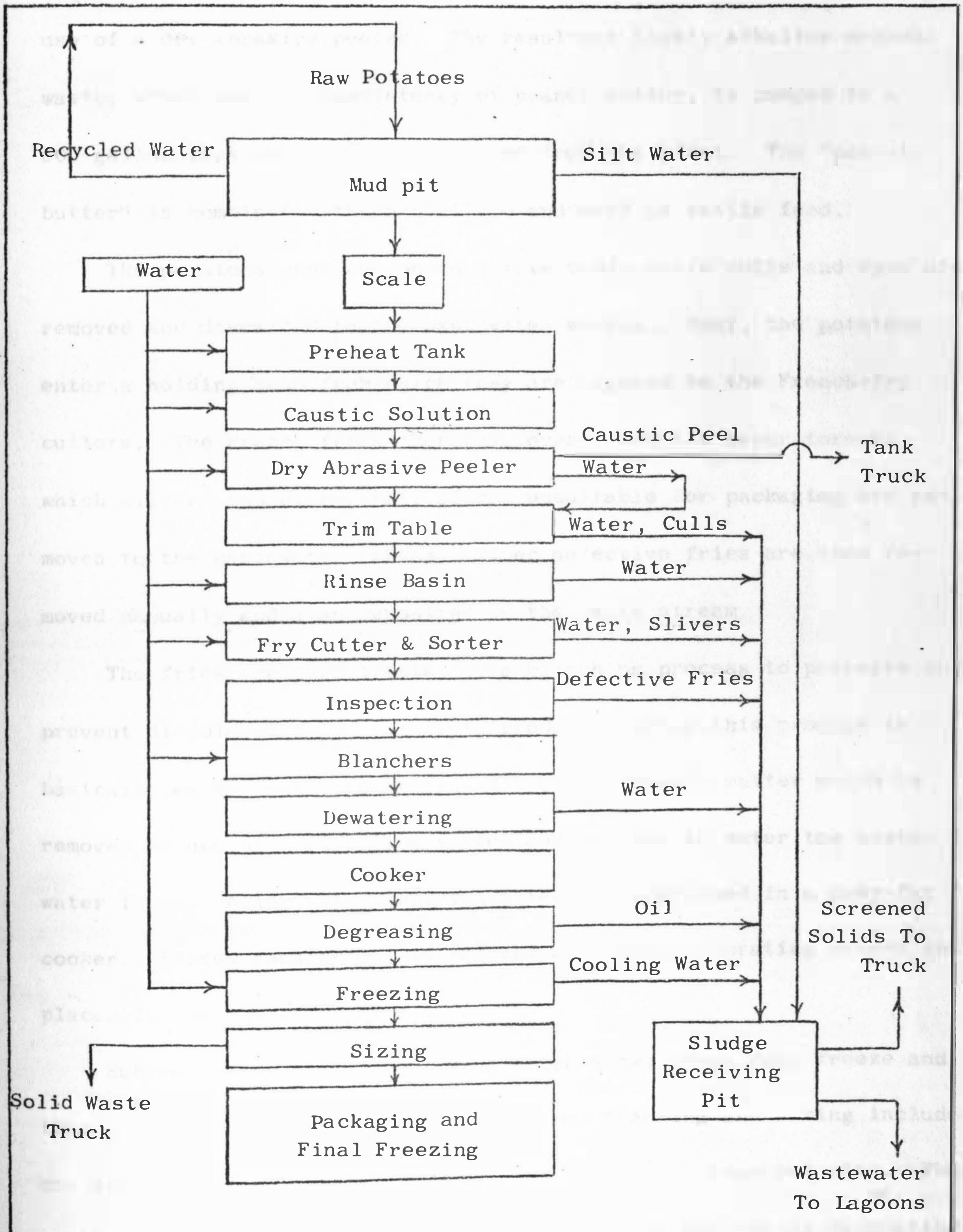


Figure 1. Potato Processing Plant Flow Diagram at Midwest Foods Corporation, Clark, South Dakota

use of a dry abrasive peeler. The resultant highly alkaline organic waste, which has the consistency of peanut butter, is pumped to a 500-gallon tank truck and transported from the plant. The "peanut butter" is combined with corn silage and used as cattle feed.

The potatoes continue on to a trim table where culls and eyes are removed and discarded to the wastewater stream. Next, the potatoes enter a holding tank from which they are augered to the French-fry cutters. The French fries then pass over automatic separators in which slivers and other small pieces unsuitable for packaging are removed to the wastewater stream. Other defective fries are then removed manually and also deposited in the waste stream.

The fries are then treated by a blanching process to preserve and prevent discoloration. The waste produced during this process is basically excess water containing dissolved organic matter which is removed by use of a vibrating screen and allowed to enter the wastewater flume. After this step, the fries are precooked in a deep-fat cooker. Excess cooking oil is removed by another vibrating screen and placed in the raw waste stream.

Subsequently, the French fries enter a two-stage deep freeze and then are automatically sized. Wastes from freezing and sizing include cooling water from the freezer and French fries of improper size. The cooling water is discharged to the wastewater stream during defrosting operations. The rejected French fries from the sizing operation are augered to a truck and used for cattle feed. Following sizing, the French fries are automatically packaged in plastic bags and transported to another freezer and stored for shipping.

According to the flow diagram in Figure 1, the flume silt-water and raw wastewater streams evolved during sorting, cutting, blanching, cooking and freezing are all flumed to the sludge receiving pit. These wastes are pumped over a 20-mesh vibrating screen where the larger solids are removed and sold for cattle feed. The liquid passing through the screen then flows by gravity to the anaerobic lagoon. The caustic peel produced during the peeling process and the solids produced during the automatic sizing operation are both removed from the plant by trucks. Thus, there are five major wastes derived from the production line. Three of these are solid wastes and are removed from the plant by trucks. The remaining two wastes are essentially waterborne and are discharged to the lagoon treatment system.

Processing Alterations Since April, 1972

The investigations by Hagin were performed from December, 1971, to April, 1972. Since then, certain alterations have been made in the processing line. From the standpoint of wastewater reduction, the most significant change that was made was the installation of a new dry-abrasive peeler for the 1973-74 processing season. The new peeler is a model 26 sine-wave peeler manufactured by Vanmark of Creston, Iowa.

Nylon brushes mounted on six rotating sine-wave rollers perform the peeling. After exposure to caustic, the potatoes move over the rollers to loosen the skins. Spray nozzles distribute water over the potatoes to remove the caustic "peanut butter" waste. The new dry-abrasive peeler was added to reduce peeling loss and water usage although data concerning the degree of reduction were not obtained.

Another significant process alteration was the elimination of the peel waste from discharging to the lagoon treatment system. A 500-gallon tank truck was purchased to transport the highly alkaline peel waste from the plant. This in-plant modification has undoubtedly resulted in a marked reduction in organic loading to the lagoons.

Revamping the French fry cutters was a third change made. Smaller spray nozzles were placed on the spray washers to reduce water usage and the automatic separators were tightened to prevent the previously excessive loss of French fries.

Also subsequent to the investigations conducted by Hagin was the implementation of an excessive in-plant water conservation program to help reduce the volume of wastewater flow. Cleanup of the entire plant was limited to once a day rather than the continuous practice employed previously. This eliminated the unnecessary and wasteful use of water for cleaning purposes. Some of the water used during the peeling process was used to remove the caustic peel waste and not allowed to enter the raw wastewater stream; whereas, the remaining wash water from the new peeler was collected and used to flume defective potatoes from the trim table to the sludge receiving pit. Another important factor in achieving lower water consumption was the reuse of cooling water for freezing.

A holding tank was installed between the trim table and French fry cutters for use as an additional rinse basin. This addition was made to reduce the amount of water used in the French fry cutters. Water from the cutters was collected and discharged to the flume to aid in transporting defective potatoes to the sludge receiving pit.

Silt-water was pumped from the mudpit once-a-day rather than continuously. Reduction in the amount of make-up water required for fluming and washing of the raw potatoes resulted.

Description of the Treatment Facilities

The wastewater treatment facilities employed by Midwest Foods Corporation are located northeast of the plant and consist of an anaerobic lagoon, an aerated lagoon, and a stabilization pond in series as shown in Figure 2. The wastewater is pumped over a 20-mesh vibrating screen where large potato solids are removed. The screened wastewater then flows by gravity through a three-inch Parshall flume to the anaerobic lagoon.

The anaerobic lagoon has a liquid volume of 101,000 cubic feet. It is approximately rectangular in shape having a mean width of 100

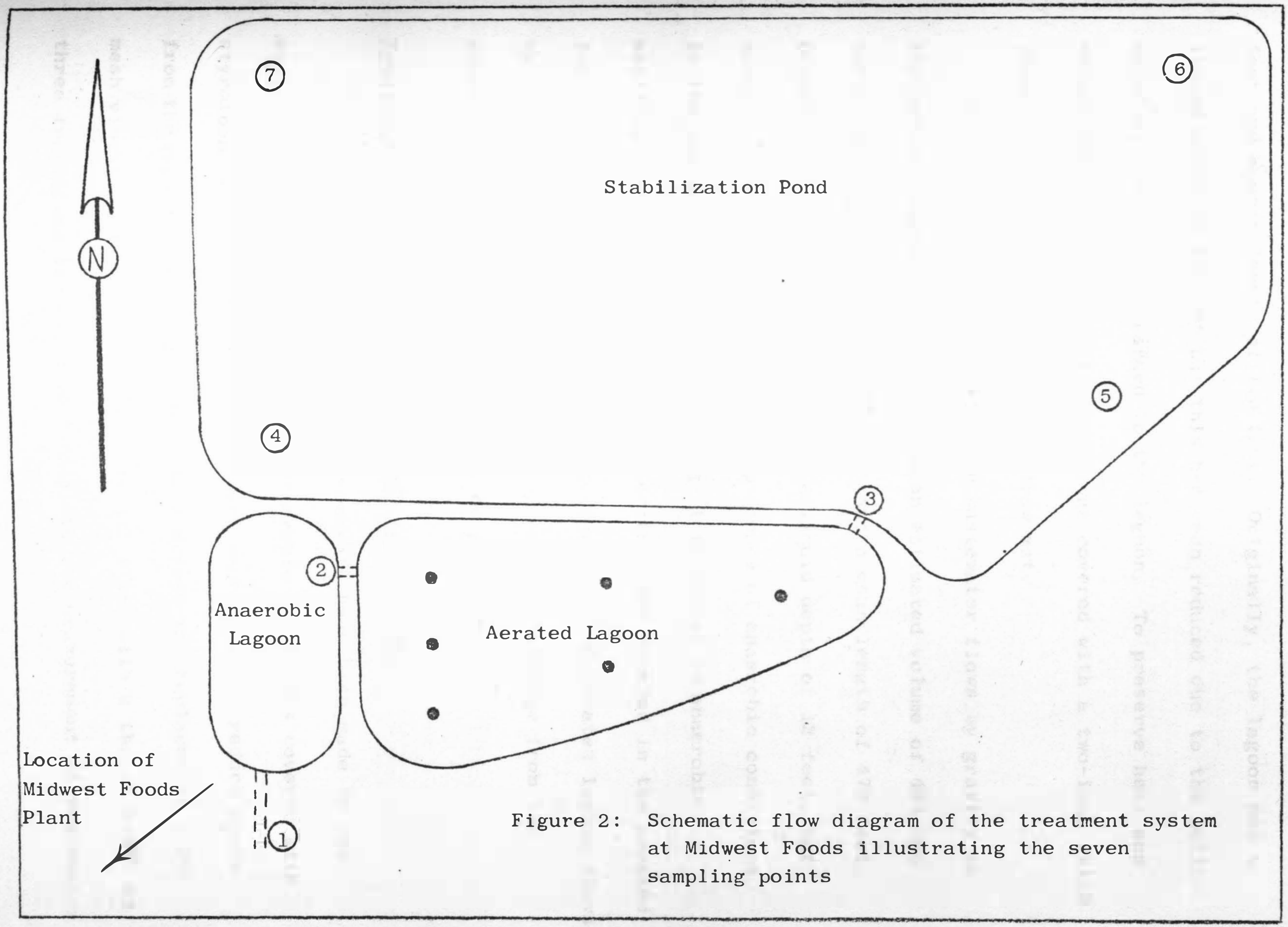


Figure 2: Schematic flow diagram of the treatment system at Midwest Foods illustrating the seven sampling points

feet and a mean length of 170 feet. Originally, the lagoon had a liquid depth of 20 feet but this has been reduced due to the build-up of silt solids discharged to the lagoon. To preserve heat and reduce odors, the anaerobic lagoon was covered with a two-inch thick layer of styrofoam topped with a straw mat.

From the anaerobic lagoon, the wastewater flows by gravity to the aerated lagoon. This unit has an estimated volume of 404,000 cubic feet, a mean width of 50 feet and a mean length of 470 feet. Originally, the aerated lagoon had a liquid depth of 12 feet, but again this was reduced due to the presence of anaerobic conditions in the lagoon prior to 1973 causing it to act as an anaerobic settling pond. Six 25-horsepower aerators are located in the aerated lagoon as shown in Figure 2. Wastewater from the aerated lagoon flows by gravity to a 22-acre stabilization pond. Discharge from the stabilization pond is not practiced or permitted.

Treatment Facility Improvements Since April, 1972

Since 1971-72, four major improvements have been made to the wastewater treatment system. The anaerobic lagoon was covered with styrofoam overlain with straw to retard heat loss and reduce odors from the lagoon. Secondly, the 64-mesh screen was replaced by a 20-mesh vibrating screen. Also, a Parshall flume with a throat width of three inches was installed to facilitate the measurement of wastewater flows from the plant. Finally, additional rip-rap was added to the dikes of the aerated lagoon and stabilization pond to retard dike erosion. All improvements were made during 1973, just prior to the 1973-74 processing season.

METHODOLOGY

Sampling Procedures and Frequency

The investigations presented herein were initiated on August 1, 1973, and were completed on November 16, 1973, a period of three and one-half months. Potatoes were actually processed from September 6 to November 14, 1973. Therefore, the investigations began about one month before processing was initiated by collecting several samples from the treatment units during August. Analyses of these samples were used to establish the conditions of the lagoon system before subjecting these units to the 1973-74 wastewater discharge.

Samples were collected on a weekly basis from the seven locations shown in Figure 2. Grab samples were taken from each quadrant of the stabilization pond to determine if the quality of the pond contents varied with location in the pond. Samples were collected at approximately 12 noon each sampling day.

The raw waste, anaerobic lagoon and aerated lagoon effluent samples were grab samples taken every two hours and composited over an eight-hour period. The period of collection was the day shift from 8:00 a.m. to 4:00 p.m. The raw waste was collected at the Parshall flume and composited according to the flow measurements obtained during the collection of each grab sample. Flow from the anaerobic and aerated lagoons was assumed to be constant during the collection period. Therefore, equal portions were taken from each grab sample to make the composite samples from both the aerated lagoon effluent and anaerobic lagoon. Samples from the anaerobic lagoon were collected within a few feet of the effluent pipe. Samples from this location were assumed to have the same quality as the effluent from the anaerobic lagoon. The aerated lagoon samples were collected from the effluent of the lagoon during the processing season and from two points within the lagoon prior to the processing season. All samples were stored at approximately 4°C in the plant laboratory during the sampling period.

Flume silt-water samples were collected throughout the period in which the silt water pumps were operating. At least four grab samples were collected with equal portions of each sample being added to the composite.

Following collection and compositing, the samples were transported to the Sanitary Engineering Laboratory in the Civil Engineering Department at South Dakota State University for analysis. During transport the samples were maintained at 4°C. The time lapse between the end of the sampling period and arrival at the University laboratory was about one and one-half hours.

Flow Measurements

A Parshall flume was installed downstream from the vibrating screen to measure the wastewater flows discharged to the anaerobic lagoon. Initially, a Stevens Type F recorder (Model 61) was used to continuously record the water level in the Parshall flume. However, due to the excessive vibration caused by the vibrating screen, the ink pen wore holes in the charts and frequently became plugged. This made it difficult to obtain accurate, continuous water-level readings. On October 8, 1973, the flow recorder was abandoned in favor of manual flow measurements. Further problems in flow measurement were encountered, however, because of the daily accumulation of solids in the stilling well. To alleviate this accumulation, a drain plug was installed in the stilling well on October 17, 1973. Subsequently, manual flow measurements were taken every hour during the day shift when the plant was processing frozen French fries. Flow measurements were not taken during the other processing shifts. Because of the difficulties, flow measurements obtained from October 18 to November 14, 1973, were more accurate than those obtained prior to this period.

Flume silt-water flow was obtained by utilizing the peak flow measurements obtained during use of the automatic Stevens flow recorder. The average peak flow was determined arithmetically. To determine the average flume silt-water flow rate, the average raw wastewater flow rate was subtracted from the average peak flow rate. To determine the frequency and duration of flume silt-water pumping, a calendar was placed near the flume silt-water pump. Over a three-week period, employees recorded the time of pump operation during each pumping period. The data revealed that flume silt-water was discharged to the anaerobic lagoon on an average of once per day. Also, the average length of pump operation was 11.8 minutes. These averages, along with the average flume silt-water flow rate, were utilized to calculate the average daily volume of flume silt-water discharged to the anaerobic lagoon.

Analytical Determinations and Procedures

Fifteen analytical determinations were performed on the waste-water samples. Temperature, pH, dissolved oxygen and oxidation-reduction potential (ORP) determinations were performed at the treatment units. Tests performed in the laboratory were BOD_5, COD, suspended solids, total residue, specific conductance, alkalinity, phosphorus, volatile acids, nitrate-nitrogen (NO_3^--N), total kjeldahl nitrogen (T.K.N.), and ammonia-nitrogen (NH_3-N). The analyses performed and approximate frequency of each are listed in Table 4.

In Table 5, the analytical procedure utilized for each analysis is presented. As shown in the table, most of the analyses were conducted in accordance with <u>Standard Methods for the Examination of Water and Wastewater</u>, 13th edition (25). The particular modifications and optional procedures for the analyses are also noted. Analyses on the

Table 4

Frequency of Analyses

Sample	Analyses Schedule		
	Weekly	Monthly	Bi-weekly
Raw Waste	BOD_5 COD Total Residue Suspended Solids Specific Conductance Alkalinity Temperature pH	T.K.N. NH_3-N NO_3^--N Phosphorus	
Anaerobic Lagoon	BOD_5 COD Total Residue Suspended Solids Specific Conductance Alkalinity Temperature pH Volatile Acids	T.K.N. NH_3-N NO_3^--N Phosphorus	ORP
Aerated Lagoon and Stabilization Pond	BOD_5 COD Total Residue Suspended Solids Specific Conductance Alkalinity Temperature pH	T.K.N. NH_3-N NO_3^--N Phosphorus	Dissolved Oxygen ORP

flume silt-water samples were limited to total residue, suspended solids and settleable solids. These determinations also were performed according to _Standard Methods for the Examination of Water and_

Table 5

Analytical Procedures Used

Parameter	Analytical Procedure
pH	Beckman portable pH meter with glass electrode
Temperature	Thermometer in ^{o}C.
Dissolved Oxygen	Standard Methods (25) - Azide modification
ORP	Beckman portable pH meter with platinum electrode
BOD_5	Standard Methods (25) - Azide modification with unseeded samples
COD	Standard Methods (25) - Potassium dichromate as oxidant
Total Residue	Standard Methods (25) - Drying at 103^{o}C
Suspended Solids	Standard Methods (25) - Whatman #40 glass fiber filter, 5.5 cm. in diameter, drying at 103^{o}C
Specific Conductance	Wheatstone bridge and Conductivity Cell
Alkalinity	Standard Methods (25) - Sulfuric acid titrant
Phosphorus	Standard Methods (25) - Persulfate digestion with stannous chloride colorimetric method
NO_3^--N	Standard Methods (25) - Brucine method
NH_3-N	Standard Methods (25) - Matheson Chemical Company "kel-pack" modification
T.K.N.	Standard Methods (25) - Matheson Chemical Company "kel-pack" modification
Volatile Acids	DiLallo and Albertson (26) - Direct titration

Wastewater, 13th edition (25). Analyses were performed on five samples collected on a weekly basis.

RESULTS AND DISCUSSION

Condition of the Treatment Units Prior to the 1973-74 Campaign

One of the objectives of this investigation was to determine if the anaerobic lagoon, aerated lagoon and stabilization pond had recovered from the overloaded conditions that prevailed from 1970-72. The contents of the stabilization pond were green instead of the pink that was evident during 1970-72 when anaerobic conditions prevailed. Whereas the pink coloration was indicative of the presence of purple sulfur bacteria which proliferate under anaerobic conditions, the green color was due to the presence of oxygen-producing algae which are normally present in a well-operating stabilization pond. Further indication that the stabilization pond was aerobic was the absence of any noticable odors emanating from the pond. The aerated lagoon was also free from odors. Slight odors were emanating from the anaerobic lagoon. Furthermore, gas bubbles were observed at the surface of the anaerobic lagoon as would be expected when anaerobic decomposition was occurring.

In addition to the visual inspection of the wastewater treatment facilities, several analytical determinations were performed to evaluate the conditions of the system. The average results obtained from these analyses are presented in Table 6.

The highly negative oxidation-reduction potential, zero nitrate-nitrogen and high ammonia-nitrogen concentrations shown in Table 6 for

Table 6

Average Analytical Results Prior to the 1973-74 Campaign

Parameter	Anaerobic Lagoon	Aerated Lagoon	Stabilization Pond
Dissolved Oxygen	-	4.5 mg/l	8.1 mg/l
ORP	-358 mv	+42 mv	+63 mv
NO_3^--N	0 mg/l	61 mg/l	0.05 mg/l
NH_3-N	133 mg/l	0.31 mg/l	1.85 mg/l

the anaerobic lagoon are results typical of anaerobic conditions. The values presented in Table 6 for the aerated lagoon and stabilization pond all indicate that these units had returned to aerobic conditions prior to the 1973-74 processing season. The dissolved oxygen results should be considered approximate values due to an unexplained release of gas that occurred when the samples were fixed. The positive oxidation-reduction potentials, low ammonia-nitrogen concentrations and presence of nitrates in both units provide additional evidence in support of the conclusion that both units were aerobic immediately prior to the 1973-74 processing season.

Quantity of Raw Waste Streams

From a frequency distribution plot of flow, based on manual flow measurements from October 18 to November 14, 1973 (Appendix III), the raw waste flow as shown in Table 7 is equal to or less than 57 gpm 50 percent of the time. Ninety percent of the time the flow was less than or equal to 125 gpm. Highest flows occurred during daily plant clean-up, cleaning of a plugged flume, and during defrosting operations. The average daily flow ranged from a low of 54,720 gpd to a high of 142,560 gpd. The average wastewater flow during the day-shift processing period was approximately 64 gpm. Assuming this average to be representative of the entire 24-hour processing period, a discharge of 92,160

Table 7

Wastewater Flows, Midwest Foods Corporation[1]

Flow that occurred 50 percent of the time, equal to or less than	57 gpm
Flow that occurred 90 percent of the time, equal to or less than	125 gpm
Range of Flow	
gallons per minute (gpm)	0 to 225
gallons per day (gpd)	54,720 to 142,560
Average Daily Flow	
gallons per minute	64
gallons per day	92,160
Unit Wastewater Flow	
gallons/ton raw potatoes processed	813
Flume Silt-Water	
average total (gpd)	4,932
average unit flow, gallons/ton raw potatoes processed	58

[1]Based on a four week period from October 18 to November 14, 1973

gallons per day would result. Approximately 4.72 tons of raw potatoes were processed per hour of operation. Based on the average flow of 64 gpm, approximately 813 gallons of wastewater were produced per ton of raw potatoes processed.

Peak flows obtained from the Parshall flume during pumping of the flume silt-water ranged from 372 to 539 gpm with an average of 482 gpm. When the average plant flow, approximately 64 gpm, was subtracted from the average peak flow (482 gpm), an average pump capacity of 418 gpm was obtained. For an average pump run of 11.8 minutes, the daily silt-water volume was approximately 4,932 gallons. Based on an average input of 85 tons of raw potatoes per day, approximately 58 gallons of silt-water were produced per ton of raw potatoes processed. Without recirculation, water consumption for fluming and washing operations was found to be from 1,300 to 2,100 gallons per ton of raw potatoes processed according to Wolters (27) and ranged from 1,000 to 1,800 gallons per ton during Alder's investigation (27). Obviously, recirculation plus silt-water discharge only once per day reduced the water usage at Midwest Foods.

<u>Quality of the Raw Waste Streams</u>

Raw Wastewater

The quantity of raw potatoes processed per day varied considerably, ranging from 41 to 122 tons with an average of 85 tons. The characteristics of the raw wastes were also highly variable. The variations in strength as measured by COD, BOD_5, and suspended solids concentrations are shown in Figure 3. The COD, BOD_5 and suspended solids concentrations followed the same general pattern, except on November 9. Also, the BOD_5 concentration ranged from 15.7 to 75.5 percent of the COD concentration. Suspended solids were unusually high on November 9 and apparently added significantly to the COD of the waste but not to the BOD_5. Some caustic peel waste was discharged to the waste stream on this date and contributed to the increase in suspended solids, COD and pH of the raw waste on this date.

The average (except for pH) characteristics of the raw waste are presented in Table 8[2]. The pH of the raw waste ranged from 9.2 to 11.6. The median value was 10.6 which was lower than obtained by Hagin, undoubtedly the result of the reduction in caustic peel allowed to enter the waste effluent stream. The temperature of the raw waste varied from 73 to 81^{o}F with the average being 77^{o}F, about the same as reported by Hagin.

The impact of the new peeling process and implementation of extensive water conservation practices is clearly evident when the average unit wastewater flow for Midwest Foods is compared with the unit flow reported in earlier studies by Hagin. As shown in Table 8,

---

[2]Along with those of earlier investigations by Hagin (Fairfield Products) as well as the characteristics of raw potato processing wastes reported in the literature.

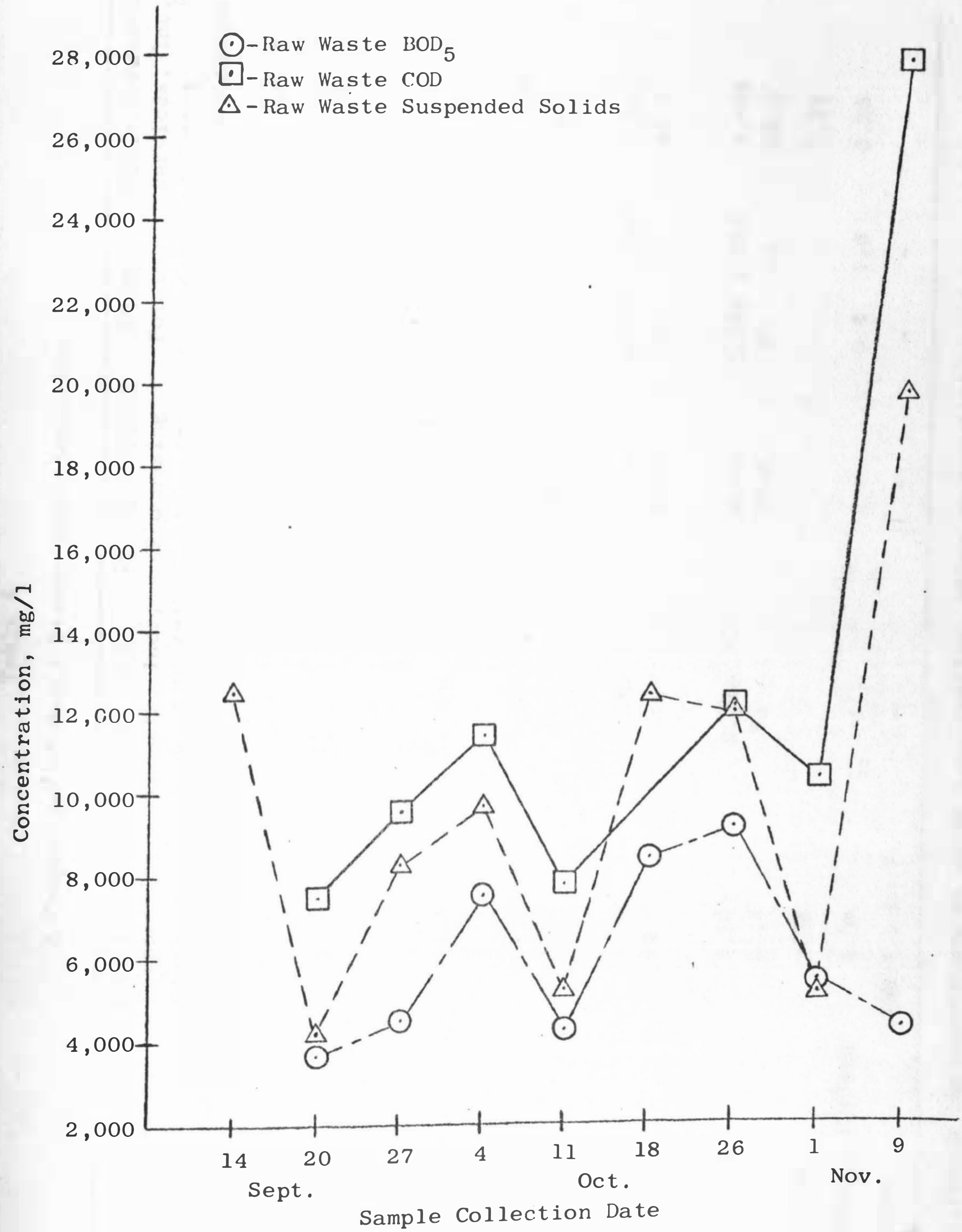


Figure 3: Characteristics of Raw Potato Waste, Midwest Foods Corporation, Clark, South Dakota, September 14 - November 9, 1973

Table 8

A Comparison of Waste Stream Characteristics

Characteristic	Midwest Foods Corporation Clark, S.D.	Fairfield Products, Inc., Clark, S.D. (7)	Typical Potato Processing Plant (5)	Maine Potato Plant(4)		Western Potato Services, Inc. (11)
Peeling Process	dry-caustic	dry-caustic	wet-caustic	wet-caustic		dry-caustic
pH	10.6	11.1	11.0	11.5	11.1*	10.8
Temperature, ^{o}F	77	78	-	-	-	-
Wastewater Flow, Gals/ton of raw potatoes	813	3,500	4,500	2,520	2,310	1,666
BOD_5,						
mg/l	5,978	3,552	1,750	2,460	1,150	2,879
lbs/ton	40.5	100	65.7	52	22	40
COD,						
mg/l	12,489	7,285	2,700	3,500	1,790	4,512
lbs/ton	84.6	216	101.3	74	34	62.7
Suspended Solids,						
mg/l	9,993	3,084	2,600	1,750	1,310	4,599
lbs/ton	67.7	91	97.6	37	25	63.9
T.K.N., lbs/ton	2.08	-	-	-	-	1.34
Inorganic Phos., lbs/ton	8.65	-	-	0.4	1.5	2.25
BOD_5:N:P ratio	100:7.1:26.7	-	-	-	-	-

*Results following implementation of water conservation, water recirculation and by-products recovery the unit wastewater flow was reduced by over 75 percent from 3,500 gallons to 813 gallons per ton of raw potatoes processed.

The COD of the raw waste varied from 7,573 mg/l to 28,093 mg/l with an average concentration of 12,489 mg/l. The BOD_5 of the raw waste varied from 3,680 mg/l to 9,280 mg/l with an average of 5,978 mg/l. The average amount of BOD_5 leaving the plant per day was 4,597 pounds or a population equivalent of greater than 27,000 people. The average BOD_5/COD ratio of the raw waste was 0.479. This value seems to be typical for potato processing wastes from frozen French fry plants in that values from 0.43 to 0.70 have been reported. Also, the investigation by Hagin resulted in an average BOD_5/COD ratio of 0.49 for the raw waste produced at Fairfield Products, Incorporated. As shown in Appendix VI, a correlation factor of 0.89 was obtained for the BOD_5 and COD concentrations in the raw waste by use of the statistical method of least squares. The suspended solids concentration varied from 4,220 mg/l to 19,990 mg/l with an average of 9,993 mg/l. The BOD_5, COD and suspended solids loadings per ton of raw potatoes processed were reduced by approximately 60, 61, and 26 percent, respectively. These reductions can be attributed to removal of the caustic peeling waste from the wastewater stream and the increased water conservation practices implemented by Midwest Foods Corporation.

Tests were performed to determine if sufficient inorganic nutrients were present in the raw waste to support biological growth.

The most commonly quoted requirement of the BOD:N:P ratio for aerobic biological treatment is 100:5:1 (28). Total inorganic phosphorus in the processing plant effluent averaged 1,165 mg/l based on two samples while the total kjeldahl nitrogen concentration averaged 308 mg/l and the average BOD_5 was 4,360 mg/l. The resultant BOD:N:P ratio was 100:7.1:26.7 which indicates that the raw wastewater contained quantities of nitrogen and phosphorus more than adequate to support aerobic biological growth. However, it is possible that during periods of extreme flow variation, a nitrogen deficiency might occur.

The typical raw waste characteristics presented in Table 8 and for one specific plant are based on the wet-caustic peeling process while the Clark, South Dakota, and Western Potato Services data represent wastewater derived from the dry-caustic peeling process. The median pH of the raw waste at Midwest Foods was approximately 0.5 unit less than the plants utilizing wet-caustic peeling processes and Fairfield Products due to removal of the caustic peel from the wastewater stream.

In comparing the wastewater flows from Midwest Foods Corporation with those of a "typical" plant and the Maine plant, it can be seen that the water usage for the wet-caustic peeling system is greater than that for the dry-caustic system utilized by Midwest Foods Corporation. These results which show a wet-caustic water usage over five times higher at the "typical" plant than at Midwest Foods would seem to be in agreement with the statement of Cyr (10) that as much as four times as much water may be used in a system employing a wet-caustic peeling process.

The reduction in wastewater discharge through water conservation and recirculation at the Maine potato processing plant utilizing the wet-caustic peeling process are readily apparent from Table 8. However, even in this case, the water use at Midwest Foods was only 35 percent of the flow at the Maine plant. A comparison of the data from Western Potato Services, with a dry-caustic peeler, indicates that the water discharge at Midwest Foods is approximately one-half that at Western Potato Services, Incorporated. Thus, it can be concluded that the water conservation programs and plant modifications employed by Midwest Foods during the 1973-74 campaign were extremely effective in reducing wastewater flow.

Although the BOD_5, COD and suspended solids concentrations of the wastes produced at the Midwest Foods Corporation plant are substantially higher than those obtained from the "typical" processing plant, the average pounds of BOD_5, COD and suspended solids produced per ton of raw potatoes were reduced by approximately 38, 16 and 31 percent, respectively, due to the decreased water usage by Midwest Foods. The in-plant modifications implemented in the Maine potato plant resulted in BOD_5, COD and suspended solids loadings per ton of raw potatoes substantially lower than those obtained for the Midwest Foods Corporation.

The primary factor contributing to this difference would seem to be the by-products recovery line at the Maine potato plant. By-product recovery would eliminate many of the potato solids discharged to the wastewater stream and, therefore, bring about a significant reduction in the BOD_5, COD and suspended solids loadings. Such modifications are being contemplated for the Midwest Foods plant, but have not yet been completed. The BOD_5, COD and suspended solids loadings per ton of raw potatoes for the dry-caustic peel process at the Western Potato Services plant were approximately equal to those for Midwest Foods.

In summary, the average BOD_5, COD and suspended solids unit waste production rates for the Midwest Foods plant compare favorably with the unit rates from a similar dry-caustic peel plant and are much lower than those reported for potato processing plants utilizing the wet-caustic peeling process. The most notable factor regarding the wastewater produced at the Midwest Foods plant is the low unit waste flow of 813 gallons of wastewater produced per ton of raw potatoes processed. This unit flow rate was over 50 percent lower than the lowest reported value found in the literature.

Flume Silt-Water

Analyses performed on the flume silt-water samples were limited to solids determinations. Complete flume silt-water analyses results are presented in Appendix VII and indicate the variability in quality of the flume silt-water. The average results of the analyses are presented in Table 9. Total residue concentrations varied from 5,544 mg/l to 34,558 mg/l and suspended solids concentrations varied from 2,040 mg/l to 31,220 mg/l. The average suspended solids concentration of 14,044 mg/l is comparable to results from other studies (6)(11). Settleable suspended solids after 23 hours of settling varied from 22 ml/l to 107 ml/l with an average of 61.6 ml/l.

Table 9

Average Results of Analyses of Flume Silt-Water

Parameter	Concentration
Total Residue, mg/l	17,438
Suspended Solids, mg/l	14,044
Settleable Solids, ml/l	
After 1 hr.	111.5
After 23 hr.	61.6
Settleable Solids/Total Residue, ml/mg	0.0037
Unit Silt Production, lbs. S.S./ton raw potatoes	6.8

Using the average suspended solids concentration of 14,044 mg/l and the average daily silt-water volume of 4,932 gallons, calculations indicate that 578 pounds of silt are discharged to the anaerobic lagoon per operating day. This is an average production of 6.8 pounds of suspended solids per ton of raw potatoes processed. Wolters (27) determined that from 100 to 400 pounds of solids were produced per ton of raw potatoes processed without recirculation of the water used for fluming and washing of the raw potatoes. Obviously, the raw potatoes used by Midwest Foods were not as heavily laden with soil as those during Wolters' study. Assuming this silt would occupy an average volume of 61.6 ml/l in the anaerobic lagoon, after settling, an average of 40.5 cubic feet of compacted silt was produced per operating day during the 1973-74 processing season. Midwest Foods operated for approximately 50 days during 1973, so approximately 2,025 cubic feet of silt were deposited in the anaerobic lagoon. Consequently, the volume of the anaerobic lagoon was reduced by two percent. A normal production year of about 245 operating days would produce approximately 9,925 cubic feet of compacted silt resulting in a 9.8 percent reduction in anaerobic lagoon volume. Continued volume reduction as a result of silt deposition could reduce the detention time significantly and result in decreased efficiency of the anaerobic lagoon.

Anaerobic Lagoon Performance

The average loadings and conditions under which the anaerobic lagoon operated are presented in Table 10. The pH in the anaerobic lagoon ranged from 6.8 to 7.4 and the median value was 7.1. The pH range usually specified for anaerobic and facultative bacteria is 6.6 to 7.6 with an optimum pH of 7.0 (29). Thus, the pH maintained in the

Table 10

Anaerobic Lagoon Performance

	Midwest Foods	Recommended Values	Fairfield Products	J.R.Simplot Company
pH range	6.8-7.4	6.6-7.6[1]	6.1-8.4	-
median pH	7.1	7.0[1]	7.2	-
Average temperature, ^{o}F	73	60[2]	53	62-71
Average influent flow, gpd	92,160	-	237,000	5,760
Average retention time, days	8.2	2-10[2]	9.8	8.8
Average Volatile Acids: Alkalinity Ratio	0.25	0.8[3]	-	0.5-3.5
Average alkalinity concentration, mg/l	3,853	2,000[2]	-	-
Average volatile acid conc., mg/l acetic acid	956	-	-	600-3,500
Average Loadings				
lbs COD/day	9,593	-	14,822	-
lbs COD/1000 cubic feet/day	95.0	-	47.8	-
lbs BOD_5/day	4,597	-	6,855	-
lbs BOD_5/1000 cubic feet/day	45.5	15[4]	22.1	11
lbs S.S./day	7,684	-	6,253	-
lbs S.S./1000 cubic feet/day	76.1	-	20.2	-
Average Removals				
lbs COD/day	5,986	-	-4,498	-
lbs COD/1000 cubic feet/day	59.3	-	-14.5	-
lbs BOD_5/day	3,388	-	-3,979	-
lbs BOD_5/1000 cubic feet/day	33.5	-	-12.8	2.75
lbs S.S./day	5,986	-	1,757	-
lbs S.S./1000 cubic feet/day	59.3	-	5.7	-
Average Removal Efficiencies, percent				
COD	62.4	-	-30	33
BOD_5	73.7	60-80[4]	-58	25
S.S.	77.9	-	28	82

[1] Eckenfelder (29)
[2] Dornbush (18)
[3] Dostal (17)
[4] White (20)

anaerobic lagoon was nearly ideal. The median pH of 7.1 was nearly the same as that obtained during Hagin's investigation, but as indicated in Table 10, Hagin encountered a greater variation in pH. The range obtained at Midwest Foods was within acceptable limits, whereas, some of the values obtained by Hagin could have been inhibitory to methane-forming bacteria in an anaerobic lagoon.

It is important to note that the raw waste pH was reduced from a median value of 10.6 to about neutrality (pH of 7.1) in the anaerobic lagoon. The mechanism for this neutralization has been delineated by Pohland and Bloodgood (30) and Pohland and Engstrom (31). According to these investigators, the hydrolysis of lipids and the fermentation of carbohydrates and proteins results in the production of organic fatty acids. These acids react with alkalinity present in the medium to form acid salts.

$$\underset{\text{bicarbonate alkalinity}}{Ca(HCO_3)_2} + \underset{\text{organic acid}}{2CH_3COOH} \longrightarrow \underset{\text{acid salt}}{(CH_3COO)_2Ca} + \underset{\text{water}}{2H_2O} + \underset{\text{carbon dioxide}}{2CO_2\uparrow} \; \ldots\ldots \; 1$$

The organic acids are eventually degraded to methane and carbon dioxide by further anaerobic decomposition resulting in the destruction of the acid salts and production of alkalinity.

$$\underset{\text{acid salt}}{(CH_3COO)_2Ca} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{methane}}{2CH_4\uparrow} + \underset{\text{bicarbonate alkalinity}}{Ca(HCO_3)_2} \ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

Ammonia is also produced as a result of protein decomposition. At the pH of normal digestion, the ammonia ion is in equilibrium with various end products of anaerobic digestion. For example, in the carbonate system,

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \text{ .... } 3$$

ammonia can react with the bicarbonate to form ammonium bicarbonate.

$$NH_4^+ + HCO_3^- \rightleftharpoons NH_4HCO_3 \text{............... } 4$$

Thus, the production of CO_2 would eventually lead to an increase in ammonium bicarbonate alkalinity. Ammonia can also react with the dissociated organic acids. Using acetic acid as an example,

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^- \text{...........5}$$

$$CH_3COO^- + NH_4^+ \rightleftharpoons CH_3COONH_4 \text{.............6}$$

The ammonium acetate is almost completely dissociated and, therefore, tends to increase the acetate ion concentration which concommittently depresses the dissociation of acetic acid. Thus, the hydronium ion concentration is smaller when ammonium acetate is present than when acetic acid is present alone. From equation 5, it can be seen that if acid is added, the shift will be to the left and if a base is added, the shift will be to the right. Added hydroxyl ions would be neutralized by the hydrogen ions released by further dissociation of acetic acid, whereas, added hydrogen ions would react with the excess acetate ions. The hydronium ion concentration will not change radically as long as there is a large excess of acetate ions and undissociated acetic acid compared to the amount of acid or base added.

The median raw waste pH of 10.6 was largely the result of the caustic peeling process which contributed large quantities of hydroxyl ions to the waste. From the above considerations, neutralization of the added hydroxyl ions would be accomplished in the anaerobic lagoon by the hydrogen ions released via dissociation of the organic acids. Thus, the anaerobic lagoon provided an effective neutralization of the caustic waste through a well-documented mechanism.

Temperature will also affect the performance of an anaerobic lagoon. An average temperature of 73°F was maintained in the anaerobic lagoon during the course of these studies. This value is well above the recommended minimum value of 60°F at which anaerobic biological activity is sharply curtailed. In 1971-72, Hagin found an average temperature of 53°F in the anaerobic lagoon, which at that time was uncovered. Thus, the styrofoam-straw cover utilized by Midwest Foods appears to have contributed substantially to maintaining a more suitable temperature in the lagoon.

The average BOD_5/COD ratio of the lagoon contents was 0.335 with a least squares correlation factor of 0.963. Reduction of the BOD_5/COD ratio from 0.479 in the raw waste to 0.335 in the anaerobic lagoon reflects removal of the more readily biologically oxidizable material in the anaerobic lagoon.

From Table 10, the daily flow entering the anaerobic lagoon for these studies averaged about 92,000 gallons per day. During Hagin's study, the average flow was almost 255 percent higher. However, the retention times obtained for each study were similar because the present lagoon volume is about 101,000 cubic feet, whereas, during the investigations of Hagin, the lagoon volume was approximately 310,000 cubic feet.

The average BOD_5 loading rate for these investigations was 45.5 pounds/1000 cubic feet/day. This value was approximately four times greater than the loading rate at the J. R. Simplot pilot-plant and more than twice as high as that reported by Hagin. Also, the BOD_5 loading rate was three times higher than that recommended for anaerobic lagoons in South Dakota (20). However, the anaerobic lagoon obtained a 73.7 percent average BOD_5 removal compared to the negative removal reported by Hagin and the 25 percent removal obtained in the pilot plant.

The higher efficiencies obtained in the most recent investigations were probably due to the higher average temperature within the lagoon. Also, the higher suspended solids loadings may have resulted in an increase in the amount of BOD_5 removed by sedimentation. This would appear to have been the case since suspended solids removals were about three times higher than that reported by Hagin. Because influent to the anaerobic lagoon is introduced at mid-depth, perhaps the silt-water could have acted as a "weighting agent" which may have aided sedimentation in this unit. Furthermore, average volatile acid concentrations in the anaerobic lagoon were fairly high (956 mg/l as acetic acid). The high concentration would indicate that the conversion of volatile acids to methane may have been inhibited slightly. However, the average volatile acid to alkalinity ratio and average alkalinity concentration in the lagoon were both sufficient to maintain the proper pH so that pH should not have impaired methane fermentation. Detention time should not have affected the results because all three studies reported approximately the same retention times and were within the recommended range.

The anaerobic lagoon at Midwest Foods operated very efficiently even though it received an average BOD_5 loading in excess of three times the recommended value. Maintaining the proper pH range and a sufficient temperature within the lagoon were very instrumental in the efficiencies obtained. From the data obtained, it is evident that the anaerobic lagoon at Midwest Foods was capable of effectively handling the BOD_5 and suspended solids loadings that were discharged to it.

Aerated Lagoon Performance

The average loadings and conditions under which the aerated lagoon operated are presented in Table 11. The average dissolved oxygen

Table 11

Aerated Lagoon Performance

	Midwest Foods	Recommended Values (16)	Fairfield Products[1]	J.R.Simplot Company
pH range	8.4-9.0	-	8.1-8.55	-
Temperature range, °F	35-63	-	49-54	42-53
Dissolved oxygen, mg/l	1.2(ave.)	1.5(min.)	0	-
Average retention time, days	32.9	1.6-16	14.8	8.8
k-factor, $days^{-1}$	0.160	0.25-1.0[2]	-	-
BOD_5:N:P ratio	100:25:90	100:5:1	-	-
Average Influent Concentrations, mg/l				
BOD_5	1,573	-	4,495	-
COD	4,692	-	8,016	-
Suspended Solids	2,200	-	1,858	-
Average Effluent Concentrations, mg/l				
BOD_5	251	-	2,405	-
COD	815	-	6,426	-
Suspended Solids	712	-	924	-
Average Loadings				
lbs BOD_5/day	1,210	-	10,834	-
lbs BOD_5/1000cu.ft./day	3.0	10	20.3	8
lbs COD/day	3,608	-	19,321	-
lbs COD/1000cu.ft./day	8.9	-	36.1	-
lbs S.S./day	1,691	-	4,478	-
lbs S.S./1000 cu.ft./day	4.2	-	11.1	-
Average Removals				
lbs BOD_5/day	990	-	5,378	7
lbs BOD_5/1000cu.ft./day	2.5	-	10.1	-
lbs COD/day	2,980	-	4,744	-
lbs COD/1000 cu.ft./day	7.4	-	8.9	-
lbs S.S./day	1,143	-	2,382	-
lbs S.S./1000 cu.ft./day	2.8	-	4.5	-
Average Removal Eff., percent				
BOD_5	81.8	-	49.6	88
COD	82.6	-	24.6	49
Suspended Solids	67.6	-	53.2	-230

[1]Aerated lagoon was operating under anaerobic conditions during this investigation

[2]Metcalf and Eddy (21)

concentration over four sampling periods was 1.2 mg/l with three of the four values being less than the minimum recommended dissolved oxygen concentration of 1.5 mg/l. Not only were three of the dissolved oxygen concentrations below the recommended value but two were zero. Therefore, it is possible that an oxygen deficiency existed periodically in the aerated lagoon. The low values were obtained when at least one of the six 25-horsepower aerators was not operating.

Sufficient inorganic nutrients were present in the influent to the aerated lagoon to support aerobic biological activity as indicated by the average BOD_5:N:P ratio of 100:25:90. Whereas the raw waste BOD_5:N:P ratio was 100:7.1:26.7, indicating a possible nitrogen deficiency at certain times, the BOD_5:N:P ratio present in the anaerobic lagoon effluent reveals that the anaerobic lagoon conserved the inorganic nutrients discharged to it. The increased nitrogen fraction was probably due to the reduction in carbon (BOD) brought about through the escape of carbon dioxide and methane from the degradation of nitrogen containing compounds. Because of the higher cellular growth rates and commensurate requirement for nitrogen, an aerobic treatment unit would probably not bring about a similar conservation of nitrogen. Therefore, the use of an anaerobic lagoon appears to be of considerable value in providing a BOD_5:N:P ratio suitable for biological treatment of potato wastes which might otherwise have been nitrogen deficient.

The temperatures in the lagoon were similar to those obtained during Hagin's investigation and the pilot-plant studies at the J. R. Simplot plant. As a result, temperature would not be a factor in comparing the efficiencies obtained by the three aerated lagoons. However, according to statistical analysis by the least squares method, as the temperature in the lagoon increased, BOD_5 removal also increased (Appendix VIII).

The pH of the aerated lagoon effluent ranged from 8.4 to 9.0 with a median of 8.9. The influent to the aerated lagoon had a median pH of 7.1. Thus, pH increased in the aerated lagoon. Oxidation of ammonia would appear to result in Equations (4) and (3) shifting to the left with a subsequent reduction in bicarbonate alkalinity and increase in pH due to the accompanying reduction in hydrogen ion concentration. Also, the organic matter and volatile acids entering the aerated lagoon would be oxidized under aerobic conditions to the end products of carbon dioxide and water. Due to the mixing action of the aerators, the carbon dioxide produced in the aerated lagoon would escape and result in an additional increase in the pH of the wastewater.

According to the experimental data (Appendix II), bicarbonate alkalinity was reduced from an average of 3,853 mg/l to an average of 3,339 mg/l in the aerated lagoon while the volatile acids concentration was reduced from an average of 956 mg/l to an average of 88 mg/l. Also, the influent ammonia-nitrogen concentration was about 50 mg/l, whereas, the aerated lagoon effluent ammonia-nitrogen concentration was approximately 5 mg/l. Nitrate-nitrogen, which was not present in the aerated lagoon influent, averaged about 56 mg/l in the effluent. These results would appear to be in agreement with the above explanation.

Average retention time in the aerated lagoon was twice as long as the maximum design value recommended by Thimsen; more than double that during Hagin's study; and approximately four times longer than that in the study by Dostal at the J. R. Simplot Company. The much longer retention time was undoubtedly the result of decreasing the average daily water usage from 237,000 gallons to 92,160 gallons. The overall first-order BOD_5 removal rate constant (k-factor) can be calculated using Equation (7).

$$\frac{S}{S_o} = \frac{1}{1 + k(V/Q)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

where;

S = effluent BOD_5 concentration, mg/l
S_o = influent BOD_5 concentration, mg/l
k = overall first-order BOD_5 removal rate constant
V = lagoon volume, million gallons
Q = flowrate, million gallons per day

Utilizing the average data obtained during this investigation, k was determined to be 0.160 $days^{-1}$. Typical values of k, according to Metcalf and Eddy (21-544), vary from 0.25 to 1.0. Therefore, the k-factor for the aerated lagoon was less than would be expected.

Because k is an overall BOD_5 removal rate which includes removal by biological oxidation and sedimentation, the low value of k could be due to the excessively long retention time provided in the aerated lagoon. From Equation (7), a reduction in the lagoon volume would theoretically result in a shorter retention time and larger k-factor without experiencing a change in effluent BOD_5 concentration. Therefore, it would appear that the long retention time provided in the aerated lagoon represents a safety factor which would permit higher loadings to the aerated lagoon without increasing the effluent BOD_5 concentration.

The average BOD_5 and COD concentrations in the influent to the aerated lagoon were substantially lower than during Hagin's investigation. However, influent suspended solids concentration was slightly higher during the present investigation. As a result of the reduction in wastewater flow, the BOD_5, COD and suspended solids loading rates were reduced by 85, 75 and 62 percent, respectively. The average BOD_5 loading rate of three pounds/1000 cubic feet/day was well below the maximum recommended value of 10 pounds/1000 cubic feet/day. A linear relationship existed between the BOD_5 and COD concentrations in the aerated lagoon effluent as indicated by a least squares correlation factor of 0.927 (Appendix VI). The average BOD_5/COD ratio was reduced from 0.335 to 0.308 as the wastewater passed through the aerated lagoon indicating further treatment of the oxidizable organic matter present in the waste.

Average BOD_5, COD and suspended solids removals of 81.8, 82.6 and 67.6 percent, respectively, were obtained by the aerated lagoon. A comparison of the removals obtained during Hagin's investigation and the present study cannot be completely justified because the unit was operating under anaerobic conditions from 1970-72. During the Hagin study, the unit received twice the recommended maximum BOD_5 loading. The unit operating under aerobic conditions did obtain higher BOD_5, COD and suspended solids removal efficiencies than while operating under anaerobic conditions. Sedimentation probably resulted in the BOD_5 and COD removals obtained under anaerobic conditions; whereas, sedimentation plus biological activity resulted in the higher percentages of BOD_5 and COD removed under aerobic conditions. The increased retention time during the present investigation probably resulted in the increased percentage of COD removal.

A shorter retention time and higher BOD_5 loading rate were utilized at the J. R. Simplot completely-mixed aerated lagoon. The aerated lagoon at Midwest Foods did not produce an increased BOD_5 reduction as a result of the increased retention time. However, a larger suspended solids removal was obtained along with a greater percentage of the COD removed. The increased suspended solids removal and increased retention time may have resulted in the higher percentage of COD removal.

Stabilization Pond Performance

The average loadings and conditions under which the stabilization pond operated are presented in Table 12. No discharge from the pond was permitted and, therefore, the retention time within the pond should have been in excess of the recommended value. The median pH in the stabilization pond was 9.5. As a result of the conservation of nutrients in the anaerobic lagoon, the BOD_5:N:P ratio indicates that more than enough nitrogen and phosphorus were present to support biological growth.

Dissolved oxygen was always present in the pond with an average concentration of 14.2 mg/l. During the previous study (7), dissolved oxygen could not be detected in the pond due to the anaerobic conditions resulting from an average BOD_5 loading of 248 pounds/acre/day, over ten times higher than the recommended loading for northern climates. The average BOD_5 loading rate during the present study was 8.8 pounds/acre/day which was 56 percent less than the recommended rate of 20 pounds/acre/day. Therefore, the average BOD_5 loading to the pond was approximately 96 percent less than reported by Hagin. The average COD and suspended solids loading rates were reduced by 96 and 74 percent, respectively. The reductions were primarily the result of the

Table 12

Stabilization Pond Performance

	Midwest Foods	Fairfield Products[4]	Recommended Values
pH range	9.4-9.9	7.9-8.1	
Average retention time, days	No discharge	-	7-30,[1] up to 120[2]
Dissolved oxygen, mg/l	14.2	0	>0
BOD_5:N:P ratio	100:17.7:179	-	100:5:1[3]
Average Loadings			
lbs COD/day	626.7	14,577	-
lbs COD/acre/day	28.5	663	-
lbs BOD_5/day	193	5,456	-
lbs BOD_5/acre/day	8.8	248	20-50[1], 20[2]
lbs S.S./day	547.5	2,096	-
lbs S.S./acre/day	24.9	95.3	-
Average Removals			
lbs COD/day	264.5	10,641	-
lbs COD/acre/day	12.0	484	-
lbs BOD_5/day	147.6	3,928	-
lbs BOD_5/acre/day	6.7	179	-
lbs S.S./day	433.1	1,488	-
lbs S.S./acre/day	19.7	67.6	-
Average Removal Efficiencies, percent			
COD	42.2	73	-
BOD_5	76.5	72	75-85[1]
Suspended Solids	79.1	71	-

[1]Eckenfelder (29)
[2]Olson, et al. (23)
[3]Thimsen (16)
[4]Stabilization pond was operating under anaerobic conditions during this study.

effectiveness of the anaerobic and aerated lagoons during the investigations described herein, and the overall reduction in waste loadings from the processing plant when compared to the conditions prevailing during the investigations by Hagin.

During the 1973-74 processing season, the stabilization pond obtained an average BOD_5 removal of 76.5 percent, which would be expected from a properly operating unit. The BOD_5 and suspended solids removal efficiencies under aerobic conditions were slightly higher than those obtained when the pond was anaerobic. However, the average percentage of COD removed under aerobic conditions was 30 percent less. The smaller percentage of COD removed would be expected because, based on BOD_5/COD ratios, the COD entering the stabilization pond during the present study was not as amenable to treatment by oxidation as that during the investigation by Hagin. The average BOD_5/COD ratio of the stabilization pond contents was 0.125 which indicates that stabilization was much more complete during the present study than during the investigation by Hagin in which the average BOD_5/COD ratio of the stabilization pond was 0.374. A linear correlation factor of 0.658 was determined for the BOD_5 and COD concentrations in the stabilization pond (Appendix VI).

Adequacy of the Existing System

The overall removal efficiencies of the wastewater treatment system employed by Midwest Foods Corporation are summarized in Table 13.

Table 13

Overall Treatment System Efficiencies

	Midwest Foods	Fairfield Products
Average Final Concentrations in Stabilization Pond, mg/l		
COD	471	1,740
BOD_5	59	680
Suspended Solids	149	266
Average Overall System Removal Efficiencies, percent		
COD	96.2	76
BOD_5	99	81
Suspended Solids	98.5	91

As indicated from Table 13, the average overall BOD_5, COD and suspended solids concentrations in the stabilization pond were substantially lower than those obtained during Hagin's investigation. Also, the average overall system removal efficiencies were higher during the present study with the average BOD_5, COD and suspended solids removals being 99, 96.2 and 98.5 percent, respectively. Along with the increased removal efficiencies was the absence of the obnoxious odors present during the investigation by Hagin during which the treatment units operated under anaerobic conditions.

Although the average BOD_5 and suspended solids removals were high, the average final BOD_5 and suspended solids concentrations exceed the recommended discharge limits of 30 mg/l of BOD_5 and 30 mg/l of suspended solids adopted by the South Dakota Committee on Water Pollution. As a result, effluent from the stabilization pond could not be discharged to surface waters in South Dakota without additional treatment. However, because of the low hydraulic loading to the pond, no direct discharge from the pond existed, primarily due to evaporative losses from the aerated lagoon and stabilization pond.

Average BOD_5, COD and suspended solids removals obtained by the various treatment units are depicted by the pie graphs in Figure 4. The graphs indicate that the anaerobic lagoon is the major treatment unit in the system removing an average of 73.7 percent of the BOD_5, 62.4 percent of the COD and 77.9 percent of the suspended solids.

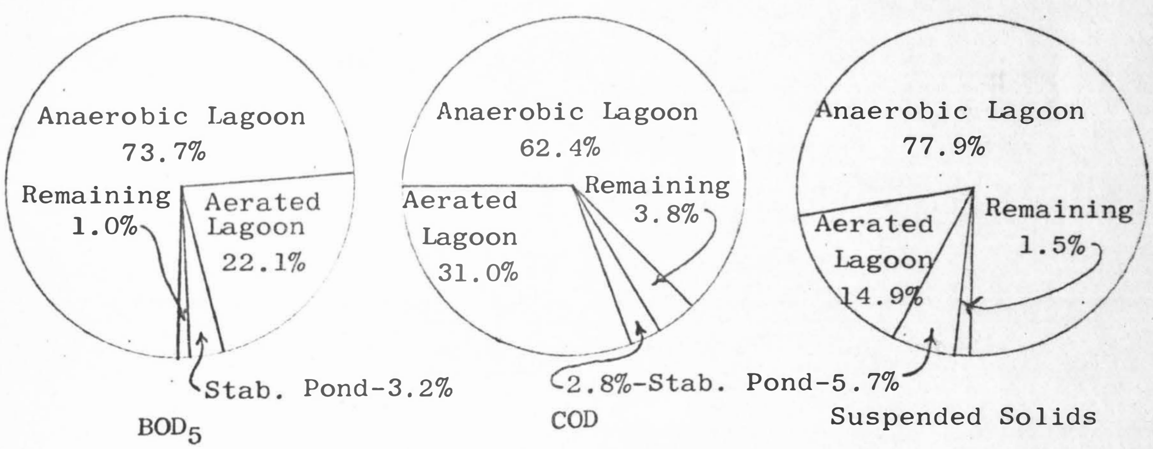


Figure 4: Average Removals Obtained by the Various Treatment Units Based on Raw Waste Characteristics

Continued discharge of the flume silt-water to the anaerobic lagoon could eventually decrease the retention time of this unit. A reduction in the efficiency of the anaerobic lagoon and the entire system could result. Therefore, the flume silt-water should be discharged to an acceptable alternative lagoon or clarifier prior to being discharged to the anaerobic lagoon.

The excellent removal efficiencies obtained with the present system can be attributed to (1) reduction in BOD_5, COD and suspended solids loadings by 60, 61 and 26 percent, respectively, and (2) reduction in the hydraulic loading from an average of 0.24 mgd to 0.092 mgd.

SUMMARY AND CONCLUSIONS

This investigation of the treatment system for the potato processing wastes at Midwest Foods Corporation, Clark, South Dakota, covered a three and one-half month period. During this time, analytical determinations and flow measurements were utilized to calculate loadings and removal efficiencies for the various treatment units. The following conclusions were drawn from these investigations.

1. Immediately prior to the 1973-74 processing season, aerobic conditions prevailed in the aerated lagoon and stabilization pond indicating that these units had recovered from the overloaded conditions that existed from 1970 to 1972.
2. Utilization of a new dry-caustic peeling process and extensive in-plant water conservation have reduced the water usage from 3,500 gallons per ton of raw potatoes to approximately 813 gallons per ton which is approximately 50 percent less than the lowest value reported in the literature.
3. The anaerobic lagoon was an effective treatment unit in which average BOD_5 and suspended solids removals of 74 and 78 percent, respectively, were obtained despite an average BOD_5 loading rate of 45.5 pounds/1000 cubic feet/day, over three times higher than the recommended design value.
4. The styrofoam-straw cover on the anaerobic lagoon was effective in maintaining an adequate temperature in the lagoon.

5. It is evident from the BOD_5:N:P ratios obtained that it is advantageous to use an anaerobic lagoon prior to aerobic treatment if conservation of inorganic nutrients is desired.
6. The aerated lagoon, operating well within the BOD_5 loading range, performed within anticipated efficiencies removing 82 percent of the BOD_5 and 68 percent of the suspended solids.
7. The stabilization pond was operating at about 50 percent of its design BOD_5 loading. The BOD_5 and suspended solids removal efficiencies in this unit were 77 and 79 percent, respectively.
8. During this investigation, overall average removal efficiencies of 99 percent, 98.5 percent and 96.2 percent were obtained for BOD_5, suspended solids and COD, respectively.
9. Although the treatment system obtained high BOD_5 and suspended solids removals, further treatment would be required before direct discharge to a surface water in South Dakota could be practiced.
10. The anaerobic lagoon was effective in reducing the pH of the raw waste from a median value of 10.6 to 7.1.
11. Although slight odors were detected in the vicinity of the anaerobic lagoon, they were not considered a nuisance during the period of investigation.

12. Silt build-up at the present rate of 40.5 cubic feet/ operating day, could eventually decrease the volume of the anaerobic lagoon, thus, reducing the retention time in the lagoon and possibly the efficiencies obtained by the anaerobic lagoon.

RECOMMENDATIONS

1. Midwest Foods should continue its water conservation practices and should place an employee in charge of waste handling operations in order that strict in-plant control of the various processes can be maintained at all times.
2. The flume silt-water should not be discharged to the anaerobic lagoon, but should be discharged to a separate lagoon or clarifier before being sent to the anaerobic lagoon.
3. The treatment system should be analyzed during winter months under normal loading conditions to determine its capability during winter conditions.
4. A suitable platform for an automatic flow recorder should be installed so that the daily variations in flow can be obtained. The platform should be anchored so that vibration will not affect the performance of the flow recorder.

LITERATURE CITED

1. Talburt, William F., and Smith, Ora, Potato Processing, the Avi Publishing Company, Inc., Westport, Connecticut, (1967).

2. Douglass, Irwin B., "By-products and Waste in Potato Processing," Proceedings 15th Industrial Waste Conference, Purdue University, Lafayette, Indiana, 99-106, (1960).

3. The U.S. Book of Facts, Statistics and Information for 1969, Bureau of Census, U.S. Department of Commerce, 89th edition, (84,632).

4. Dostal, Kenneth A., "Secondary Treatment of Potato Processing Wastes," Report No. 12060-07/69, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., (1969).

5. Guttormsen, Kristian, and Carlson, Dale A., "Status and Research Needs of Potato Processing Wastes," Proceedings First National Symposium on Food Processing Wastes, Report No. 12060-04/70, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 27-38, (1970).

6. Grames, Lloyd M., and Kueneman, Ray W., "Primary Treatment of Potato Wastes with By-product Feed Recovery," Water Pollution Control Federation Journal, 41, No. 7, 1358-1367, (1969).

7. Hagin, Terry L., A Study of the System Treating Potato Processing Wastes at Fairfield Products, Inc., Clark, South Dakota, Master of Science Thesis, South Dakota State University, Brookings, South Dakota, (1972).

8. Cooley, A. M., Wahl, E. D., and Fossum, G. O., "Characteristics and Amounts of Potato Wastes from Various Process Streams," Proceedings 19th Industrial Waste Conference, Purdue University, Lafayette, Indiana, 379-390, (1964).

9. Sproul, O., Keshavan, K., Hall, M. W., and Barnes, B. B., "Wastewater Treatment from Potato Processing," Water and Sewage Works, 15, February, 1968, 93-96.

10. Cyr, Joseph W., "Progress Report: Study of Dry Caustic vs Conventional Caustic Peeling and the Effect on Waste Disposal," Proceedings Second National Symposium on Food Processing

Wastes, Report No. 12060-03/71, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 129-136, (1971).

11. R. T. French Company, "Aerobic Secondary Treatment of Potato Processing Wastes," Report No. 12060 EHV-12/70, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., (1970).

12. Graham, R. P., Huxsoll, C. C., Hart, M. R., Weaver, M. L., and Morgan, A. I. Jr., "Prevents Potato Peel Pollution," Food Engineering, June, 1969, 91-93.

13. Fossum, G. O., Cooley, A. M., and Wahl, E. D., "Stabilization Ponds Receiving Potato Wastes with Domestic Sewage," Proceedings 19th Industrial Waste Conference, Purdue University, Lafayette, Indiana, 96-111, (1964).

14. Atkins, Peter F., and Sproul, Otis J., "Feasibility of Biological Treatment of Potato Processing Wastes," Water Pollution Control Federation Journal, 38, No. 8, 1287-1297, (1966).

15. Clark, John W., Viessman, Warren Jr., and Hammer, Mark J., Water Supply and Pollution Control, International Textbook Company, Scranton-London-Toronto, (1971).

16. Thimsen, Donald J., "Biological Treatment in Aerated Lagoons," Twelfth Annual Waste Engineering Conference, University of Minnesota, (1965).

17. Dostal, Kenneth A., "Pilot Plant Studies on Secondary Treatment of Potato Processing Wastes," Potato Waste Treatment, Federal Water Pollution Control Administration, Corvallis, Oregon, 27-42, (1968), distributed by National Technical Service, U.S. Department of Commerce, Springfield, Virginia.

18. Dornbush, James N., "State of the Art-Anaerobic Lagoons," 2nd International Symposium for Waste Treatment Lagoons, distributed by Ross E. McKinney, University of Kansas, Lawrence, Kansas, 382-387, (1970).

19. Pfeffer, John T., "Anaerobic Lagoons—Theoretical Considerations," 2nd International Symposium for Waste Treatment Lagoons, distributed by Ross E. McKinney, University of Kansas, Lawrence, Kansas, 310-320, (1970).

20. White, James N., "Current Design Criteria for Anaerobic Lagoons," 2nd International Symposium for Waste Treatment Lagoons, distributed by Ross E. McKinney, University of Kansas, Lawrence, Kansas, 360-363, (1970).

21. Metcalf and Eddy, Inc., Wastewater Engineering, McGraw-Hill Book Company, New York, (1972).

22. Benjes, Henry Jr., "Theory of Aerated Lagoons," 2nd International Symposium for Waste Treatment Lagoons, distributed by Ross E. McKinney, University of Kansas, Lawrence, Kansas, 210-217, (1970).

23. Olson, O. O., Van Heuvelan, W., and Vennes, John W., "Aeration of Potato Waste," Proceedings 19th Industrial Waste Conference, Purdue University, Lafayette, Indiana, 180-194, (1964).

24. Purushothaman, K., "Field Studies on Stabilization Ponds in South India," 2nd International Symposium for Waste Treatment Lagoons, distributed by Ross E. McKinney, University of Kansas, Lawrence, Kansas, 80-88, (1970).

25. Standard Methods for the Examination of Water and Wastewater, 13th edition, American Public Health Association, Incorporated, New York, New York, (1971).

26. DiLallo, R., and Albertson, O. E., "Volatile Acids by Direct Titration," Water Pollution Control Federation Journal, 33, 4,356-, (Apr. 1961).

27. Guttormsen, K., et al., "Current Practice in Potato Processing Waste Treatment," Washington University, Seattle, Washington, (1969), distributed by National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia.

28. Dostal, Kenneth A., "Aerated Lagoon Treatment of Food Processing Wastes," Report No. 12060-03/68, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., (1968).

29. Eckenfelder, W. W. Jr., Industrial Water Pollution Control, McGraw-Hill Book Company, New York, (1966).

30. Pohland, F. G., and Bloodgood, D. E., "Laboratory Studies on Mesophilic and Thermophilic Anaerobic Sludge Digestion," Water Pollution Control Federation Journal, 35, 1, 11-42, (1963).

31. Pohland, F. G. and Engstrom, R. J., "High Rate Digestion Control," Proceedings 19th Industrial Waste Conference, Purdue University, Lafayette, Indiana, 80-89, (1964).

APPENDIX I

Summary of Results Prior to the 1973-74 Campaign

Treatment Unit and Parameters Tested	Sampling Date			Average
	Aug.1	Aug.14	Aug.31	
ANAEROBIC LAGOON				
Oxidation-Reduction Potential, mv	-390	-318	-366	-358
Nitrate-Nitrogen, mg/l	-	0	0	0
Ammonia-Nitrogen, mg/l	-	111	155	133
AERATED LAGOON				
Dissolved Oxygen, mg/l	4.5	4.15	4.75	4.5
Oxidation-Reduction Potential, mv	+21	+72	+33	+42
Nitrate-Nitrogen, mg/l	-	74	48	61
Ammonia-Nitrogen, mg/l	-	0	0.62	0.31
STABILIZATION POND				
Dissolved Oxygen, mg/l	12.7	6.1	5.5	8.1
Oxidation-Reduction Potential, mv	+12	+138	+39	+63
Nitrate-Nitrogen, mg/l	-	0.045	0.045	0.045
Ammonia-Nitrogen, mg/l	-	0	3.7	1.85

APPENDIX II

Summary of Results From Each Point of Sampling
During Processing Season At Midwest Foods Corporation
Clark, South Dakota
September 14, 1973-November 9, 1973

PLANT EFFLUENT

Date	pH (units)	Temp. (°C)	BOD_5 (mg/l)	COD (mg/l)	S.S. (mg/l)	Total Residue (mg/l)	Specific Conduct. (μmhos/cm)	Alkalinity M.O. (mg/l)	Alkalinity P. (mg/l)	Phos. (mg/l)	T.K.N. (mg/l)	NO_3^--N (mg/l)	NH_3-N (mg/l)
9-14-73	10.6	-	-	>19,768	12,500	19,944	6,284	2,851	911	-	-	0.04	-
9-20-73	10.2	23	3,680	7,573	4,220	10,636	5,778	2,274	510	-	-	0.12	14
9-27-73	10.5	23.5	4,560	9,630	8,320	14,508	6,283	2,397	944	-	-	-	-
10-4-73	10.3	27	7,600	11,467	9,760	14,125	5,722	2,040	612	-	-	-	-
10-11-73	9.2	26	4,320	7,858	5,230	12,900	5,926	1,734	459	990	190	0	14
10-18-73	10.7	26	8,480	-	12,520	20,034	7,820	2,856	943	1,500	-	0.25	-
10-26-73	11.6	26.5	9,280	12,262	12,120	20,568	5,977	2,295	638	-	-	0.25	-
11-1-73	11.2	-	5,500	10,543	5,280	13,464	6,572	2,423	1,046	-	-	0.40	-
11-9-73	11.45	24	4,400	28,093	19,990	27,960	10,485	4,437	2,652	1,340	427	0.45	60
Average	10.6	25.1	5,978	12,489	9,993	17,127	6,801	2,590	968	1,277	308	0.22	29.3

ANAEROBIC LAGOON CONTENTS NEAR EFFLUENT

Date	pH (units)	ORP (mv)	Temp. (°C)	Vol. Acids (mg/l)	BOD_5 (mg/l)	COD (mg/l)	S.S. (mg/l)	Total Residue (mg/l)	Specific Conduct. (µmhos/cm)	Alk. M.O. (mg/l)	Phos. (mg/l)	T.K.N. (mg/l)	NH_3-N (mg/l)
9-14-73	6.8	-402	23	1,065	1,380	>1,977	470	5,930	6,386	3,861	508	-	-
9-20-73	7.2	-	-	1,140	1,400	3,088	820	5,865	6,053	3,881	-	88.2	14
9-27-73	7.1	-408	23	1,380	3,880	9,742	5,760	10,652	5,773	3,468	-	-	-
10-4-73	No Sample Collected												
10-11-73	No Sample Collected												
10-18-73	7.3	-	24.5	810	1,280	4,896	3,070	8,477	6,923	3,978	870	238	14
10-26-73	7.1	-384	22.5	885	1,360	3,794	1,980	7,601	6,539	3,774	-	-	-
11-1-73	7.0	-	22	840	1,200	4,070	2,060	7,432	6,624	3,825	-	-	-
11-9-73	7.4	-390	21	570	510	2,564	1,240	6,922	7,062	4,182	740	214	60
Average	7.1	-396	22.7	956	1,573	4,692	2,200	7,554	6,480	3,853	706	180	50.2

Notes: (1) P. Alkalinity was zero on each sampling date

(2) Nitrate-Nitrogen concentration was zero on each sampling date

AERATED LAGOON EFFLUENT

Date	pH (units)	Temp (^{o}C)	D.O. (mg/l)	ORP (mv)	BOD_5 (mg/l)	COD (mg/l)	S.S. (mg/l)	Alkalinity M.O. (mg/l)	Alkalinity P. (mg/l)	Phos. (mg/l)	T.K.N. (mg/l)	NH_3-N (mg/l)	NO_3^--N (mg/l)
9-14-73	9.0	17	3.4	-21	148	426	240	4,871	297	252	-	-	>125
9-20-73	8.6	-	-	-	206	640	472	4,253	78	-	37	7.7	>110
9-27-73	9.0	16.5	1.4	-78	288	1,007	876	3,825	102	-	-	-	-
10-4-73	9.0	16.5	-	-	228	783	600	3,290	102	-	-	-	-
10-11-73	8.9	-	-	-	233	707	432	3,188	102	416	39.2	7.7	44
10-18-73	8.4	14	0	-	280	937	872	3,213	25.5	676	-	-	72
10-26-73	8.4	15	-	-12	367	1,027	1,176	3,086	38	-	-	-	62.5
11-1-73	8.4	9.5	0	-	255	891	904	3,060	51	-	-	-	42
11-9-73	8.85	1.5	-	-96	37	914	832	2,958	51	456	57	0	60
Average	8.7	12.9	1.2	-52	251	815	712	3,527	94	450	44.4	5.1	56

Notes: (1) Total Residue concentrations varied from 5,505 to 6,613 mg/l with an average of 6,017 mg/l

(2) Specific Conductance values ranged from 6,003 to 7,314 µmhos/cm with an average of 6,740 µmhos/cm

STABILIZATION POND CONTENTS

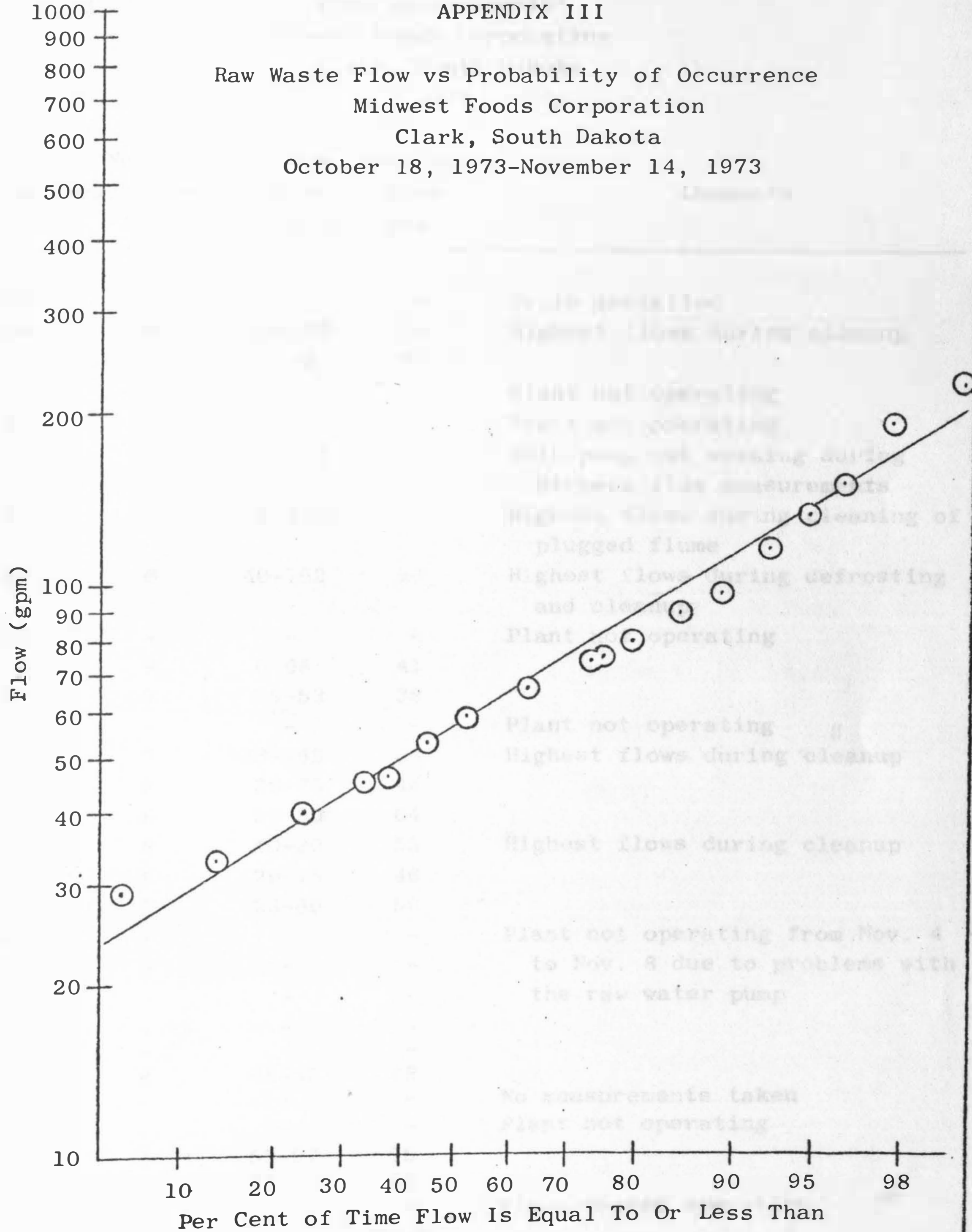
Date	pH (units)	Temp (^{o}C)	D.O. (mg/l)	BOD_5 (mg/l)	COD (mg/l)	S.S. (mg/l)	Total Residue (mg/l)	Specific Conduct. (μmhos/cm)	Alkalinity M.O. (mg/l)	Alkalinity P. (mg/l)	Phos. (mg/l)	T.K.N. (mg/l)	NO_3^--N (mg/l)
9-14-73	9.5	18	8.8	86	548	172	7,152	8,434	5,515	983	240	-	0.06
9-20-73	9.4	-	-	60	441	141	6,711	8,566	5,616	869	-	17.9	0.14
9-27-73	9.7	17	22.7	52	493	142	6,403	8,163	4,998	791	-	-	-
10-4-73	9.9	15	-	83	512	173	6,491	8,313	4,769	884	-	-	-
10-11-73	9.8	-	-	64	452	129	6,693	8,409	4,756	867	236	18.9	0.05
10-18-73	9.5	12	14.7	39	406	86	6,390	9,078	4,909	867	294	-	0.07
10-26-73	9.5	13.4	-	63	450	105	6,662	8,493	4,718	816	-	-	0.24
11-1-73	9.6	5	10.7	44	441	93	6,398	8,356	4,807	867	-	-	0.26
11-9-73	9.5	1.5	-	41	497	300	7,203	9,288	5,253	901	269	29.6	0.33
Average	9.6	11.7	14.2	59	471	149	6,678	8,567	5,038	872	260	22.1	0.16

Notes: (1) Oxidation-Reduction Potentials varied from -3 to -23 mv with an average of -11.8 mv during the processing season

(2) Ammonia-nitrogen concentrations in the stabilization pond were zero throughout the processing season

APPENDIX III

Raw Waste Flow vs Probability of Occurrence
Midwest Foods Corporation
Clark, South Dakota
October 18, 1973-November 14, 1973



APPENDIX IV

Flow Measurements[1]
Midwest Foods Corporation
Clark, South Dakota
1973

Date	No. of Measurements	Flow Range (gpm)	Ave. Daily Flow (gpm)	Comments
10-17	-	-	-	Drain installed
10-18	8	40-225	99	Highest flows during cleanup
10-19	4	60-97	77	
10-20	-	-	-	Plant not operating
10-21	-	-	-	Plant not operating
10-22	8	53-117	75	Skim pump not working during highest flow measurements
10-23	9	29-134	73	Highest flows during cleaning of plugged flume
10-24	6	40-192	96	Highest flows during defrosting and cleanup
10-25	-	-	-	Plant not operating
10-26	9	0-66	41	
10-27	7	29-53	38	
10-28	-	-	-	Plant not operating
10-29	7	33-152	64	Highest flows during cleanup
10-30	8	29-75	44	
10-31	6	29-90	64	
11-1	8	10-90	53	Highest flows during cleanup
11-2	6	29-75	46	
11-3	2	33-66	50	
11-4	-	-	-	Plant not operating from Nov. 4 to Nov. 8 due to problems with the raw water pump
11-5	-	-	-	
11-6	-	-	-	
11-7	-	-	-	
11-8	-	-	-	
11-9	8	45-80	68	
11-10	-	-	-	No measurements taken
11-11	-	-	-	Plant not operating
11-12	6	53-97	75	
11-13	3	40-53	46	
11-14	-	-	-	Plant ceased operation
Total	105	0-225	63.6	

[1]After installation of the drain on the stilling well in which the flow measurements were obtained

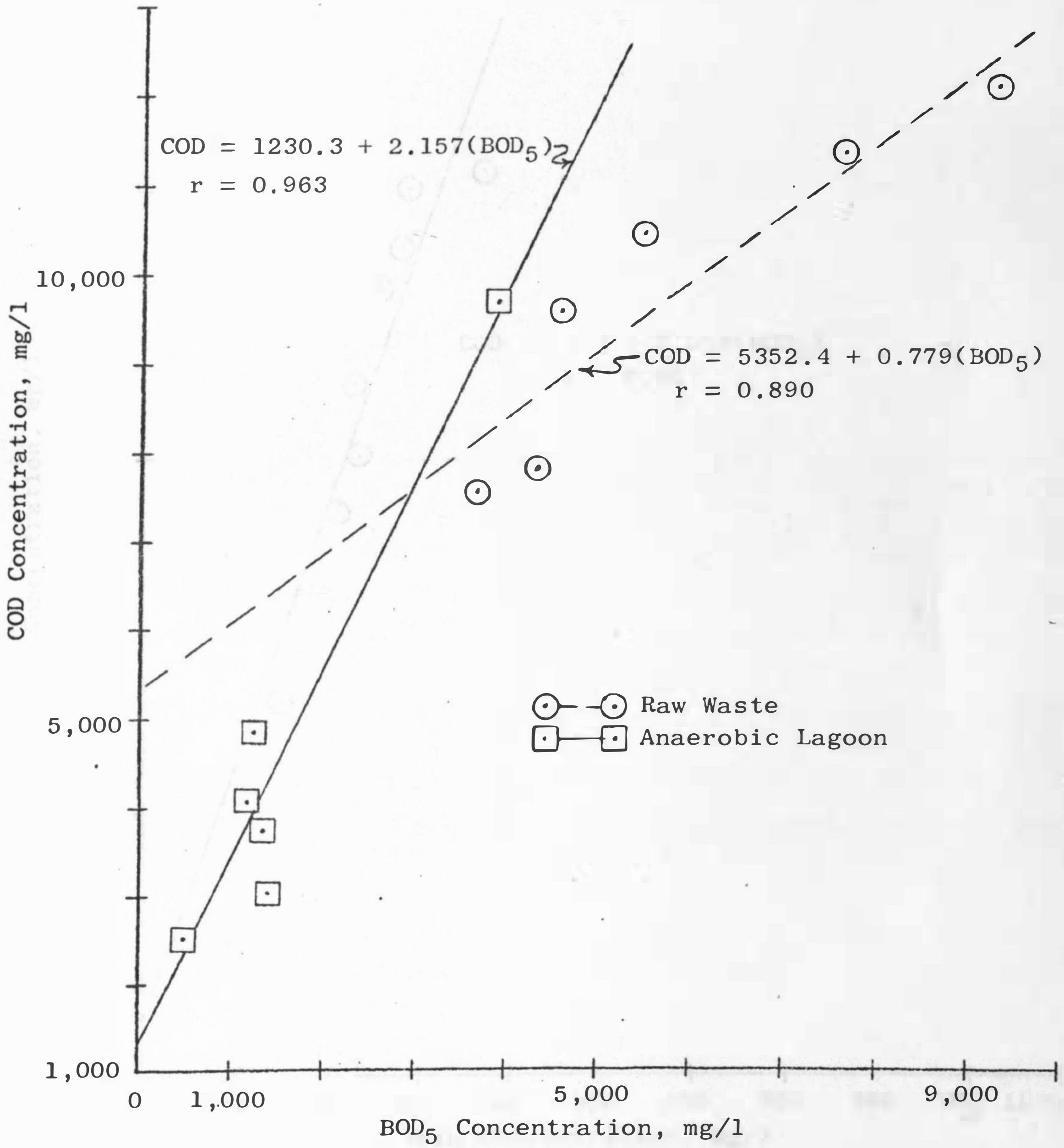
APPENDIX V

Summary of 1973 Potato Production
on Sampling Dates
Midwest Foods Corporation
Clark, South Dakota

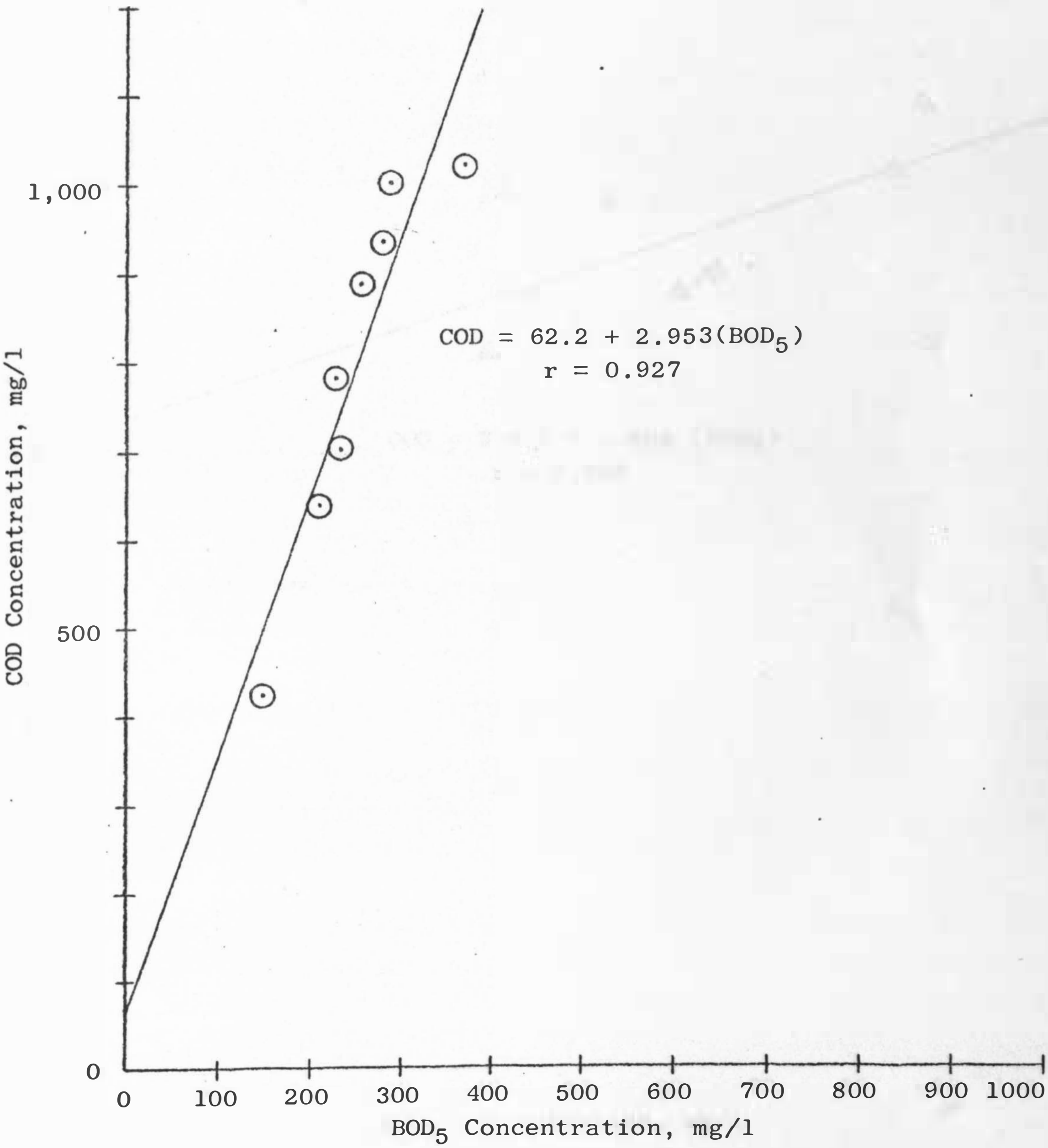
Sampling Date	Production Hours	French Fries Produced (tons)	Raw Potatoes Processed (tons)	Raw Potatoes Processed/Hr. (tons/hr.)
9-14-73	-	-	-	-
9-20-73	3	7.095	12.02	4.01
9-27-73	11.5	29.525	50.05	4.35
10-4-73	-	-	-	-
10-11-73	6.25	18.73	31.75	5.08
10-18-73	6.5	16.075	27.25	4.19
10-26-73	6	19.25	32.63	5.44
11-1-73	7	21.675	36.74	5.25
11-9-73	8	22.10	37.46	4.68
Total	48.25	134.45	227.89	
Average				4.72

APPENDIX VI

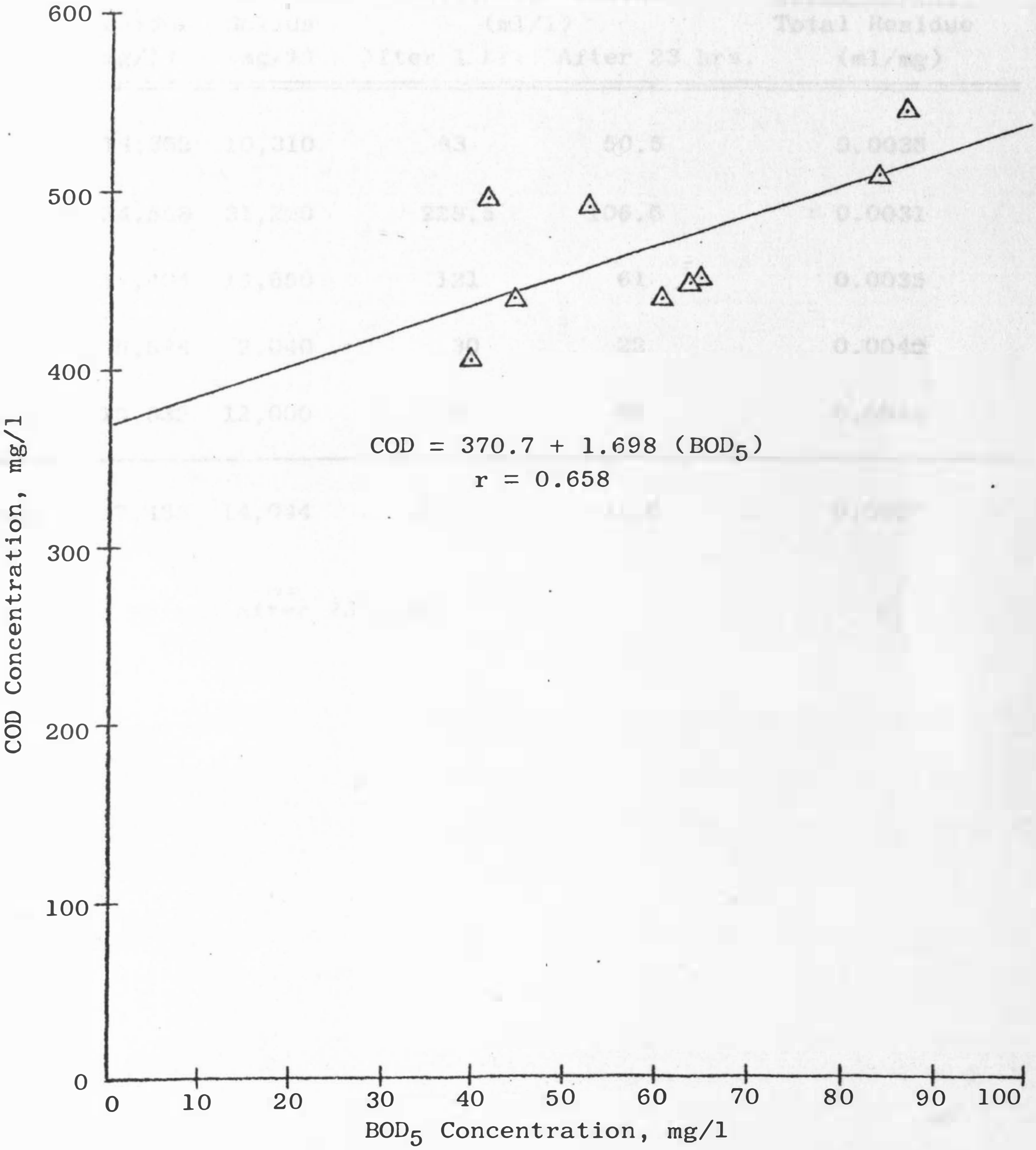
Least Squares Analyses of Relationship Between BOD_5 and COD
Midwest Foods Corporation
Clark, South Dakota
1973



APPENDIX VI
(Continued)
Aerated Lagoon



APPENDIX VI
(Continued)
Stabilization Pond



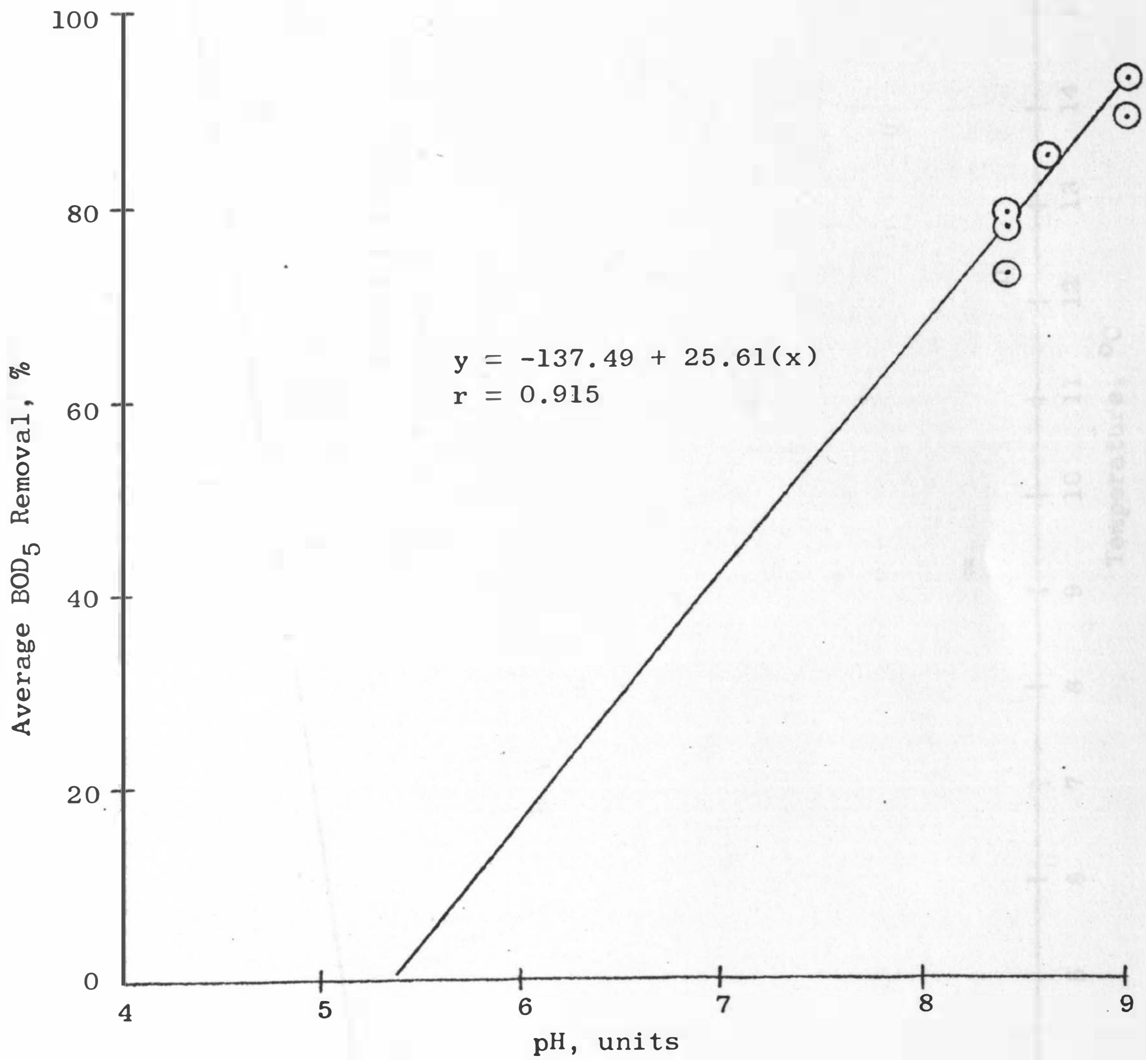
APPENDIX VII

Results of Analyses of Flume Silt-Water, 1973

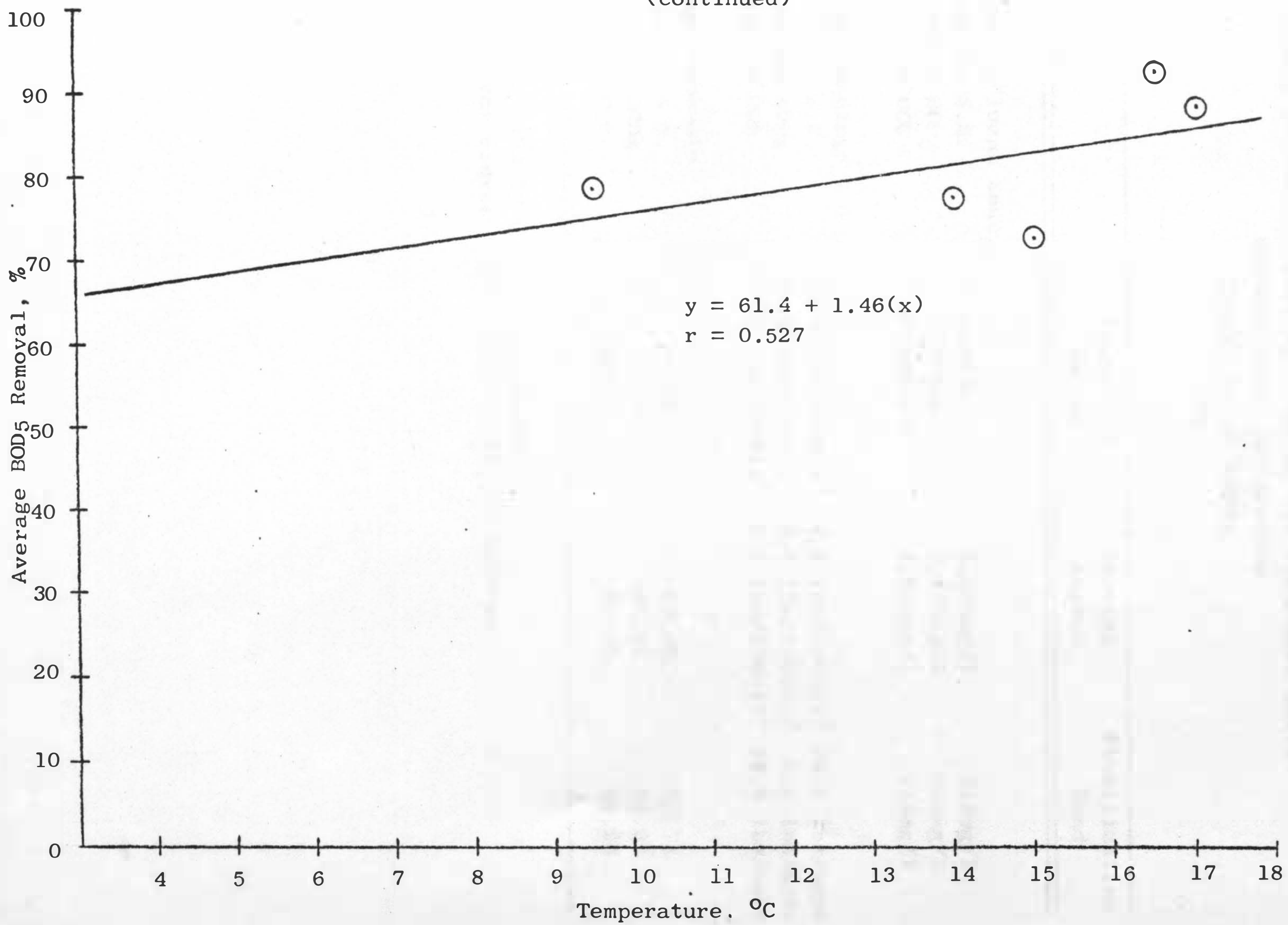
Date	Total Residue (mg/l)	Suspended Solids (mg/l)	Settleable Solids (ml/l) After 1 hr.	Settleable Solids (ml/l) After 23 hrs.	Sett. Solids* / Total Residue (ml/mg)
10-11-73	14,352	10,310	83	50.5	0.0035
10-18-73	34,558	31,220	228.5	106.5	0.0031
10-26-73	17,404	14,650	121	61	0.0035
11-1-73	5,544	2,040	30	22	0.0040
11-9-73	15,332	12,000	95	68	0.0044
Average	17,438	14,044	111.5	61.6	0.0037

*Settleable solids after 23 hours

APPENDIX VIII
Least Squares Analyses of Factors Affecting the Performance of the Aerated Lagoon



APPENDIX VIII
(continued)



APPENDIX IX

Summary of Average Loading Rates to the Treatment Units[1]
Midwest Foods Corporation
Clark, South Dakota
1973

	Anaerobic Lagoon	Aerated Lagoon	Stabilization Pond
Average Influent Conc.:			
Based on S.S.	9,993mg/l	2,200mg/l	712mg/l
Based on BOD_5	5,978mg/l	1,573mg/l	251mg/l
Based on COD	12,489mg/l	4,692mg/l	815mg/l
Average Loadings[2]:			
Based on S.S.	76.0 $lbs/1000ft^3$	4.2 $lbs/1000ft^3$	24.9 lbs/acre
Based on BOD_5	45.5 $lbs/1000ft^3$	3.0 $lbs/1000ft^3$	8.8 lbs/acre
Based on COD	95.0 $lbs/1000ft^3$	8.9 $lbs/1000ft^3$	28.5 lbs/acre
Average Removals:			
Based on S.S.	77.9%	67.6%	79.1%
Based on BOD_5	73.7%	81.8%	76.5%
Based on COD	62.4%	82.6%	42.2%

[1]During the 1973-74 processing season
[2]Based on the average daily flow of 92,160 gallons

APPENDIX X

Summary of Raw Waste BOD_5, COD and Suspended Solids Loadings
Midwest Foods Corporation
Clark, South Dakota
1973

Sampling Date	Ave. Flow (gpm)	Raw Potatoes Processed (tons/hr)	Concentrations BOD_5 (mg/l)	Concentrations COD (mg/l)	Concentrations S.S. (mg/l)	Loadings BOD_5 (lbs/ton raw potatoes)	Loadings COD (lbs/ton raw potatoes)	Loadings S.S. (lbs/ton raw potatoes)
9-14-73	64*	-	-	-	12,500	-	-	-
9-20-73	64*	4.01	3680	7573	4220	29.4	60.5	33.7
9-27-73	64*	4.35	4560	9630	8320	34.4	70.9	61.3
10-4-73	64*	-	7600	11,467	9760	-	-	-
10-11-73	64*	5.08	4320	7858	5230	27.2	49.5	33.0
10-18-73	99	4.19	8480	-	12,520	100.2	-	147.9
10-26-73	41	5.44	9280	12,262	12,120	35.0	46.2	45.7
11-1-73	53	5.25	5500	10,543	5280	27.8	53.2	26.7
11-9-73	68	4.68	4400	28,093	19,990	32.0	204.2	145.2
Average	64	4.72	5978	12,489	9993	40.6	84.8	67.8

*Assumed to be the average daily flow