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Development Document for
Proposed Effluent Limitations Guidelines
and New Source Performance Standards
for the

ANIMAL FEED, BREAKFAST CEREAL, AND WHEAT STARCH

Segment of the

GRAIN MILLS

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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DEVELOPMENT DOCUMENT

for

PROPOSED EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

ANIMAL FEED, BREAKFAST CEREAL, AND

WHEAT STARCH SEGMENTS OF THE

GRAIN MILLS POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the animal feed, breakfast cereal, and wheat starch segments of the grain milling industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines and Federal standards of performance for the industry, to implement Section 304 and 306 of the "Act".

Effluent limitations guidelines contained in this document set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The standards of performance for new sources contained herein set forth the degree of effluent reduction that is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

Separate effluent limitations guidelines are described for the following subcategories of the grain milling point source category: animal feed manufacturing, hot cereal manufacturing, ready-to-eat cereal manufacturing, and wheat starch and gluten manufacturing. Treatment technologies are recommended for the two subcategories with allowable discharges: ready-to-eat cereal manufacturing and wheat starch and gluten manufacturing. These technologies are generally similar, and may include equalization and biological treatment followed by secondary clarification. In order to attain the 1983 limitations, additional solids removal techniques will be required. The standards of performance for new sources in the ready-to-eat cereal category are the same as the 1983 limitations, while the standards of performance for the wheat starch subcategory lie between the 1977 and 1983 effluent limitations guidelines, reflecting the difficulty in treating the high strength waste waters involved.

The cost of achieving these limitations are described. For a medium-sized ready-to-eat cereal plant with production of 226,800 kg/day (500,000 lbs/day), the investment cost for the entire treatment system to meet the 1977 limitations is estimated to be $812,000. An additional $64,000 will be required to meet the 1983 standards. Investment costs for a typical wheat starch plant with a capacity of 45,400 kg/day (100,000 lbs/day) are $964,000 for 1977 and $996,000 for 1983.

Supportive data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

The segment of the grain milling industry that is covered in this document (Phase II) includes three industry subgroups: animal feed manufacturing (SIC Code 2048), breakfast cereal manufacturing (SIC Code 2043), and wheat starch manufacturing (part of SIC Code 2046). These industries have been classified into four subcategories based on products manufactured. Available information on factors such as age and size of plant, production methods, and waste control technologies does not provide a sufficient basis for further subcategorization.

The subcategories covered in this segment of the grain milling industry are as follows:

1. Animal feed manufacturing.

2. Hot cereal manufacturing.

3. Ready-to-eat cereal manufacturing.

4. Wheat starch and gluten manufacturing.

SECTION II

RECOMMENDATIONS

The recommended effluent limitations for the waste water parameters of significance are summarized below for the subcategories of the grain milling industry covered in this document. These values represent the maximum average allowable loading for any 30 consecutive calendar days. Excursions above these levels should be permitted with a maximum daily average of 3.0 times the average 30-day values listed below. The effluent limitations are expressed in weight of pollutant per weight of raw material (wheat flour) for the wheat starch and gluten subcategory and per weight of finished product of the ready-to-eat ceral subcategory. The effluent limitation of no discharge of process waste water pollutants to navigable waters for the animal feed and hot cereal manufacturing subcategory makes quantatives expression of limits unnecessary.

The effluent limitations to be achieved with the best practicable control technology currently available are as follows:

	BOD kg/kkg(lbs/1000 lbs)	Suspended Solids kg/kkg(lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process waste water pollutants		
Hot cereal manufacturing	No discharge of process waste water pollutants		
Ready-to-eat cereal manufacturing	0.40	0.04	6-9
Wheat starch and gluten manufacturing	2.0	2.0	6-9

Using the best available control technology economically achievable, the effluent limitations are:

	BOD kg/kkg(lbs/1000 lbs)	Suspended Solids kg/kkg(lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process waste water pollutants		
Hot cereal manufacturing	No discharge of process waste water pollutants		
Ready-to-eat cereal manufacturing	0.20	0.15	6-9
Wheat starch and gluten manufacturing	0.50	0.40	6-9

The recommended new source performance standards are as follows:

	BOD kg/kkg(lbs/1000 lbs)	Suspended Solids kg/kkg(lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process waste water pollutants		
Hot cereal manufacturing	No discharge of process waste water pollutants		
Ready-to-eat cereal manufacturing	0.20	0.15	6-9
Wheat starch and gluten manufacturing	1.0	1.0	6-9

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operating methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for a portion of the grain milling point source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performance for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F. R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the grain milling point source category, which was included within the list published January 16, 1973.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in the plant; and (2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of waste waters that should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, and of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time was also identified. In addition, the non-water quality environmental impacts, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology economically achievable," and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements), and other factors.

SOURCES OF DATA

The data utilized in preparing the proposed effluent limitations guidelines for animal feed, breakfast cereal, and wheat starch manufacturing were derived from a number of sources. These sources included published literature, previous EPA technical publications on the industries, a voluntary information retrieval form distributed to the American Feed Manufacturers Association, Cereal Institute, and individual manufacturers, information contained in U.S. Army Corps of Engineers discharge permit applications, industrial waste sampling data from several municipalities, and on-site visits, interviews, and sampling programs at selected manufacturing plants throughout the United States. A more detailed explanation of the data sources is given below. All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this document.

During this study the trade associations representative of the industry subcategories were contacted. The American Feed Manufacturers Association and the Cereal Institute were informed of the nature of the study and their assistance was requested. Data and retrival forms were voluntarily circulated and completed by the industries The data retrival form is shown in Figure 1. The completed forms provided a detailed source of information about the various plants including data on raw materials and finished products, water requirements, waste characterization and sources, and waste treatment. In addition to the trade associations, all major feed manufacturers and all of the existing plants in the breakfast cereal and wheat starch industries were contacted. Specifically, contact was made with ten feed manufacturers, 26 companies manufacturing cereal at 47 plants, and six companies producing wheat starch and gluten at seven plants in the United States. Retrieval forms with usable data were returned by 16 cereal plants and six wheat starch plants.

Refuse Act Permit Program (RAPP) applications to the U.S. Army Corps of Engineers for discharges to navigable waters under the Rivers and Harbors Act of 1899 were also used as a limited source of data. These data included the identification of the plant, water usage, the number of waste discharge points, the volumes of discharge, and the character and quantity of waste water. RAPP applications for 21 animal feed mills and six cereal manufacturing plants were reviewed. All of the feed mill discharges and five of the six cereal plant discharges were non-contact cooling water. Only one application from a cereal plant recorded a direct discharge of process waste water to navigable waters..

During the study, requests for information on waste discharges were made to municipalities receiving waste waters from plants within the industries covered. Twelve municipalities responded with data on 13 breakfast cereal and wheat starch plant discharges. Included was usable sampling data records for ten of the plants.

EPA EFFLUENT LIMITATIONS GUIDELINE STUDY
OF THE GRAIN MILLING INDUSTRY - PHASE II
by
Sverdrup & Parcel and Associates, Inc.
Information Retrieval Guide
October, 1973

I GENERAL

A. Company name

B. Corporate address

C. Corporate contact

D. Address of plant reporting

E. Plant contact

II MANUFACTURING PROCESS CHARACTERIZATION

A. Manufacturing process pertinent to this study

B. Other processes at this plant

C. Chief raw materials

D. Products

E. Plant Capacity

1. Annual raw material processed

2. Average daily raw material processed

F. Operating schedule (hours/day and days/year)

G. Number of employees

H. Age of plant

III WATER REQUIREMENTS

A. Volume and sources

B. Uses (including volumes)

1. Process

2. Cooling

3. Boilers

4. Plant cleanup

5. Sanitary

6. Other (specify)

C. Available information on raw water quality

D. Water treatment provided

1. Volume treated

2. Describe treatment system and operation

3. Type and quantity of chemicals used

E. Available information on treated water quality

F. Fate of water used (including volumes)

1. Municipal sewer

2. Evaporation

3. Consumed in process

4. On-site treatment facility

5. Discharge to stream, river, etc.

6. Other (specify)

G. Has a Corps of Engineers' or NPDES permit to discharge into navigable waters been applied for at this plant?

FIGURE 1

DATA RETRIEVAL FORM

IV PROCESS WASTEWATER

A. Volumes and sources

B. Does the source, volume, or character of the wastewater vary depending on the type or quality of product?

C. How do wastewater characteristics change during start-up and shutdown as compared to normal operation?

D. Available data on characteristics of untreated wastewaters from individual sources and combined plant effluent. (Not just single average numbers, but actual data or weekly or monthly summaries).

1. pH
2. BOD
3. COD
4. Suspended solids
5. Dissolved solids
6. Total solids
7. Temperature
8. Alkalinity and acidity
9. Phosphorus
10. Chlorides
11. Sulfates
12. Oil and grease
13. Other (all available information should be provided)

E. Wastewater treatment

1. Identify wastewater sources and volumes going to treatment facility.
2. Reason for treatment

E. Wastewater treatment (cont)

3. Describe treatment system and operation
4. Type and quantity of chemicals used, if any
5. Available data on treated wastewater quality (Same items as in Section III. D. above)
6. Describe any operating difficulties encountered
7. Results of any laboratory or pilot plant studies
8. Known toxic materials in wastewater

F. Wastewater recycle

1. Is any wastewater recycled presently?
2. Can wastewater be recycled? What are the restraints on recycling.

G. In-plant methods of water conservation and/or waste reduction

H. Identify any air pollution, noise, or solid wastes resulting from treatment or other control methods. How are solid wastes disposed of?

I. Cost information related to water pollution control

1. Treatment plant and/or equipment and year of expenditure
2. Operation (personnel, maintenance, etc.)
3. Power costs
4. Estimated treatment plant and equipment life

J. Water pollution control methods being considered for future application

V COOLING WATER

A. Process steps requiring cooling water

B. Heat rejection requirements (Btu/hour)

FIGURE 1 (CONTD.)

C. Type of cooling system, i.e., once-through or recirculating

D. Cooling tower

1. Recirculating flow rate
2. Blowdown rate
3. Type and quantity of chemicals used
4. Blowdown water quality

E. Once-through water quality

1. Flow rate
2. Type and quantity of chemicals used
3. Discharge water temperature

VI BOILER

A. Capacity

B. Blowdown flow rate and characteristics

FIGURE 1 (CONTD.)

Plant visits provided information about the manufacturing process, water usage within the plant, sources of wastes, in-plant waste water control, and waste treatment. A total of 17 plants were visited in the following subcategories:

Industry	Total Plants Visited
Animal Feed	5
Breakfast Cereal	10
Wheat Starch	2

In addition to the above visits, many plant personnel at plants in each subcategory were contacted by telephone for information on the industry and waste water handling and disposal. Detailed data were obtained during these conversations consisting of product description, size and operation schedule of the plant, quantity of water used, waste water quantities, and waste treatment.

Plant sampling was provided at a total of five plants with emphasis focused on plants having representative waste loads and waste treatment facilities. Specifically, one wheat starch and four breakfast cereal plants were sampled during the study. The sampling program provided data on the raw and treated waste streams. It also provided verification of data on waste water characteristics provided by municipalities and other individual plants.

GENERAL DESCRIPTION OF THE INDUSTRIES

The animal feed, breakfast cereal, and wheat starch industries all utilize products from the basic grain processing mills for raw materials. Grain and grain milling by-products are the chief ingredients in animal feed. The manufacture of breakfast cereals utilizes both milled and whole grain, particularly corn, wheat, oats, and rice. Wheat starch manufacturing employs wheat flour as its raw material.

Animal Feed Industry

Of all the cereal grain produced in the U.S., only about 15 percent is used as food for human consumption. The vast majority of the grain harvested is used to feed poultry and livestock.

The formula feed business is a relatively new one, having its beginnings late in the 19th Century. Prior to that time, farmers and livestock growers fed their animals grain. A need to merchandise by-products from the food industry, coupled with increasing knowledge of animal nutrition, led to the origin of the feed industry. Blatchford's in Waukegan, Illinois, the oldest feed manufacturing company in continuous operation in the

U.S., began operating in 1875. Early mills were located near rivers and centers of population to take advantage of cheap transportation, but since World War II, trucking has changed the economics of the industry. Today, the large mills have decentralized, and feed manufacturers operate smaller mills near their markets.

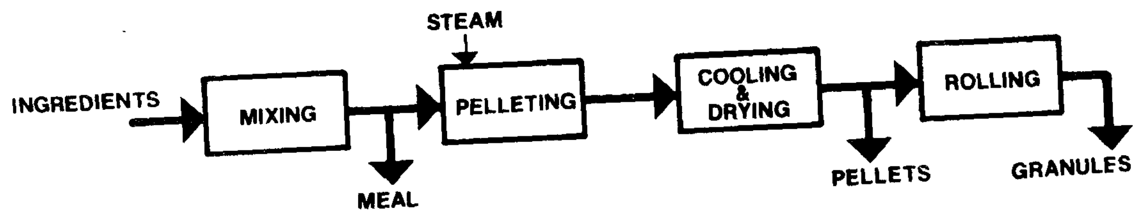
In the past, so-called "complete feeds" were predominantly manufactured. Complete feeds contain all the necessary ingredients for livestock, including grain, protein, drugs, vitamins, and minerals. In the late 1920's, feed concentrates containing protein, trace minerals, and vitamins were introduced. This concentrate was ideally suited for the grain-producing areas of the country; the farmer simply mixed it with his own grain on the farm. Production of feed concentrates has increased considerably since its introduction and accounts for about one-third of present total feed tonnage. A typical listing of concentrate ingredients might include soybean meal, animal and fishery by-products (protein sources), fat, minerals, and trace quantities of antibiotics and other substances for disease and parasite prevention and growth stimulation.

In the last decade, many manufacturers of drugs and feed ingredients have developed combinations of drugs and vitamins known as premixes to which protein and grain must be added. A typical complete feed formula would include about two-thirds grain, 25 to 35 percent concentrate, and 5 to 10 percent premix ingredients. Nearly all feed manufacturers offer complete and concentrate feeds; a few offer premixes.

The manufacture of formula feed represents 12 percent of total farm production, and in agriculture ranks fifth behind cattle, feed grains, dairy products, and pigs. Usage of formula feed in the livestock industry is distributed as follows:

Poultry	58%
Dairy Cattle	28
Swine	8
Work Animals	3
Range and Beef Cattle	2
Sheep and Goats	1
	100%

The animal feed industry has undergone tremendous growth since its inception some 80 years ago; it is now the tenth largest industry in the U.S. There are presently over 6000 feed manufacturers, plus related industries such as drug, chemical, and mineral suppliers. Consumption of formula feed increased 37 percent from 1940 to 1966, and current production is approximately 45 million tons annually, representing over $3 billion in sales. Today, about 40 percent of the feed consumed by animals in the U.S. is formula feed. There are presently about 8000 feed mills in the country individually producing at least 907 kkg (1000 tons) of feed per year. Daily production of feed mills ranges from 3.6 to 1800 kkg (4 to 2000 tons).



ANIMAL FEED MANUFACTURING

The basic production sequence in the manufacture of animal feed is shown in the accompanying diagram. The various ingredients are first received and stored. Whole grains are often ground or cracked before use, but cleaning is not performed and water is only used as necessary to raise the moisture content prior to grinding. Next, the ingredients are mixed in proper proportion, after which some of the product may be removed as a meal form of feed. A pelleting operation follows, in which steam is added and the mixture is forced through dies. The pellets are cooled and dried, then either packaged in pellet form or rolled and packaged as a granular feed. Finished feed is transported from the plant in packages or in bulk shipments.

Breakfast Cereal Industry

Man has been aware of the food value of grains since ancient times, but prior to the turn of this century, grain was only consumed in a cooked form. Thus early Americans boiled and baked grain into porridges and breads. Around the mid 1800's, the Scottish dish of oatmeal became popular in the U.S. An American innovation was added when the oats were rolled rather than ground. Rolled oats were first sold as a health food, but eventually developed into a grocery store staple. It was also found that other grains, such as cracked wheat and rolled wheat, could be prepared in the same manner.

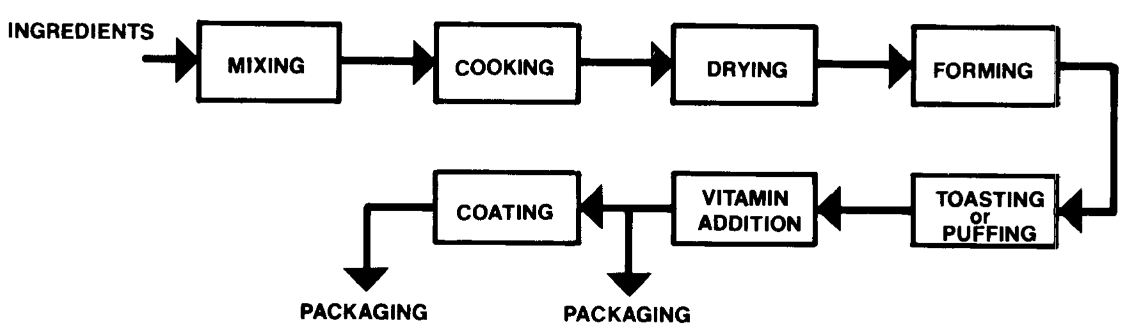
The first ready-to-eat cereal was probably "Granula", developed by Dr. James C. Jackson in 1863 at Dansville, New York. Sold as a health food, Granula was produced by baking a coarse whole meal dough in thin sheets until brittle, breaking the sheets into chunks, baking again, and then grinding the chunks into granules.

Four discoveries or developments near the turn of the century led to the ready-to-eat cereal industry. The first occurred in 1893 when Henry D. Perkey of Denver produced and marketed a shredded wheat product. The following year W. K. Kellogg and his brother, Dr. John H. Kellogg, developed the flaked cereal. It was first used at the Battle Creek Sanitarium as a health food, then later the product was mass-marketed by W. K. Kellogg. In 1897, Charles W. Post produced a ground cereal product in Battle Creek called "Grape Nuts". The fourth development came in 1902 when Alexander Anderson produced the first puffed cereal.

The cereal industry has grown considerably since then. Today over one and one-half billion pounds of cereal are produced annually; sales are approximately $1 billion each year. Seventy-five million servings of cereal are consumed each day in the U.S., which amounts to eight pounds of cereal per person per year. There are some 26 companies operating 47 plants in the U.S., with the major plants located as shown in Figure 2. Plant capacities range from 4.5 to almost 680 kkg (10,000 to 1,500,000 lbs) of cereal per day.

Breakfast cereals can be broadly classified as either hot cereals or ready-to-eat cereals. Hot cereals require cooking before serving and are normally made from oats or wheat. Basic processes in the manufacture of hot cereals include cleaning, milling, sizing, and enrichment for wheat; and cleaning, roasting, sizing, de-hulling, steaming, and rolling for oats. Manufacturing methods are described in more detail later in this section.

A wide variety of ready-to-eat cereals is manufactured in the U.S., and production methods vary depending on the type of cereal. Raw materials include whole grain wheat and rice, corn grits, oat flour, sugar, and other minor ingredients. The general processes involved include ingredient mixing, cooking, tempering or drying, forming (either flaking or extrusion), toasting or puffing, and vitamin addition. The accompanying diagram outlines a basic cereal manufacturing operation, although the particular type of cereal being produced will dictate which specific unit processes are utilized.



CEREAL MANUFACTURING

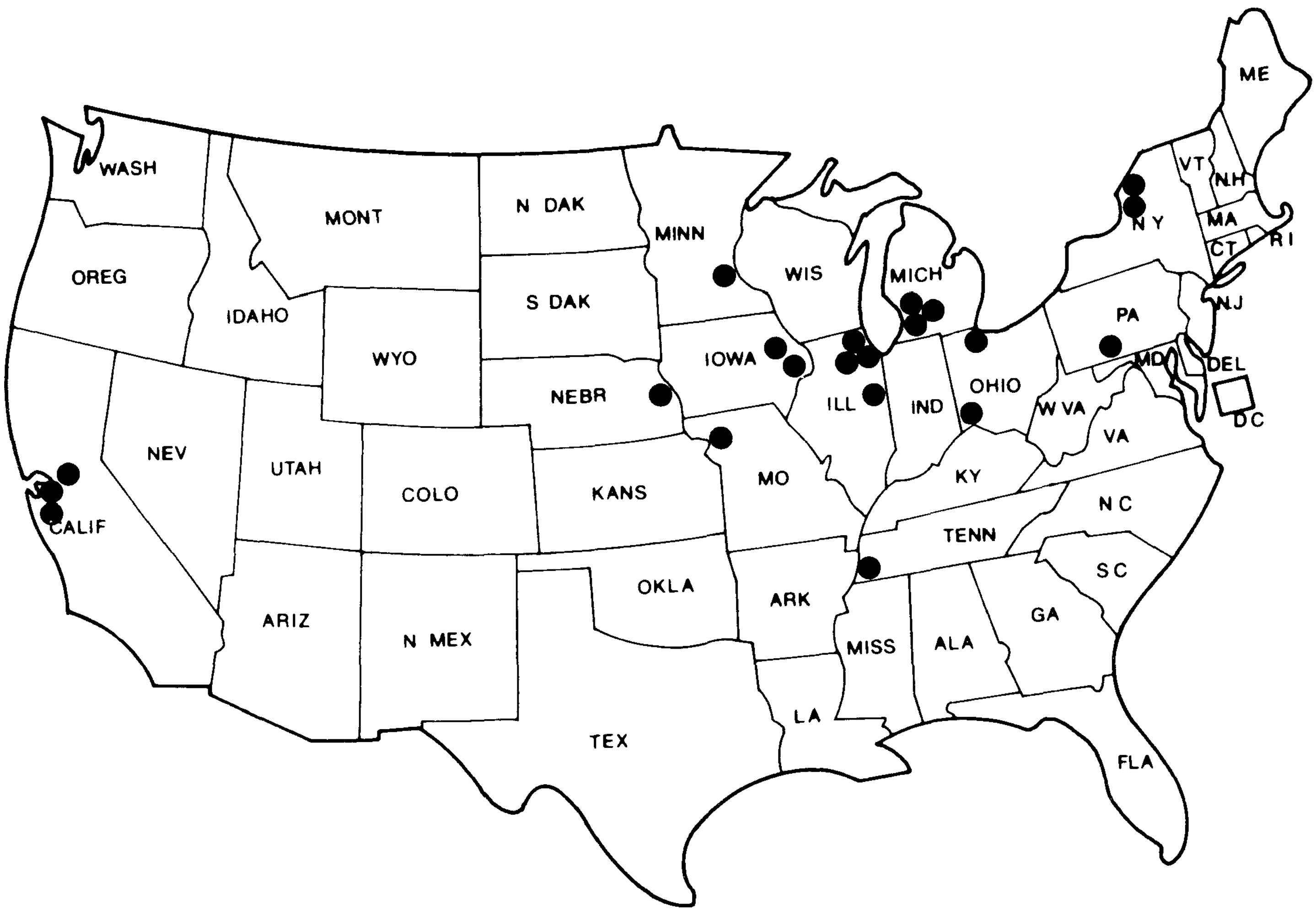


FIGURE 2

LOCATION OF MAJOR CEREAL PRODUCING PLANTS IN U.S.

Wheat Starch Industry

Today the wheat starch industry might be more properly termed the wheat gluten and starch industry, as gluten presently brings a higher economic return than starch. Basically, wheat starch manufacture involves the physical separation and refinement of the starch and gluten (protein) components of wheat flour.

The preparation of starch from cereal grains was carried on in ancient times. The Egyptians as early as 3000 B.C. used starch for sizing papyrus, and a Roman treatise written in 184 B.C. describes a method of preparing starch from wheat by fermentation. Wheat was the major source of starch from primitive times until the late 18th Century, when cheaper sources of starch were sought. Potatoes and finally corn replaced wheat as major starch sources.

The first American wheat starch plant was built in 1807 in Utica, New York. Many plants were constructed in the early 1800's, but by the end of the century, all but a few had been converted to corn starch plants. In 1895 there were five wheat starch plants utilizing 1100 bushels of wheat per day and producing 8.3 million pounds of wheat starch annually. By comparison, 16 corn starch plants were in operation of that time producing 200 million pounds of corn starch each year, and 64 potato starch plants were producing 24 million pounds of starch per year.

Production within the industry has increased considerably during the last 80 years, although the number of manufacturing plants has remained almost constant. Four wheat starch plants were operating in 1960. At present, there are seven plants in operation in the U.S., three of which were producing starch in 1960. Current wheat flour consumption in the industry is about 113,400 kkg (250 million pounds) annually. Table 1 lists the companies and plants in the U.S. presently producing wheat starch and gluten, and the plant locations are shown in Figure 3. Plant capacities range from 23 to 68 kkg/day (50,000 to 150,000 lbs/day). Early wheat starch manufacturing processes employed whole wheat as the raw material. As shown in Table 2, starch constitutes about 64 percent of the whole wheat grain.

Table 2

Composition of Whole Wheat

Starch	64.1%
Protein	12.4
Moisture	13.6
Sugar, gums, etc.	3.8
Fibre	2.6
Ash	1.8
Fat	1.7

Table 1

Wheat Starch Companies and Plants

Centennial Mills
1464 N.W. Front Avenue
Portland, Oregon 97208
Plants: Portland, Oregon 97208
Spokane, Washington 99220

General Mills Chemicals, Inc.
4620 West 77th Street
Minneapolis, Minnesota 55435
Plant: Keokuk, Iowa 52632

Keever Division, A. E. Staley
2200 Eldorado Street
Decatur, Illinois 62525
Plant: Columbus, Ohio 43207

Loma Linda Foods
11503 Pierce Street
Riverside, California 92505
Plant: Riverside, California 92505

Midwest Solvents
1300 Main Street
Atchison, Kansas 66002
Plant: Atchison, Kansas 66002

New Era Milling Company
P. O. Box 958
Arkansas City, Kansas 67005
Plant: Arkansas City, Kansas 67005

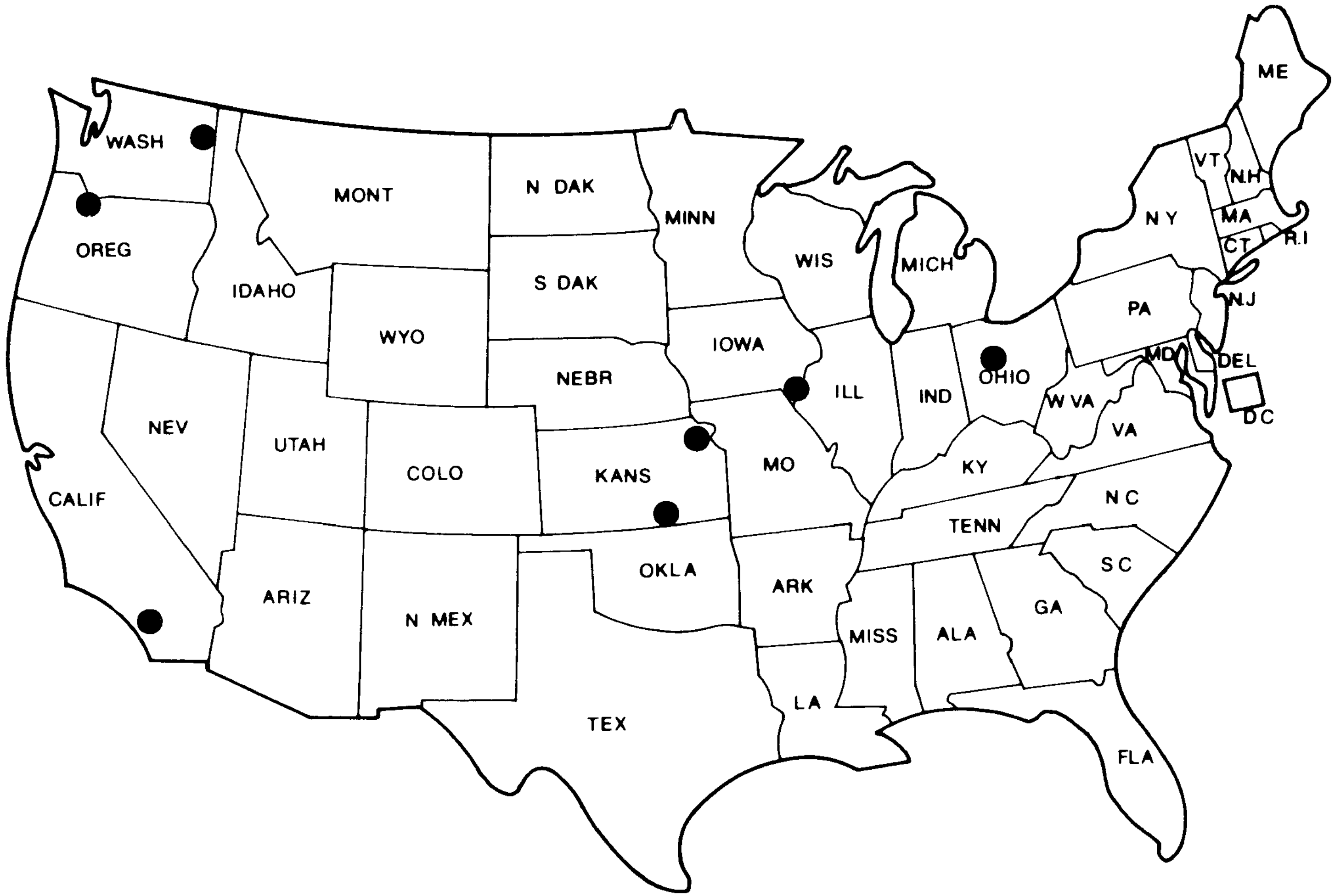
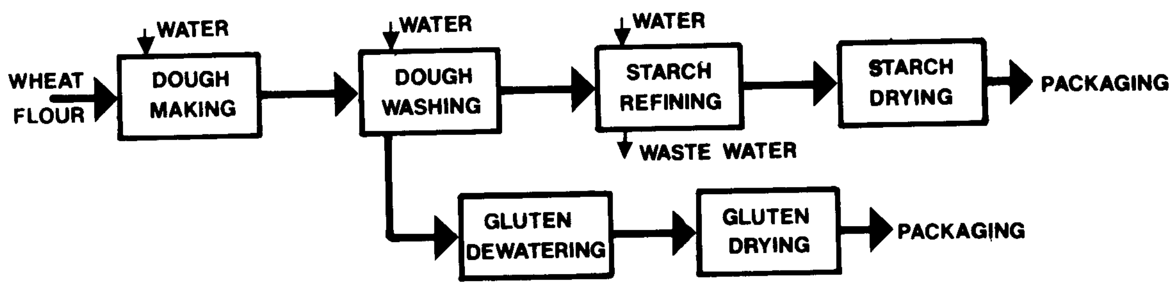


FIGURE 3

LOCATION OF WHEAT STARCH AND GLUTEN PLANTS IN U.S.

Two processes involving whole wheat were used during the early 1800's, the Halle process and the Alsatian process. In the Halle process, the wheat was steeped until soft, drained and crushed between rollers, and fermented in large vats. The fermentation softened and partially dissolved the gluten, allowing the starch to be washed out. The Halle process produced a 50 to 60 percent starch yield, but had several disadvantages. These included the long time period required, offensive odors which were produced during fermentation, and the fact that gluten could not be recovered in a commercial form. The Alsatian or Hungarian process was similar to the Halle process except that the fermentation step was excluded. This increased the difficulty of washing the starch from the gluten. The process yielded 35 to 45 percent first grade or A-starch and 10 to 20 percent second grade or B-starch. If gluten recovery was desired, a long washing process was required, and the yield was only 5 to 6 percent.

Most wheat starch plants operating today employ the Martin process or a modification thereof. This technique, which uses wheat flour rather than whole wheat, was proposed in 1835 and was widely used by the end of the 19th Century. The diagram below outlines the basic processes involved.



WHEAT STARCH AND GLUTEN MANUFACTURING

Wheat flour is first mixed with water to form a dough. The dough is then kneaded and washed to separate the starch and gluten. The gluten is dewatered, dried, and packaged, while the starch stream or so-called "starch milk" is screened, centrifuged, dewatered, dried and packaged. The Martin process generally yields 10 to 15 percent gluten, 45 to 55 percent first grade starch, and 12 to 20 percent second grade starch. Its main disadvantage lies in the relatively high percentage of gluten-contaminated B-starch produced.

PRODUCTION PROCESSES

The production methods used in manufacturing animal feeds, breakfast cereals, and wheat starch differ greatly as summarized earlier in this section. The following discussion provides a more detailed description of the manufacturing processes employed in each industry subcategory.

Animal Feed

The manufacture of animal feeds, shown in Figure 4, begins with the receiving and storage of raw materials. These ingredients might include grains such as corn, barley, milo, and oats; various meals including soybean, cottonseed, meat, and bone; and grain milling by-products such as wheat middlings and corn gluten. Dry additives, including salt, minerals, drugs, phosphorus, and vitamins, and liquid ingredients such as fat, molasses, and fish solubles are also used in feed formulas. Grains receive dry cleaning and separation with scalpers and magnets prior to storage. Whole grains are often ground, cracked, or crimped prior to feed mixing. A small amount of water is sometimes added to the grain for dust control during grinding, which is usually performed with hammermills.

Mixing is the next step in feed manufacture. Ingredients are weighed and then fed into a mixer in a ratio based on the particular feed formula. A representative medium-sized plant produces 200 to 300 different feed blends. Material from the mixer is a meal or mash and may be marketed in this form.

A pelleting operation follows mixing if pellet or granular forms of feed are desired. Pelleting is an extrusion process in which the meal is steamed and then forced through dies. The resulting pellets are 1/8 to 3/4" in diameter and length. They must be cooled and dried after extrusion. This is done in pellet coolers through which air is blown at room temperature. Feeds with a high molasses content are dusted with bentonite or cottonseed meal to prevent caking. The pellets are then sized, with fines and oversize particles being returned to the extrusion operation. Pellets can be packaged or bulk shipped. If the pellets are to be reduced in size, they are passed through a roller mill with corrugated rolls to produce granular feed or crumbles. Again a screening operation follows, with fines and overs being returned to the pellet mill. Granular feed is also either shipped in bulk or packaged.

Breakfast Cereal

A wide variety of breakfast cereals is manufactured in the U.S.; more than 100 different items, brands, and sizes of ready-to-eat and hot cereals can be found on a grocery shelf. The chief hot cereals include wheat or farina and oatmeal. Ready-to-eat varieties are made from one or more of the basic cereal grains, corn, wheat, rice, and oats, and may be flaked, puffed, extruded, shredded, coated, or non-coated. A variety of production methods are employed in the manufacture of cereals, with different

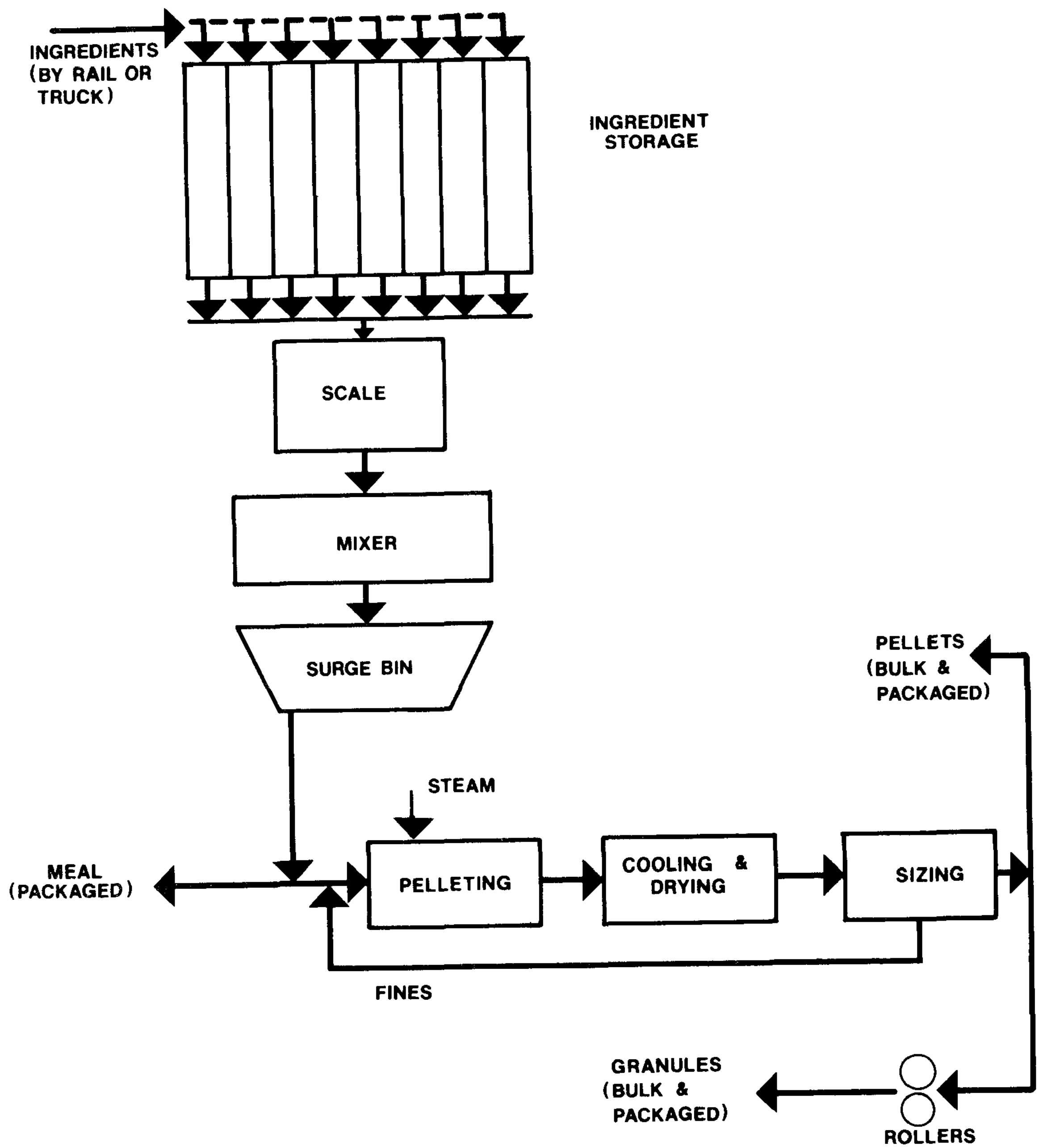


FIGURE 4

ANIMAL FEED MANUFACTURING

methods often associated with a particular type or even brand of cereal.

Hot Cereal

Hot wheat cereal or farina is comprised basically of wheat middlings - chunks of wheat endosperm free of bran and germ. Middlings are intermediate size particles produced in the milling of whole wheat. Typical hard wheat on the average yields about 30 percent middlings. The only processes involved in the manufacture of hot wheat cereal are sizing and vitamin and mineral enrichment. Occasionally flavoring ingredients such as malt or cocoa are mixed in with the farina. One company employs a pre-cooking operation to produce an instant product. This operation involves addition of steam, extrusion, and cooling or drying.

The second major type of hot cereal is oatmeal or rolled oats. The manufacture of rolled oats is basically a dry milling operation. Whole oats are received, dry cleaned and stored. A dry roasting operation follows, during which the moisture content is reduced to six percent, the starch is partially dextrinized, and the hulls become fragile. The oats are then cooled, sized, and de-hulled, leaving the inner berry or "groat". Rollers are then employed to produce flakes from the groats. Cutting of the groats may precede rolling to produce quick cooking or instant oats. Addition of minor ingredients and packaging follow.

Flaked and Crisped Cereals

Corn grits, whole wheat, rice, and occasionally a combination of grains are the chief raw materials used in the manufacture of flaked and crisped cereals. The basic production process is shown in Figure 5. Whole wheat is tempered prior to use; the other grains receive only dry cleaning. Flavor solution consisting of malt, sugar, salt, and other ingredients is added and the mixture is cooked under pressure with steam for a specified length of time. A tempering or drying operation follows to reduce the moisture content. Some types of flaked cereals are extruded and dried prior to flaking. Large rollers are used to produce flakes from the individual grains or pellets. The roller spacing is set close for flaked cereals and farther apart for crisped cereals. The product is then dried and toasted in large ovens, sprayed with vitamins, and packaged. Some types of flaked and crisped cereals are sprayed with a sugar solution and dried prior to vitamin addition and packaging.

Shredded Cereals

The manufacture of shredded cereals, shown in Figure 6, begins with cleaned whole wheat. The wheat is fed in batches into steam cookers where water is added. After cooking, the water is drained and the wheat is transferred to large steel tanks where it is cooled, tempered, and becomes firm. It then passes through

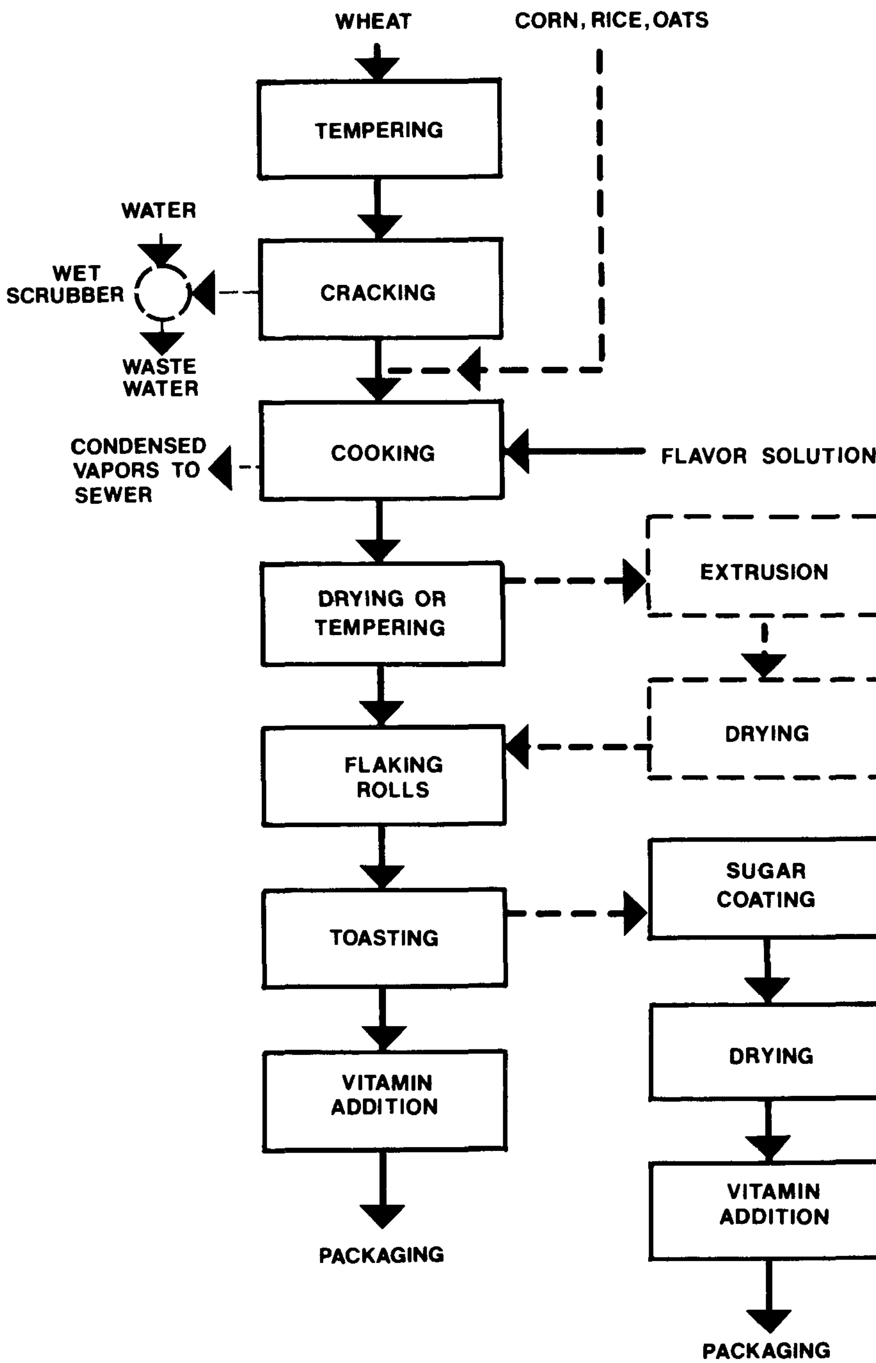


FIGURE 5

FLAKED OR CRISPED CEREAL PRODUCTION

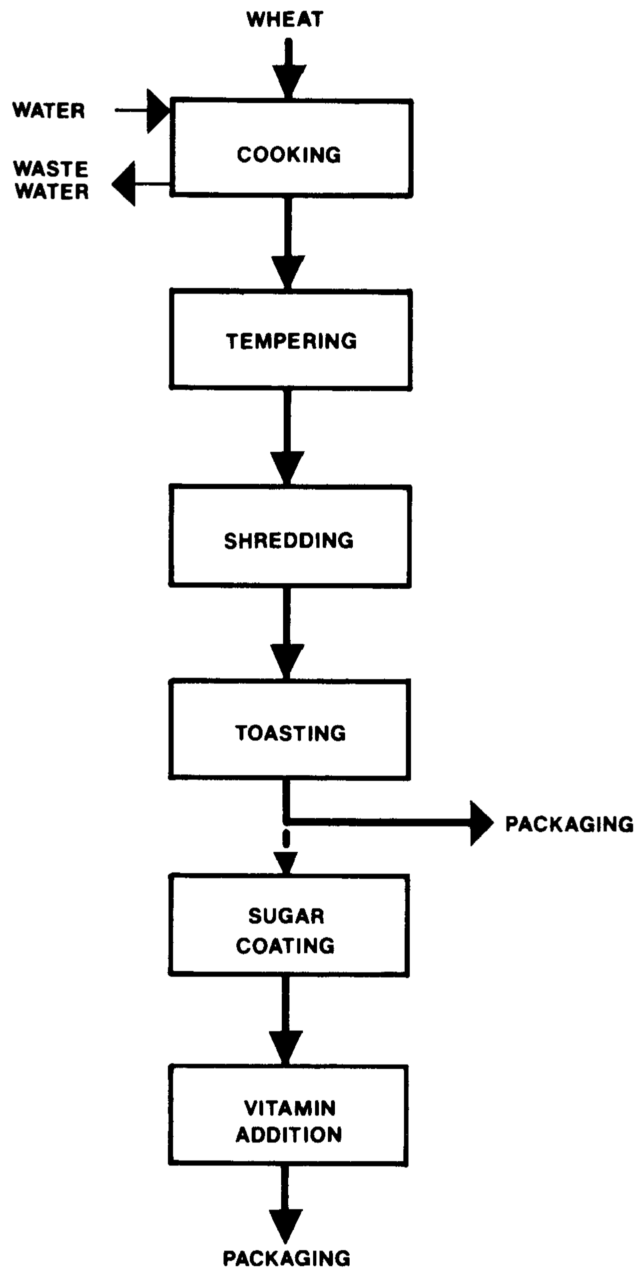


FIGURE 6

SHREDDED CEREAL PRODUCTION

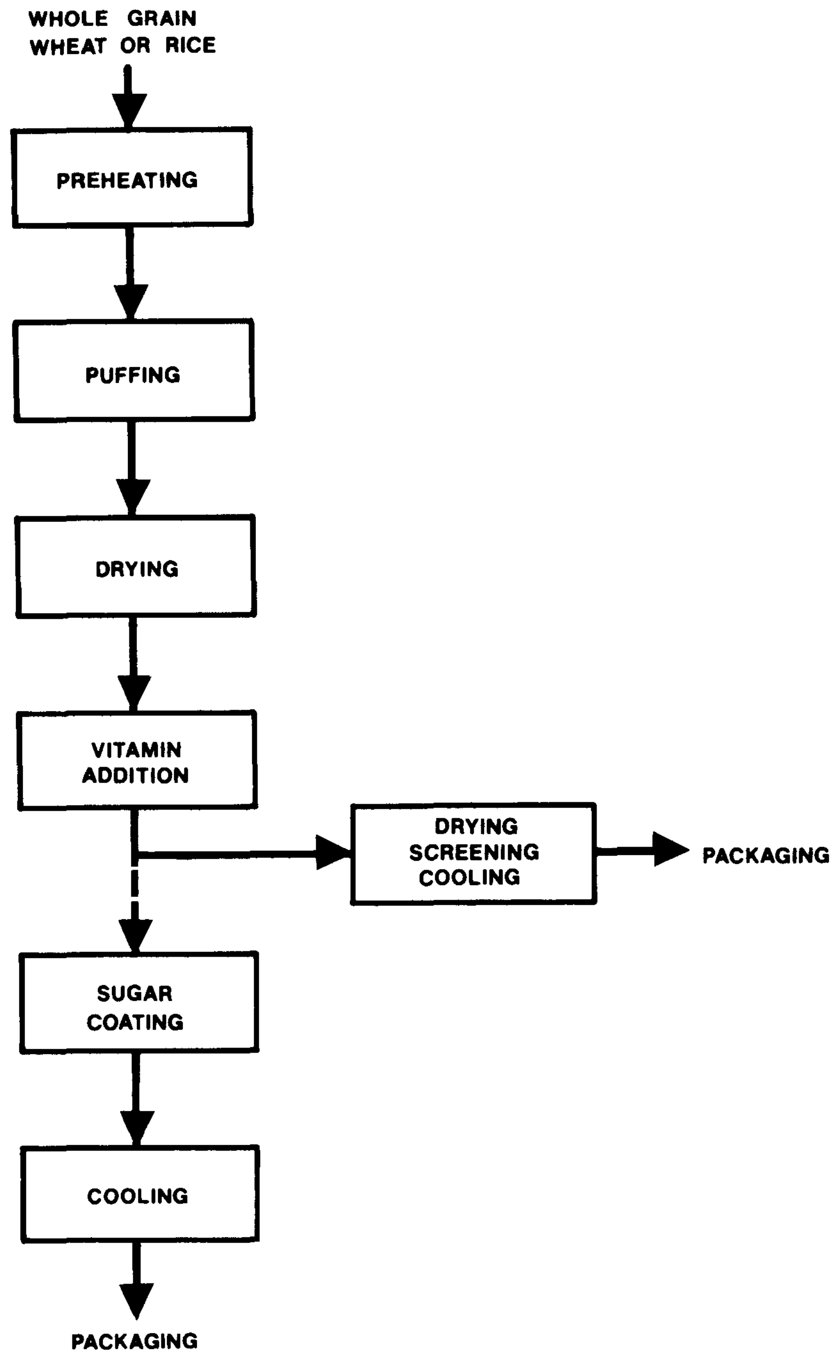


FIGURE 7

PUFFED WHOLE GRAIN CEREAL PRODUCTION

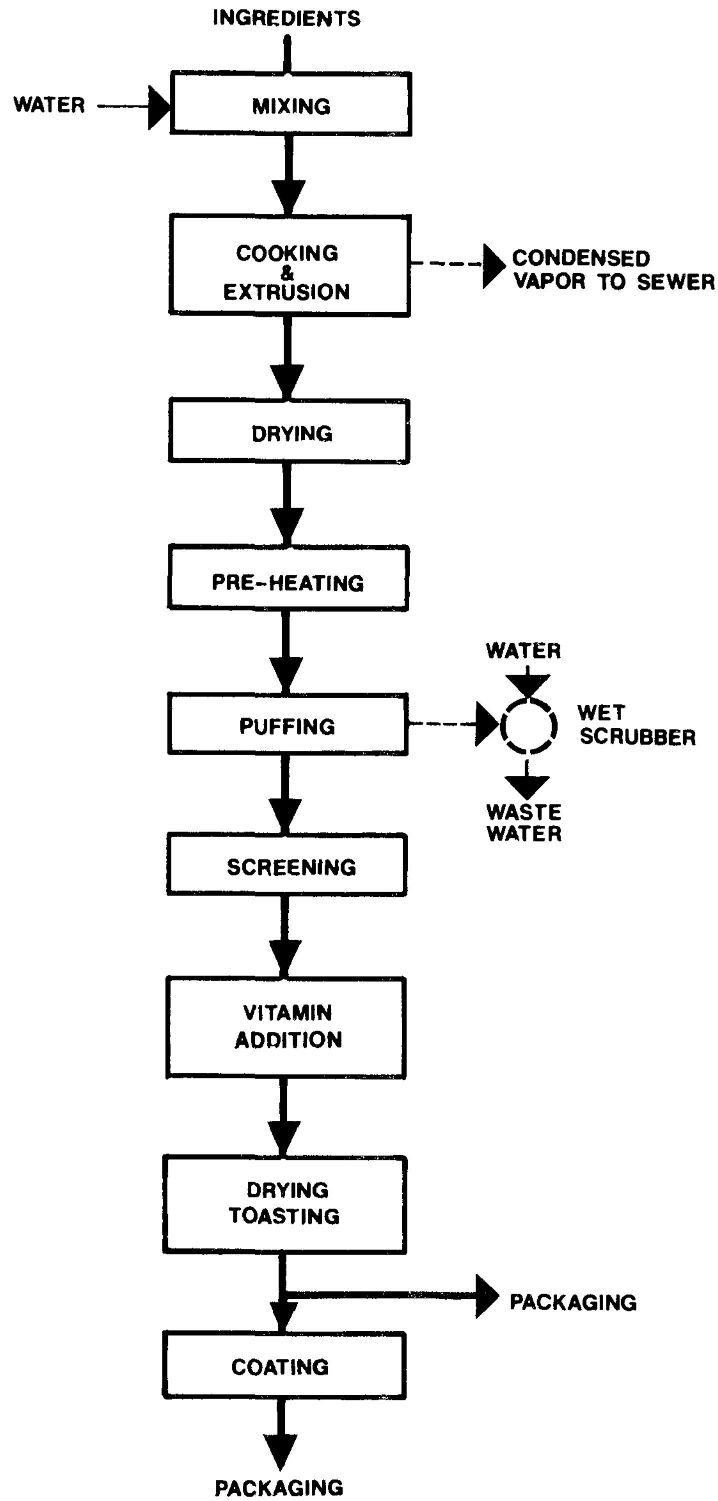


FIGURE 8

EXTRUDED/PUFFED CEREAL PRODUCTION

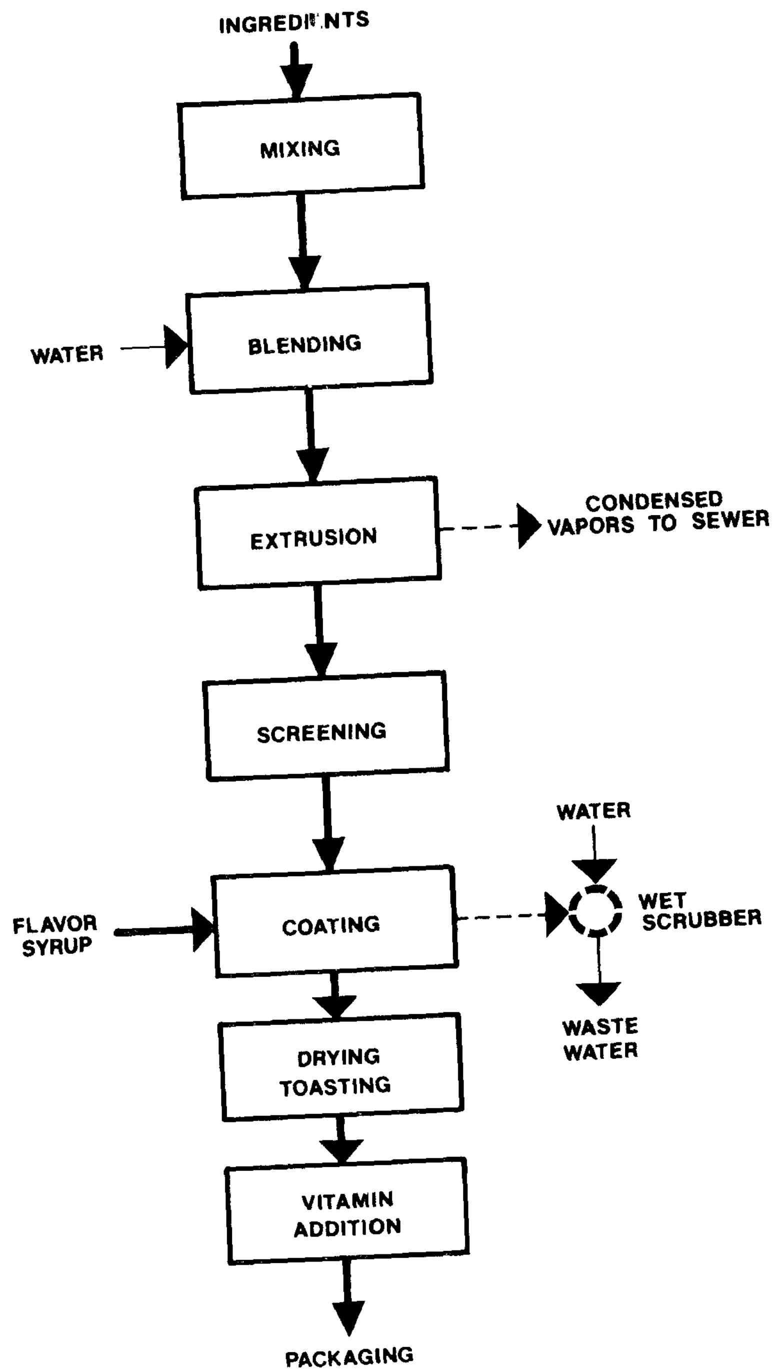


FIGURE 9

EXTRUDED CEREAL PRODUCTION

shredding rolls where the kernels are crushed and formed into long strands. Layers of wheat strands are cut into biscuits and toasted in an oven prior to packaging. Some types of shredded cereals receive a sugar coating and vitamins prior to packaging.

Puffed Whole Grain Cereals

Figure 7 depicts the operations involved in the production of puffed whole grain cereals. Wheat and rice are the primary raw materials. The grain is first preheated, then puffed by increasing and suddenly decreasing the pressure in the puffing device or "gun". The grain is dried, vitamins are applied, and the product is dried, screened, and cooled prior to packaging. Certain types of puffed whole grain cereal undergo sugar coating and cooling operations before being packaged.

Extruded/Puffed Cereals

Oat flour and corn grits are among the chief ingredients used in the manufacture of extruded/puffed cereals, shown in Figure 8. The ingredients are mixed with water to form a dough. The dough enters a combination cooking and extrusion process, where the particular cereal's characteristic shape is produced. After the moisture content has been reduced, the cereal particles are preheated and then puffed in a fashion similar to that employed in whole grain puffing. The product is sized, sprayed with vitamins and oven toasted prior to packaging. Certain varieties receive a sugar cr flavor coating before being packaged.

Extruded Cereals

Extruded cereal production processes are shown in Figure 9. Ingredients include oat and corn flours along with sugar and flavorings. The ingredients are dry mixed, then blended with water to form a dough. An extrusion process follows, producing the various cereal shapes. The product is then sized, coated with a flavor syrup, toasted, sprayed with vitamins, and packaged.

Wheat Starch

The principal raw material used in the manufacture of wheat starch and gluten is residual wheat flour known as "clears" or "second clears", comprised of grades that are unsatisfactory for the manufacture of white bread.

The first step in the process, shown in Figure 10, is dough making, where fresh water is mixed with the incoming flour. The dough is allowed to "mature" for a time and then is washed with fresh water to begin separation of the starch and gluten. The gluten, due to certain adhesive properties, adheres to itself in a sticky mass. The starch granules, lacking these properties, are separated and remain suspended in the flow of water. The separated mass of gluten is kneaded and again washed to effect

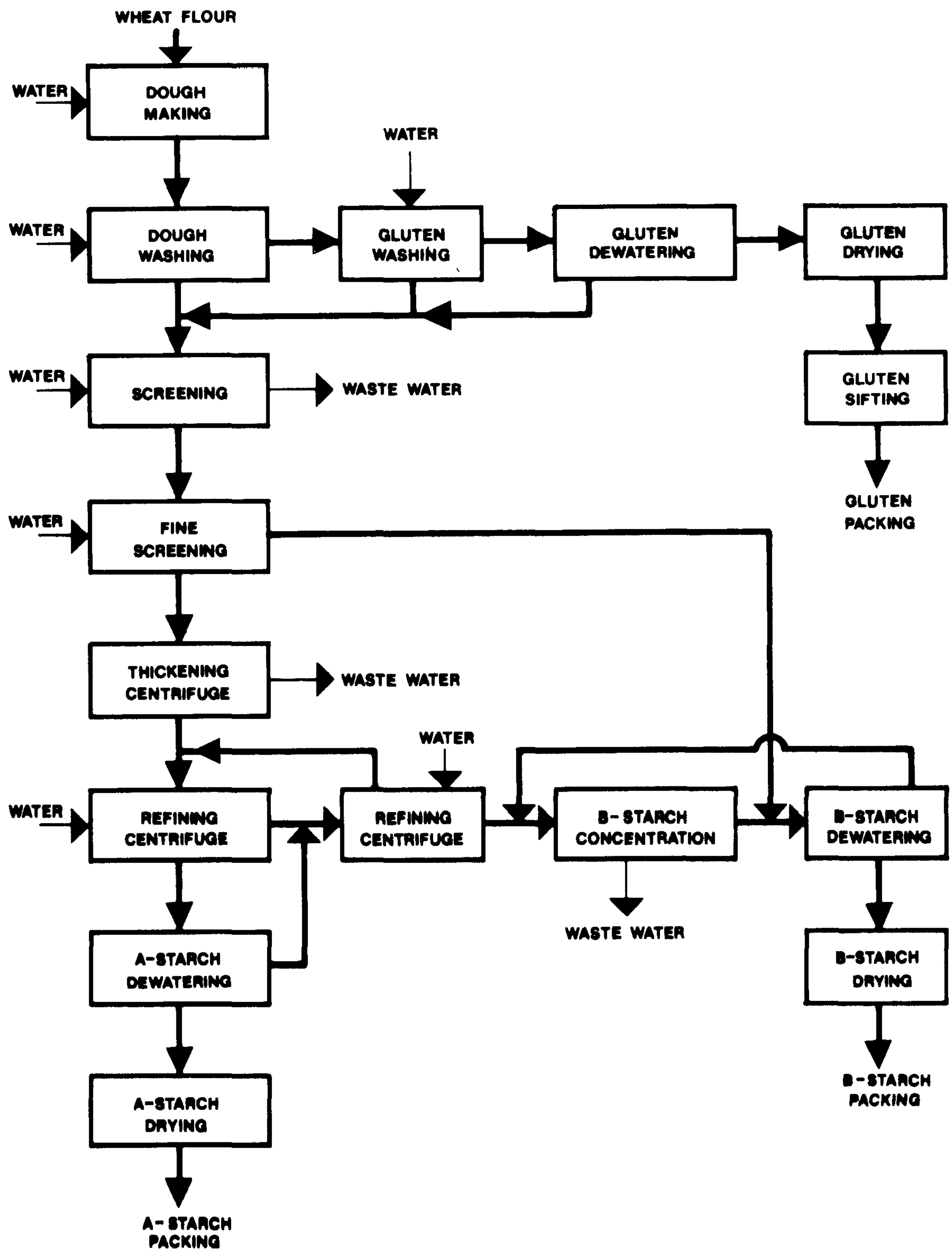


FIGURE 10

WHEAT STARCH AND GLUTEN MANUFACTURING

more complete starch removal. After removal of the starch, the gluten is either spray or drum dried, sifted, and packed. Wheat gluten, with a 75 to 85 percent protein content, is used extensively as an ingredient in bakery produce, particularly bread, to increase the protein content. About 35 percent of the protein in the gluten is in the form of the amino acid, glutamic acid. If the gluten is hydrolyzed with hydrochloric acid, glutamic acid as a crystalline solid is obtained. Separation and conversion with sodium hydroxide produces a product known as monosodium glutamate, which is used as a flavoring agent.

The starch-laden stream from the washing operation is termed the crude "starch milk". It is passed through coarse and fine screens to remove cellulose fibres. To reduce the water content prior to refining, a thickening or pre-concentrating centrifuge is often employed. Next the starch milk enters the first refining centrifuge where an initial separation of A-starch and B-starch is made. The heavier A-starch component passes on to dewatering, drying, and packing operations. The lighter B-starch component enters a second refining centrifuge which recovers additional A-starch. The B-starch stream is then concentrated with another centrifuge, dewatered, dried, and packed. Wheat starch has widespread use in the food industry. Lower grade or B-starch finds uses in textile manufacturing, as foundry starch, and in adhesives.

WASTE WATER CONSIDERATIONS IN THE INDUSTRIES

Animal feed manufacturing plants utilize little or no process water and generate no process waste waters. Water is used in steam generation, non-contact cooling of pellet mills, and occasionally for dust control during corn grinding. The only waste waters generated are from auxiliary operations and include boiler blowdown, spent cooling water, and wastes from boiler feed water treatment systems.

Hot cereal manufacturing basically involves dry milling and blending operations. Water is sometimes used for tempering and for raising product moisture content, but no process waste waters are generated.

Water is used quite extensively in ready-to-eat cereal manufacturing plants. The various operations where water is used include grain tempering, flavor solution make-up, cooking, extrusion, and coating. Substantial quantities of water are employed in the periodic cleanup of process and conveying equipment, and processing areas. Water is also used for cooling flaking and forming rolls, extruders, and other equipment such as compressors, and in wet scrubbers for air pollution control in some plants.

Most of the unit operations in ready-to-eat cereal plants do not result in process waste waters. Only the cooking operation in shredded cereal manufacture generates a continuous or semicontinuous waste stream. Other wastes from this segment of the industry are primarily from wet cleanup operations. Condensed vapors from cooking operations, wet scrubber discharges, and spent cooling waters may also contribute relatively minor quantities of waste water. Total waste water flows vary from 189 to 568 cu m/day (50,000 to 150,000 gpd) for small plants and up to 3785 cu m/day (1,000,000 gpd) for large plants. BOD_5 concentrations are moderate to high, ranging from 400 to 2500 mg/l. Suspended solids concentrations vary in the range of 100 to 400 mg/l with the higher concentrations generally being discharged from the larger plants.

At present, only one cereal plant has a direct discharge of process wastes to a receiving water, and that waste discharge is not treated. The municipal sewer system is being expanded and will collect these wastes for treatment in the near future. All other cereal plants studied discharge their wastes to municipal systems. One plant provides pretreatment, and two others are in the process of constructing pretreatment facilities.

In wheat starch manufacturing, process water is used for dough making, dough washing, backwashing of screens, and countercurrent washing of centrifuge discharges. Water is also used for plant cleanup and auxiliary systems such as boiler feed and cooling. Waste waters are generated from screening, starch milk thickening, and plant cleanup operations. The volumes are moderate, ranging from 265 to 606 cu m/day (70,000 to 160,000 gpd). These waste waters are high in BOD_5 and suspended solids and consist primarily of fine starch particles not recovered in the manufacturing process. Six of the seven plants discharge their wastes to municipal systems. One of these six plants provides pretreatment, and another is building a pretreatment facility. The seventh plant uses its starch effluent in a distillery operation from which there is a direct discharge to a receiving water. This plant is constructing a treatment plant for the distillery wastes.

SECTION IV

INDUSTRY CATEGORIZATION

This study of the grain milling industry covers the processing of milled grain into animal feed, breakfast cereals for human consumption, and wheat starch and gluten. After considering various factors, it was concluded that the industry should be subcategorized into several discrete segments for purposes of developing effluent limitations. These subcategories are as follows:

1. Animal feed manufacturing
2. Hot cereal manufacturing
3. Ready-to-eat cereal manufacturing
4. Wheat starch and gluten manufacturing

FACTORS CONSIDERED

The factors considered in developing the above subcategorization included:

1. Raw materials
2. Finished product
3. Production processes or methods
4. Size and age of production facilities
5. Waste water volume and characteristics
6. Treatability of wastes

Careful examination of all available information indicates that two of these factors, namely type of finished product and waste water characteristics, provide a meaningful basis for subcategorization this segment of the industry, as discussed in the following paragraphs.

Raw Materials

The major raw materials used by this segment of the grain milling industry are the basic cereal grains, principally corn, wheat, oats, and rice. Other raw materials are used in varying amounts depending on the specific end product. Vitamins and other additives are used in animal feed production and large quantities of sugar or syrup may be added for certain breakfast cereals. Waste water characteristics within this industrial category do not reflect the particular raw materials employed. For example, the production of animal feeds from corn generates no waste water while the manufacture of ready-to-eat corn cereals produces significant waste discharges. Accordingly, it was concluded that raw materials do not form a basis for subcategorization.

Finished Products

The finished products from this industry grouping vary widely and do provide a rational basis for subcategorizing the industry. The industry can be divided into animal feeds, breakfast cereals, and wheat starch and gluten. Not only does this grouping divide the industry into distinct product lines, but it also reflects waste water characteristics. Animal feed production generates no process waste waters, ready-to-eat cereal manufacturing usually yields substantial quantities of moderate to high strength wastes, that cereal manufacture generate no process waste water and wheat starch and gluten operations produce very high strength wastes.

The breakfast cereal industry contains two distinct subcategories, hot cereals and ready-to-eat cereals. As noted above the manufacturing operations used to produce hot cereals do not result in process waste waters as contrasted with ready-to-eat cereal production which generates waste waters from several unit operations.

The many types of ready-to-eat cereals suggest the possibility of additional subcategorization based on cereal type, such as puffed, extruded, and flaked or coated and non-coated. An examination of available waste water data indicated only one possible relationship, that being the variation of organic waste load with the percentage of cereals being sugar-coated at cereal plants. It was concluded that such a correlation may well exist, but it cannot be quantitatively defined at this time and, hence, additional subcategorization is not warranted.

One difficulty in defining characteristics of the ready-to-eat cereal industry is the fact that most plants produce a wide variety of cereal types: Some plants also produce hot cereal, and many are multiple-product plants producing items such as cake mixes, baking mixes, instant breakfast drinks, and pancake syrup. Of the ready-to-eat cereal plants in the U.S., only four or five produce strictly cereals.

Production Processes

The production methods used in this industry vary widely. Animal feed manufacturing basically consists of mixing various raw materials together followed by pelleting and packaging. Cereal manufacturing is generally more complex and varies widely depending on the specific type of cereal. The unit operations will include at least some of the following: mixing, shredding, cooking, rolling, flaking, puffing, extrusion, and packaging. Wheat starch and gluten manufacturing entails yet another set of unit operations, quite distinct from those used in other segments of this industry. While it is recognized that production methods differ greatly within the grain milling industry, such methods do not in themselves provide a consistent basis for subcategorization.

Size and Age of Production Facilities

The available data provides no evidence to support subcategorization of this industry based on age or size of plants. Relationships between waste loads and plant size or age may exist, but the information gathered during this study does not indicate a correlation except for wheat starch manufacturing. In that segment, a general trend of increasing waste loads with increasing plant age and capacity is indicated. The waste loads per unit of raw material vary within a fairly narrow range, however, making a subcategorization on this basis impractical and unwarranted.

Waste Water Characteristics

Waste water characteristics, in conjunction with finished products, form the basis for the subcategorization detailed previously in this document. Animal feed and hot cereal manufacturing do not produce process waste waters and are thereby clearly distinguished from the remaining two subcategories. Both ready-to-eat cereal and wheat starch production generate organic type wastes; the very high strength of the wheat starch waste waters (6000 to 14,000 mg/l of BOD_5) merits a separate subcategory. Ready-to-eat cereals normally generate waste waters with BOD_5 concentrations of 400 to 2500 mg/l. This range is representative of small plants and large plants, correspondingly.

Treatability of Wastes

All of the process waste waters generated by various segments of this industry are amenable to conventional physical and biological treatment systems of the same general type. The fundamental design criteria are similar and treatability is not a satisfactory basis for subcategorization. Supplemental nutrients (nitrogen and phosphorus) are required for effective biological treatment of ready-to-eat cereal process waster waters, as well as pH control for starch waste.

SECTION V

WATER USE AND WASTE WATER CHARACTERISTICS

INTRODUCTION

The industry subcategories covered by this document indicate a wide range of process water requirements and waste water characteristics. The animal feed industry, with little or no process water use, generates no process waste waters. Water use in the breakfast cereal industry varies from virtually none in hot cereal manufacture to substantial amounts in large ready-to-eat cereal plants. Wheat starch plants do not require large quantities of process water, but they do produce high-strength waste waters.

This section presents a detailed discussion of water use, individual process and total plant waste water characteristics, and factors that might influence the nature of the waste waters generated. The information presented has been collected from industrial sources, U.S. Army Corps of Engineers permit applications, municipal sampling data records, literature, and the results of a series of sampling visits to selected plants in each industrial subcategory. The sources of data are described in more detail in Section III.

In general, information on waste water characteristics of non-contact cooling water, boiler blowdown, and water treatment plant wastes has been excluded from the following discussion. These auxiliary activities are common to many industries, and the individual practices at any given plant usually do not reflect conditions that are unique to the grain milling industry. The types of treatment employed for cooling water systems, boiler feed water, and process water vary widely throughout the industry and depend on such factors as raw water characteristics, availability of surface, ground, or city water, individual company preferences, and other considerations not related to the basic nature of the industry. Separate guidelines for auxiliary wastes common to many industries will be proposed by EPA at a later date.

ANIMAL FEED MANUFACTURING

The processing of various grains, grain milling by-products, and other materials into prepared animal feeds requires only small volumes of process water. The two main areas of water use in a feed mill are boiler operation for steam generation and non-contact cooling of processing equipment such as pellet mills. Steam is

required for softening the meal and raising the moisture content prior to pelleting (see Figure 4 in Section III of this document). No water is discharged as a liquid from this operation. Only water vapor results from the pellet cooling and drying operation.

Waste waters generated by animal feed producing plants include boiler blowdown, non-contact cooling water, and wastes from boiler feed water treatment, such as ion exchange regeneration wastes. No process waste waters are discharged and, hence, this subcategory can be termed a "dry" industry.

HOT CEREAL MANUFACTURING

In general, only dry milling and blending operations are involved in the manufacture of hot cereals such as farina and rolled oats. Water is used for grain tempering and for raising product moisture during manufacture, but no waste waters result from these operations.

READY-TO-EAT CEREAL MANUFACTURING

Water Use

There are several areas of water use in ready-to-eat cereal manufacturing. A large proportion of the total water consumption of a plant is due to wet cleanup and washing operations, but several of the processing steps also require fresh water.

Many areas of a ready-to-eat cereal plant receive wet wash-downs or cleanup, including certain types of process equipment and specific processing areas. Equipment that is washed on a regular basis includes cookers for flaked and crisped cereals, flavor making or brewing tanks, ingredient and syrup mixing tanks, coating equipment such as rotating drums and spray nozzles, and belt conveyors. One plant utilizes a continuous stream of spent cooling water to wash conveyor belts and floor areas under flaked cereal cookers. The waste stream is discharged to the sewer.

Specific processing areas that are washed include diked floor areas under vitamin and sugar coating equipment, toasting ovens, conveyor belts, and ingredient mixing equipment. Dry collection of product spillage for subsequent use as feed is practiced to a greater extent in some plants than in others. A few plants have vacuum systems for this purpose. General washing of floors and walls is also carried out in most ready-to-eat cereal plants. Floors are either rinsed or mopped, and walls are occasionally scrubbed, particularly tiled surfaces around processing areas. Detergents are generally used, and some plants also use sanitizing agents in their cleanup operations.

Water is added to the product to increase the moisture content in several of the processing steps in cereal manufacturing. These steps include grain tempering, cooking operations, and extrusion operations. Except for the cooking operation in shredded cereal manufacture, the added moisture remains with the product until it is released as a vapor in a drying operation. Water is also used in coating of cereals with vitamins. In most plants, water is added to a dry vitamin mixture to form a solution which is then sprayed on the cereal. Some plants first spray the product with water and then spray the vitamins on in a dry form. The water enables the vitamins to adhere to the cereal.

Some ready-to-eat cereal plants use wet scrubbers for air pollution control. Certain processes such as cooking, extruding, coating, and puffing can produce moist vapors containing particulates. Typical flows of fresh water or spent cooling water into a wet scrubber can range from 0.32 to 0.63 liters/sec (5 to 10 gal/min).

Flaking rolls, forming rolls, cookers, extruders, air compressors, heat exchangers, air conditioning units, and other select pieces of equipment used in cereal manufacturing require cooling water when in operation. One plant withdraws water from a river for some of its cooling needs. Other plants use either municipal supplies or on-site wells. Some plants have separate non-contact cooling water discharges to receiving waters, while others combine spent cooling water with process and sanitary wastes and discharge to municipal systems.

Steam generation in cereal plants also consumes water. An average plant may use up to 75.7 to 113.6 cu m/day (20,000 to 30,000 gpd) of water for boiler feed.

Total water use in the ready-to-eat cereal industry ranges from 757 to 15,140 cu m/day (200,000 to 4,000,000 gpd) per plant. On a product basis, cereal plants use 8.3 to 25 cu m/kkg (1000 to 3000 gal/1000 lbs) of cereal produced. Interestingly, the larger volumes generally correspond to larger plants employing once-through cooling systems.

Waste Water Characteristics

Other than total raw waste data, information was obtained on only one individual process waste stream. This was the discharge from the cooking operation in shredded cereal manufacturing. Only four plants in the country produce this type of cereal, and shredded cereals are a small proportion of total production at one of these plants. In the grain cooking operation, water is discharged after each batch of grain is cooked. The volume of discharge is approximately 1.1 cu m/kkg (132 gal/1000 lbs) of grain cooked. Several samples of this discharge from a cereal plant were collected after passing through a screening operation. High concentrations of BOD_5, COD, and dissolved and suspended solids were indicated as shown in Table 3.

Table 3

Shredded Cereal Cooker Discharge
Waste Water Characteristics After Screening

	Range, mg/l
BOD_5	3414 - 3504
COD	5921 - 6040
Suspended solids	1558 - 1572
Dissolved solids	3800 - 7619
Organic nitrogen as N	70.5 - 95.1
Nitrite nitrogen as N	0.07 - 0.37
pH	4.1 - 6.1
Temperature (°C)	71 - 74

This waste is highly variable in strength, with earlier sampling by the plant indicating BOD_5 concentrations as high as 9000 mg/l.

Most of the data accumulated during this study relate to the total raw waste characteristics from ready-to-eat cereal plants. Summary data from 11 plants are presented in Table 4. The wastes can generally be characterized as medium to high in organic strength and volume. The BOD_5 varies widely, from 331 to 2500 mg/l. Correspondingly, COD levels range from 804 to 4434 mg/l.

Average suspended solids concentrations in the total waste streams vary from 80 to 1073 mg/l, although the levels at most plants are in the range of 150 to 400 mg/l. The average pH of the waste streams varies from 6.2 to 8.6, although the pH of individual samples can vary over a much wider range, from 4.5 up to 10.

Limited data on phosphorus and nitrogen indicate low levels for most plants. Typically the wastes from ready-to-eat cereal plants may be deficient in nitrogen and phosphorus for biological treatment.

The information contained in the preceding table is presented in Table 5 in terms of finished product quantity, i.e., kg/kkg (lbs/1000 lbs) of cereal. The plant numbers in the two tables do not correspond to one another.

Waste water flows from ready-to-eat cereal plants vary from 2.5 to 9.6 cu m/kkg (0.30 to 1.15 gal/lb) of cereal, with an average of 5.82 cu m/kkg (0.70 gal/lb) (See Table 4). BOD_5 in terms of finished product output ranges from 2.2 to 18.2 kg/kkg (lbs/1000 lbs) and averages 6.6 kg/kkg (lbs/1000 lbs). Limited data were available on COD, which varies from 5.7 to 42.4 kg/kkg (lbs/1000 lbs) and averages 15.7 kg/kkg (lbs/1000 lbs). Suspended solids values fall in a fairly narrow range, varying from 0.6 to 2.7 kg/kkg (lbs/1000 lbs) and averaging 1.4 kg/kkg (lbs/1000 lbs).

Factors Affecting Waste Water Characteristics

Table 4

Total Plant Raw Waste Water Characteristics
Ready-To-Eat Cereal Manufacturing

Plant	BOD, mg/l		COD, mg/l		Suspended Solids, mg/l		pH	
	Average	Range	Average	Range	Average	Range	Average	Range
1	1028	620-2200	2169	1340-4750	209	95-499	7.5	5-10
2	1761	59-6200	-	-	385	13-3272	-	-
3	420	135-885	2700	800-4000	200	148-348	6.2	5.9-7.0
4	1904	20-4852	-	-	1073	41-7712	6.2	2.2-8.1
5	637	174-2550	1325	575-1827	-	-	7.9	4.8-9.3
6	533	-970	804	-1380	80	-100	6.7	6.1-7.5
7	2500	1065-5220	4300	2000-9050	400	256-584	6.9	4.5-9.1
8	437	117-967	1415	532-3608	154	45-492	6.9	4.8-9.4
9	611	144-2480	1010	366-1991	173	4-3935	7.1	6.6-7.7
10	1344	30-7800	-	-	287	14-9758	-	-
11	1904	633-3811	4434	2310-9840	152	18-588	8.6	7.5-9.3

Table 5

Waste Water Characteristics Per Unit of Finished Product
Ready-To-Eat Cereal Manufacturing

Plant	Flow cu m/kkg	Flow gal/lb	BOD kg/kkg (lbs/1000 lbs)	COD kg/kkg (lbs/1000 lbs)	Suspended Solids kg/kkg (lbs/1000 lbs)
1	2.75	0.33	5.30	-	2.70
2	3.25	0.39	8.07	13.88	1.29
3	9.59	1.15	18.21	42.40	1.45
4	7.84	0.94	8.28	16.96	1.59
5	6.09	0.73	3.70	6.16	1.06
6	5.25	0.63	2.20	14.14	1.05
7	6.50	0.78	9.07	-	1.86
8	7.09	0.85	3.79	5.71	0.57
9	7.34	0.88	3.20	10.37	1.13
10	2.50	0.30	4.51	-	0.97
Average	5.82	0.70	6.63	15.66	1.37

As noted previously, waste waters from ready-to-eat cereal plants vary considerably in quantity and character. This variability is a function of many different factors, and attempts have been made in this study to correlate some of these factors with raw waste loads, as discussed in the following paragraphs.

Age of Plant-

In some industries, the character of waste generated is directly related to the age of the plants. Such is not the case in ready-to-eat cereal manufacturing, as evidenced in Figures 11 and 12, which relate plant age to the BOD_5 and suspended solids in the total plant effluent. Data from ten plants were used to determine regression lines and compute correlation coefficients. The value of the correlation coefficient varies between zero and plus or minus one, with zero indicating no correlation and one indicating perfect fit or correlation. The positive or negative sign merely indicates the slope of the data curve. The dashed line indicates the line of regression, while the actual data points are contained within the shaded portion of the graph. The line of regression was determined by the least squares fit of the data. A correlation coefficient of -0.324 was obtained when BOD_5 was plotted against plant age, and a correlation value of 0.303 was determined when suspended solids loadings were plotted versus plant age. Both values are quite low, indicating a low degree of correlation or a high degree of randomness. No discernible relationship between the total waste load and the age of the plants was determined. In fact, several of the newer plants generate more wastes per unit of finished product than the older plants. It should be noted that the age of the plant in this industry subcategory does not accurately reflect the degree of modernization in terms of types of equipment and production methods. Most ready-to-eat cereal plants employ similar production techniques.

Size of Plant-

Several comparisons were made between the size of plant, expressed in daily quantity of finished product, and total plant waste loads, as shown in Figures 13, 14, and 15. The total daily volume of waste water discharged was found to correlate fairly well with the plant capacity, Figure 13, as might be expected. A correlation coefficient value of 0.835 was computed. At the same time, the range of plant data reflect different process and cooling water use practices.

Data on BOD_5 and suspended solids were used to generate the graphs shown in Figures 14 and 15. These figures attempt to relate plant capacity to BOD_5 and suspended solids loads, respectively. The correlation coefficient values of 0.273 and 0.215 and the wide range of average plant data indicate that no definable relationships exist between plant capacity and either of these two pollutant parameters.

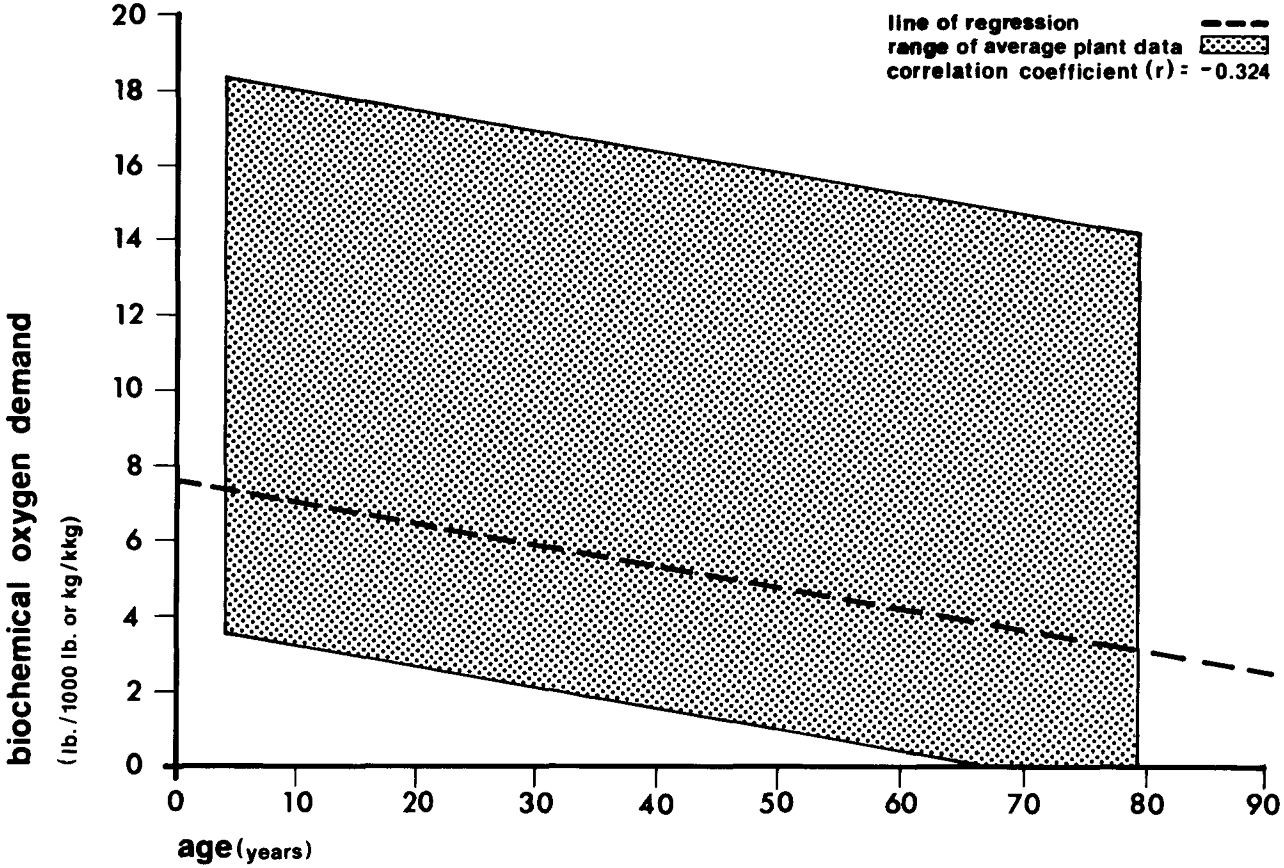


FIGURE 11

AVERAGE BOD DISCHARGED AS A FUNCTION OF AGE OF CEREAL PLANTS

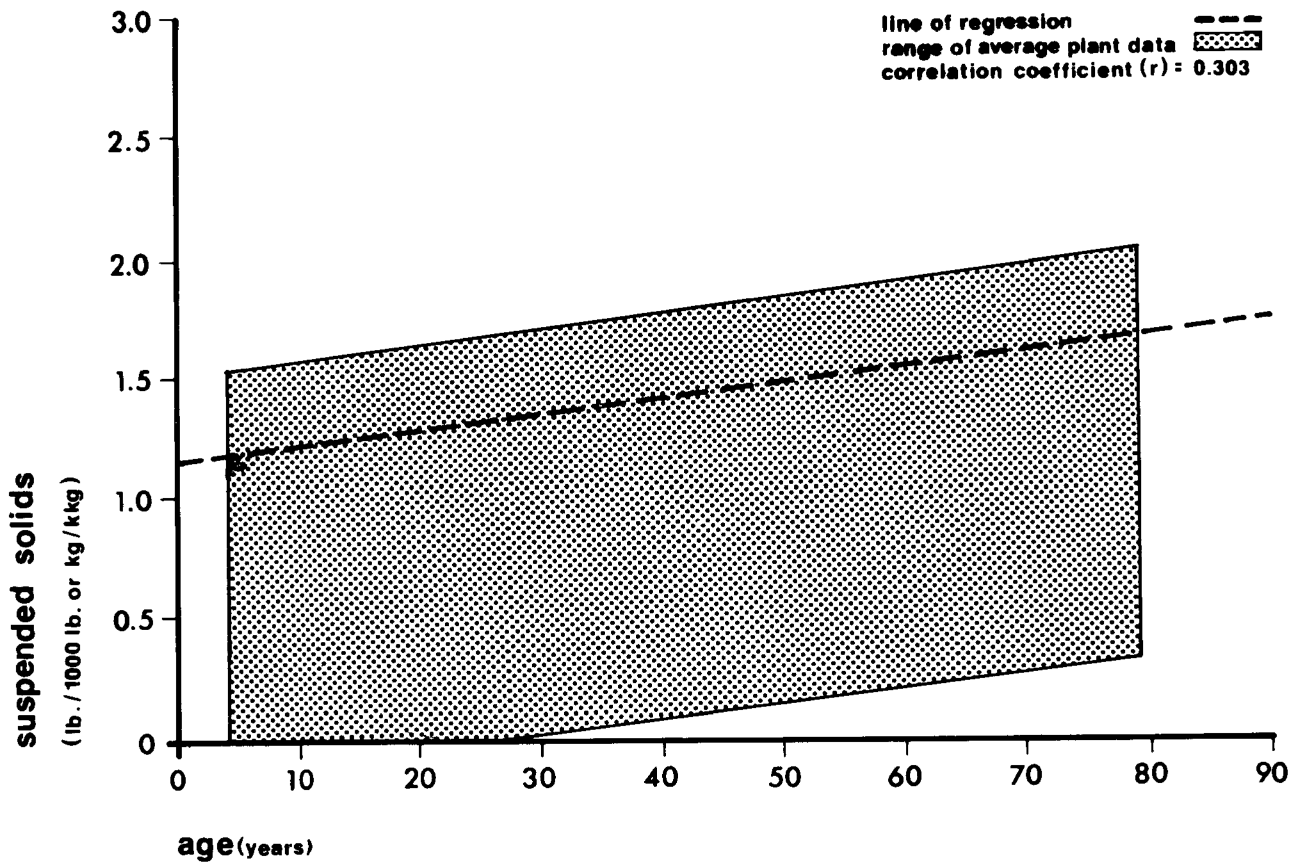


FIGURE 12

AVERAGE SUSPENDED SOLIDS DISCHARGED AS A FUNCTION OF AGE OF CEREAL PLANTS

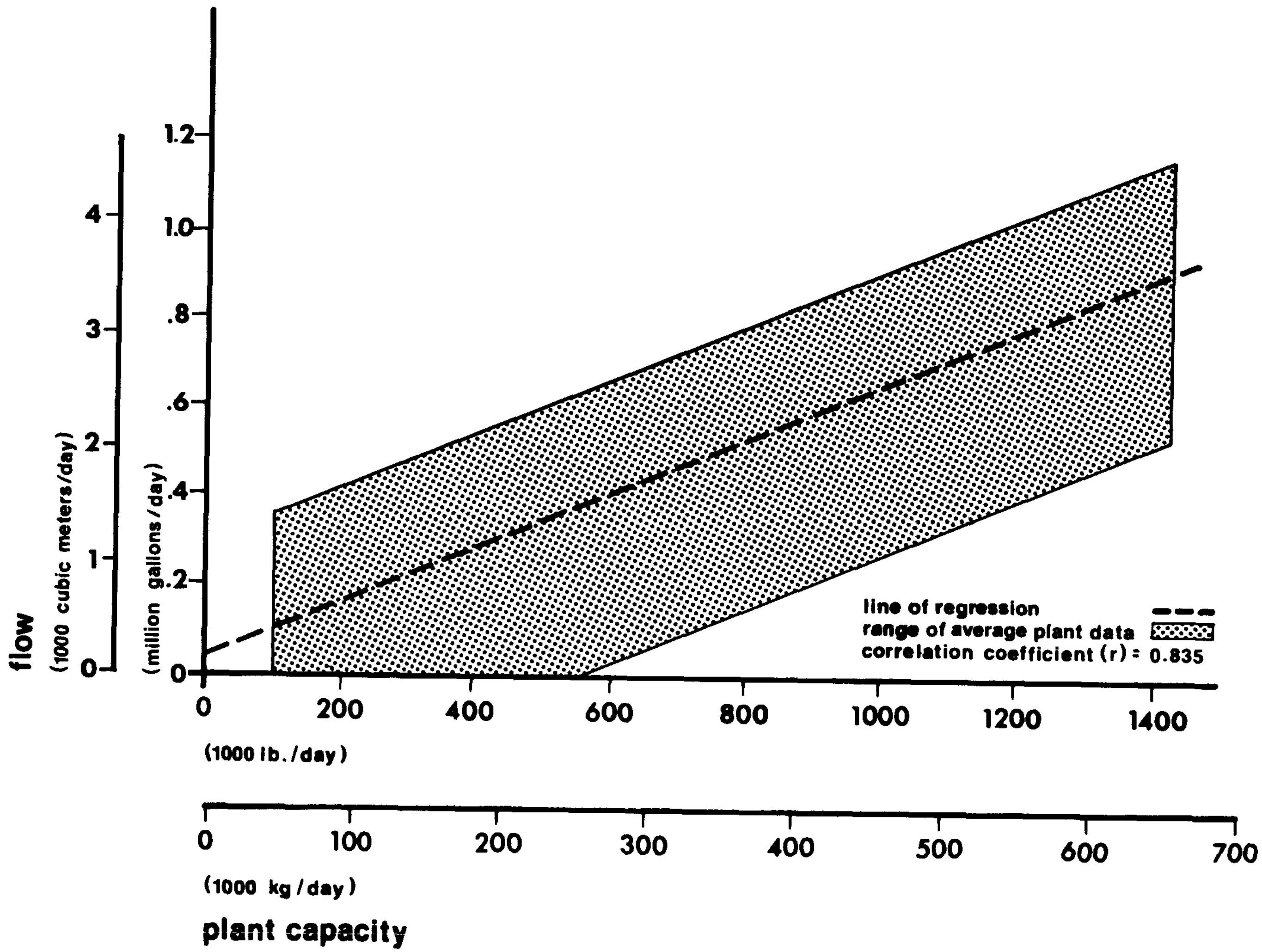


FIGURE 13

WASTE WATER FLOW AS A FUNCTION OF CEREAL PLANT CAPACITY

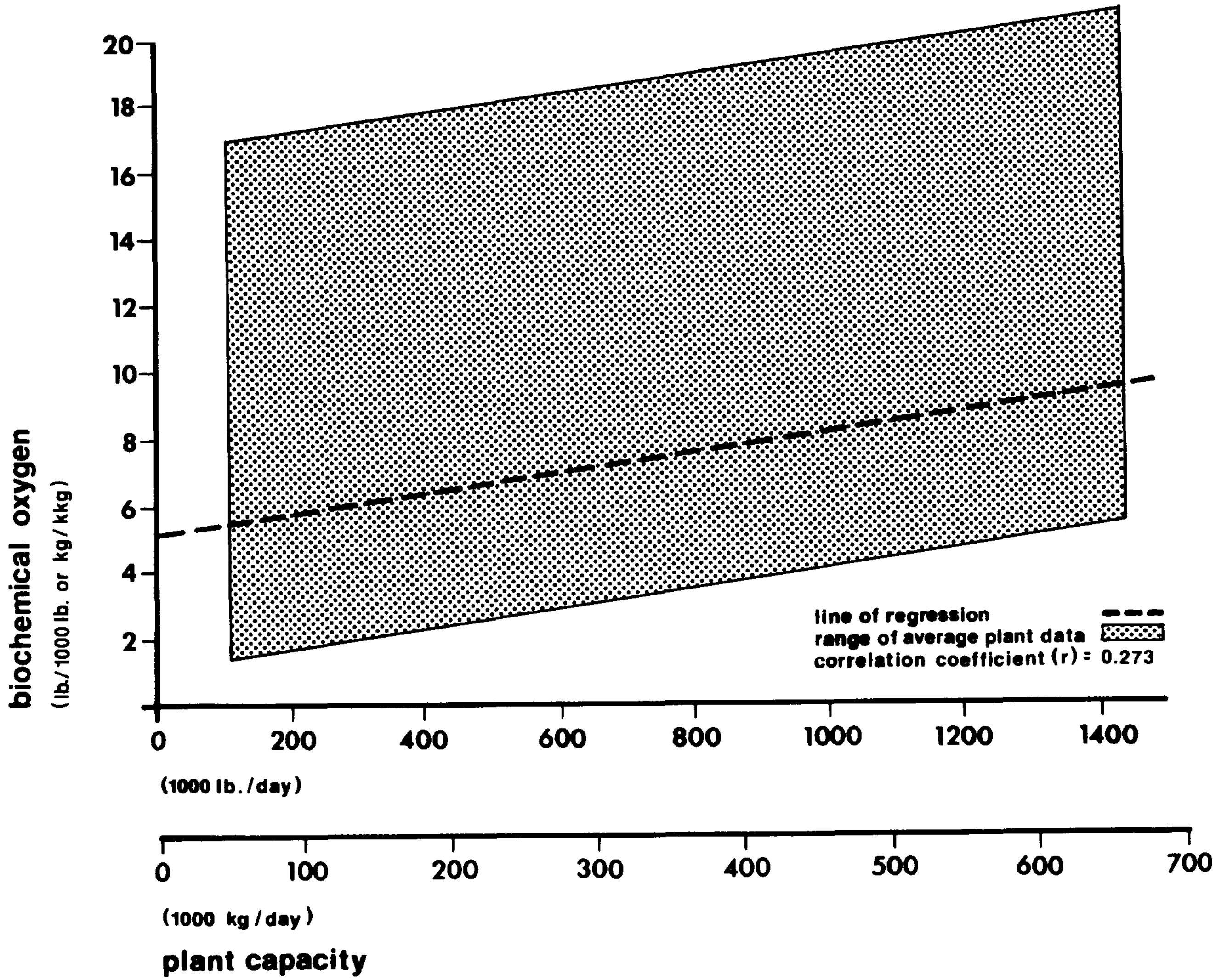


FIGURE 14

AVERAGE BOD DISCHARGED AS A FUNCTION OF CEREAL PLANT CAPACITY

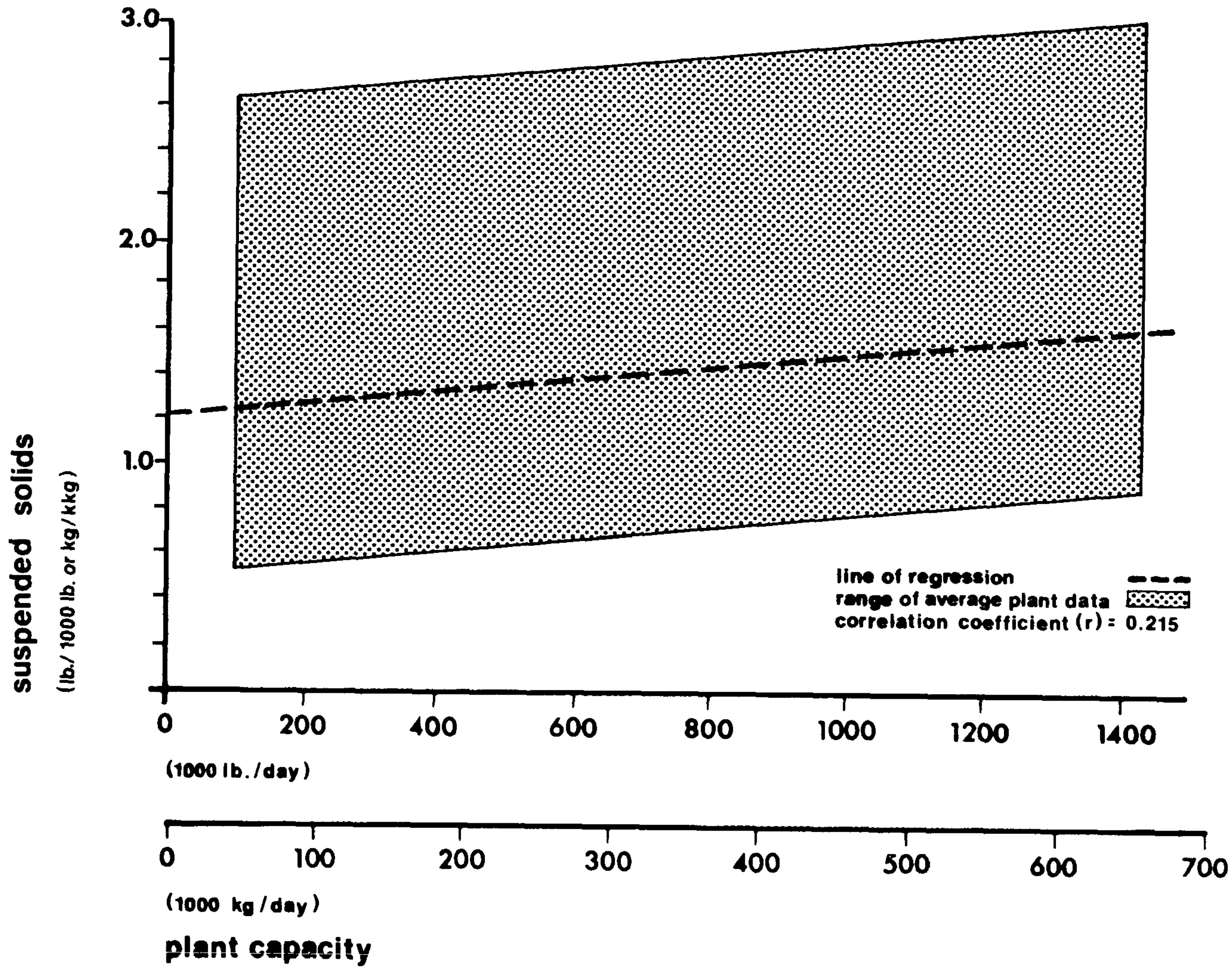


FIGURE 15

AVERAGE SUSPENDED SOLIDS DISCHARGED AS A FUNCTION OF CEREAL PLANT CAPACITY

Percentage of Sugar Coated Cereal-

In Figure 16, average BOD5 loadings per unit of finished product are compared with the proportion of cereal that is sugar coated at a plant. The value of the correlation coefficient is 0.629, indicating a fair degree of correlation between organic waste load and amount of cereal being coated. A general trend of increasing BOD5 with increasing percentage of cereal being coated is indicated. This might be expected, as increasing coating operations probably result in larger quantities of sugar entering the plant effluent during cleanup operations.

WHEAT STARCH AND GLUTEN MANUFACTURING

Water Use

The use of water is integral to the processes involved in starch and gluten manufacturing. Basically the manufacture of wheat starch is a wet separation of the starch and gluten components of wheat flour. Fresh water enters the operation at several different points, as shown in the process flow diagram, Figure 10 in Section III. Water is mixed with the flour to form a dough. More water is used in the washing operations which separate the starch from the gluten. In the screening steps, water is used for back-washing fibre collected on coarse screens and for countercurrent washing of the overflow (fibres) leaving the fine screens. A major water use in the process occurs in the refining of the crude starch milk. As the refining centrifuges separate the heavy component, A-starch, from the light component, B-starch, a fresh water stream washes the heavy component countercurrently. Smaller quantities of water are also used for cleanup, cooling, and boiler operation.

Total water use in wheat starch plants varies from 284 to 946 cu m/day (75,000 to 250,000 gpd) depending mainly on plant capacity. The water use per unit of raw material ranges from 10.4 to 13.0 cu m/kkg (1.25 to 1.56 gal/lb) of flour.

Waste Water Characteristics

In the wheat starch manufacturing process, waste waters are generated primarily from starch milk screening and centrifugation. The fibre washed from the coarse screens enters the waste stream in most plants. Data from one plant indicate that the screening operation produced a 0.17 to 0.28 liter/sec (2.7 to 4.4 gal/min) waste stream containing 5.0 to 6.0 percent solids. This is a volume of 15 to 24 cu m/day (4000 to 6300 gpd) with a total solids loading of 809 to 1494 kg/day (1783 to 3291 lb/day). Discharges from starch milk thickening and concentrating operations make up the balance of the waste waters, although cleanup may generate additional small volumes.

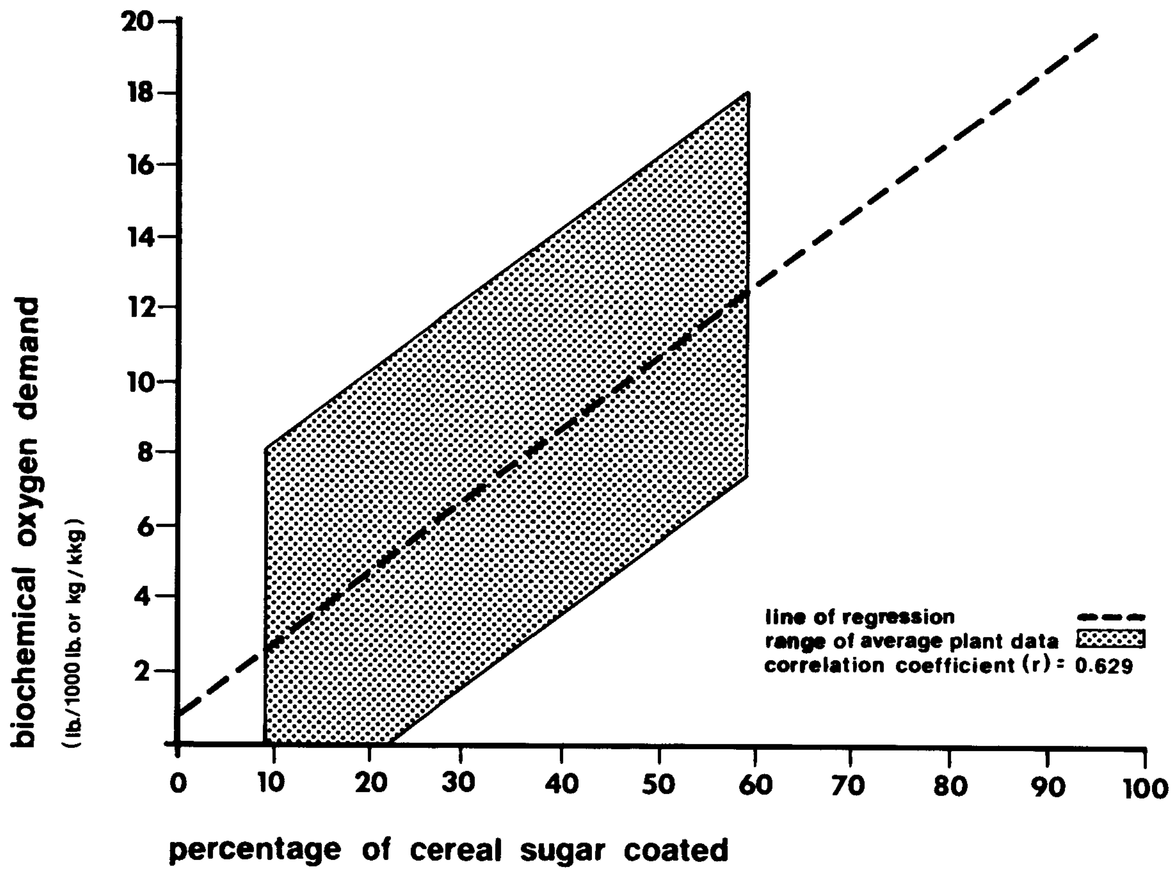


FIGURE 16

AVERAGE BOD DISCHARGED AS A FUNCTION OF PERCENTAGE OF COATED CEREAL PRODUCED

The remainder of the data accumulated on wheat starch operations relate to total waste flows. Summary data from six of the seven plants are included in Table 6. The seventh plant uses its starch waste stream as raw material feed in a distillery operation and, therefore, the plant's waste characteristics are not representative of the industry. The sixth plant listed in Table 6 also processes soybeans and has a canning operation that generates waste waters.

BOD5 values for the six plants range from 6500 to 14,600 mg/l, with the higher concentrations corresponding to larger plants. Suspended solids concentrations range from 5140 to 14,800 mg/l, and, again, the higher concentrations tend to correspond to the larger plants.

The pH of wheat starch plant effluents is generally acidic, in the range of 3 to 6, although data from one plant indicate a neutral pH. Limited data on phosphorus and nitrogen show rather high values. Total phosphorus concentrations at two plants varied from 75 to 140 mg/l, and total nitrogen values ranged from 350 to 400 mg/l. Waste temperatures varied from 70 to 80°F for the various wheat starch plants.

The information contained in the preceding table is presented in Table 7 in terms of raw material input, i.e., kg/kkg (lbs/1000 lbs) of wheat flour. <u>The plant numbers in the two tables do not correspond to one another</u>.

BOD5 in terms of raw material input ranges from 80 to 108 kg/kkg (lbs/1000 lbs), and averages 90.7 kg/kkg (lbs/1000 lbs). Suspended solids loads vary in the same range, from 52 to 110 kg/kkg (lbs/1000 lbs), with an average value of 75.7 kg/kkg

(lbs/1000 lbs). Available COD data show a range of 116 to 260 kg/kkg (lbs/1000 lbs) averaging 198.6 kg/kkg (lbs/1000 lbs). The waste water flows are fairly consistent throughout the plants studied, varying from 7.5 to 12.5 cu m/kkg (0.9 to 1.5 gal/lb), Averaging 9.9 cu m;kkg (1.19 gal/lb). Generally, the waste water characteristics in the wheat starch subcategory show good correlation when expressed in loadings per unit of raw material.

<u>Factors Affecting Waste Water Characteristics</u>

As with waste waters from ready-to-eat cereal plants, there is some variability in waste quantity and character in the wheat starch and gluten industry. Many factors may be responsible for these variations, and the following discussion outlines several attempts to correlate certain factors with raw waste loads.

<u>Age of Plant</u>

Data on five wheat starch plants were utilized in an attempt to relate raw waste loads per unit of raw material to plant age. Figures 17 and 18 show the results for BOD5 and suspended solids,

Table 6

Total Plant Raw Waste Water Characteristics
Wheat Starch Manufacturing

Plant	BOD, mg/l		COD, mg/l		Suspended Solids, mg/l		pH	
	Average	Range	Average	Range	Average	Range	Average	Range
1	10,610	-	25,040	-	9527	-	4.9	-
2	6895	600-16,200	-	-	5141	500-19,580	-	-
3	9600	8060-12,700	12,300	11,600-13,500	7500	2400-12,600	3.5	3.4-4.2
4	14,633	7968-22,495	35,057	1661-42,992	14,824	3468-21,442	4.6	4.2-5.7
5	6500	-	9300	5100-12,400	4176	-	-	-
6	6200	-	16,000	-	6910	-	3.9	-

Table 7

Waste Water Characteristics Per Unit of Raw Material
Wheat Starch Manufacturing

Plant	Flow cu m/kkg	Flow gal/lb	BOD kg/kkg (lbs/1000 lbs)	COD kg/kkg (lbs/1000 lbs)	Suspended Solids kg/kkg (lbs/1000 lbs)
1	12.42	1.49	80.8	115.6	51.9
2	7.42	0.89	108.4	259.6	109.8
3	8.50	1.02	90.3	213.0	81.0
4	9.75	1.17	93.5	206.0	73.0
5	11.67	1.40	80.5	-	60.1
Average	9.95	1.19	90.7	198.6	75.2

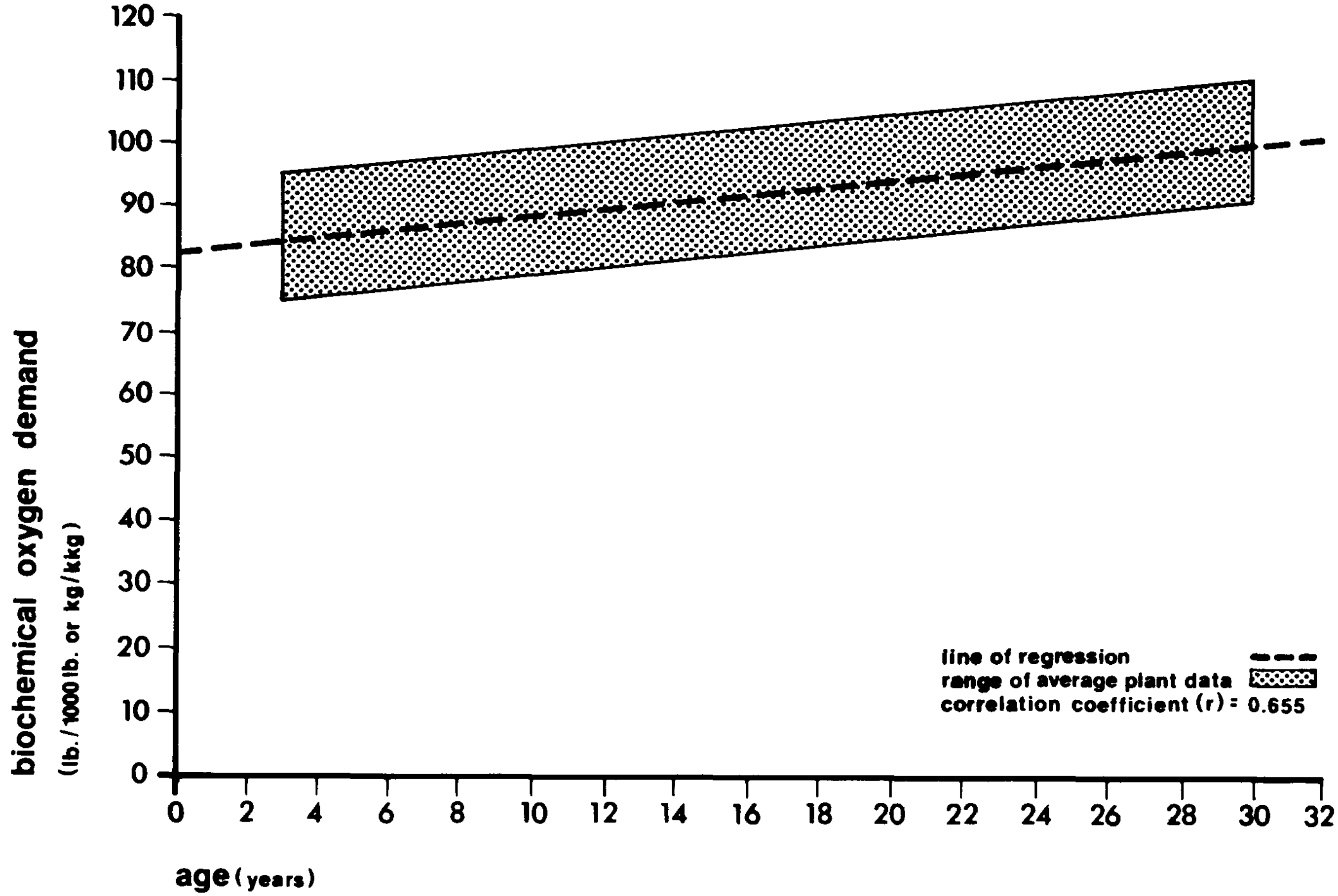


FIGURE 17

AVERAGE BOD DISCHARGED AS A FUNCTION OF WHEAT STARCH PLANT AGE

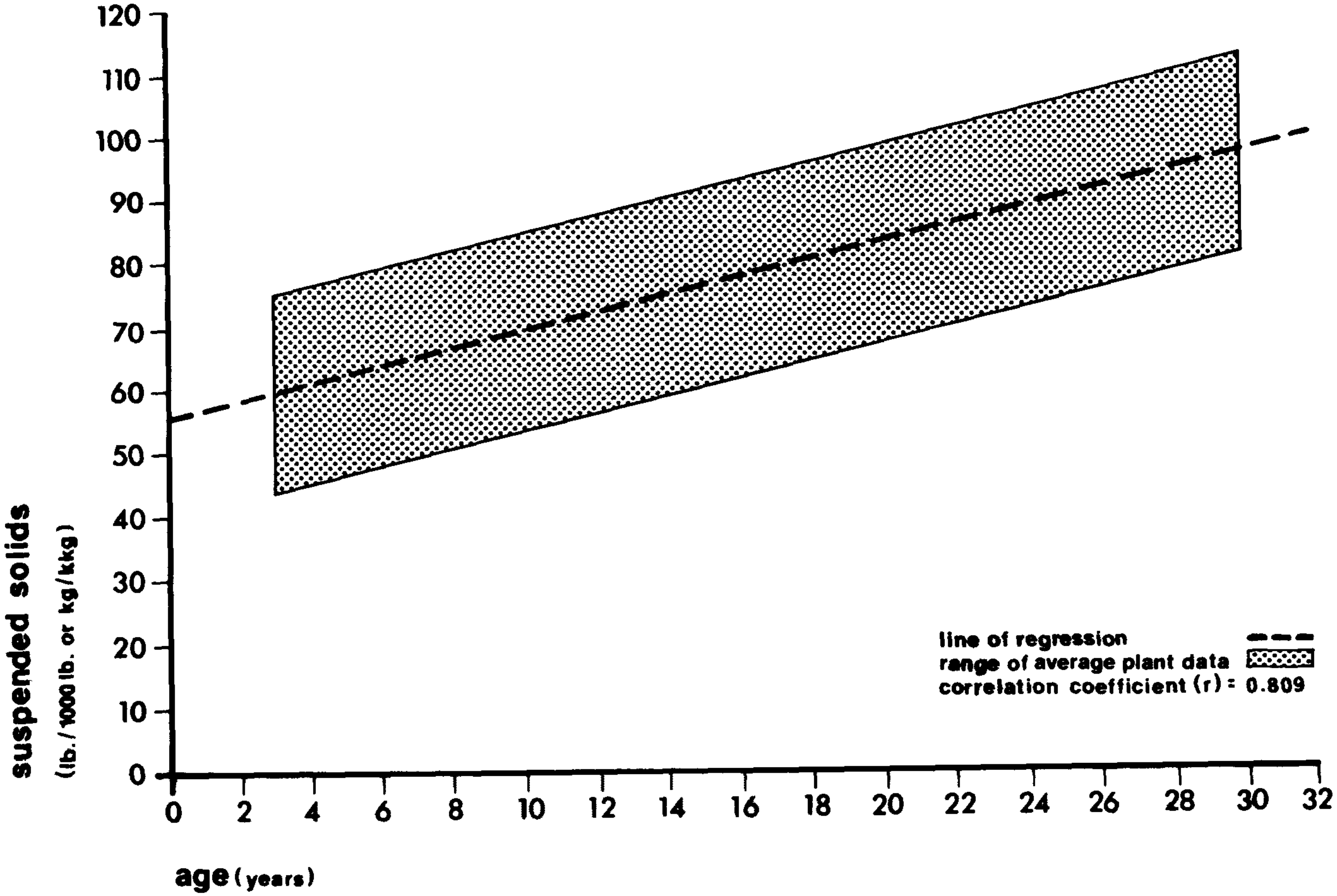


FIGURE 18

AVERAGE SUSPENDED SOLIDS DISCHARGED AS A FUNCTION OF WHEAT STARCH PLANT AGE respectively. The correlation coefficients, 0.655 and 0.809, are quite high, indicating the possibility of a definable relationship. The regression lines indicate that waste loads generally increase with increasing plant age.

Size of Plant-

The possibility of a relationship between wheat starch raw waste loads and plant capacity was investigated, and the results are shown in Figures 19, 20, and 21. Daily waste water flow correlated well with plant capacity, as shown in Figure 19. The high value of the correlation coefficient, 0.795, indicates a reasonably good fit of the data with the regression line, as might be expected. Figure 20 attempts to relate BOD_5 loadings per unit of wheat flour to plant capacity. The low correlation coefficient, 0.365, indicates that there is no definable relationship. In Figure 21, suspended solids loadings are plotted versus plant capacity. In this case, a high correlation coefficient of 0.688 was obtained, indicating a good probability that suspended solids loadings increase as plant size increases in a definable relationship.

In comparing Figures 17, 18, 20, and 21, it should be noted that the larger wheat starch plants also tend to be the older plants. Thus, a particular figure may not be showing the effect of just one variable on raw waste loads. It should also be noted that the raw waste load values, particularly for BOD_5, do not vary a great deal from plant to plant. This fact, plus the limited number of data points, influenced the decision not to further subcategorize the wheat starch industry on the basis of age and size of plant or waste water characteristics.

Water Use and Waste Water Discharge-

It has been speculated that there might be a relationship between the total waste load and the volume of waste water discharged. Figures 22 and 23 were developed to evaluate this hypothesis and clearly show that no such relationship exists. The correlation coefficient values of -0.109 and 0.106 indicate little or no correlation.

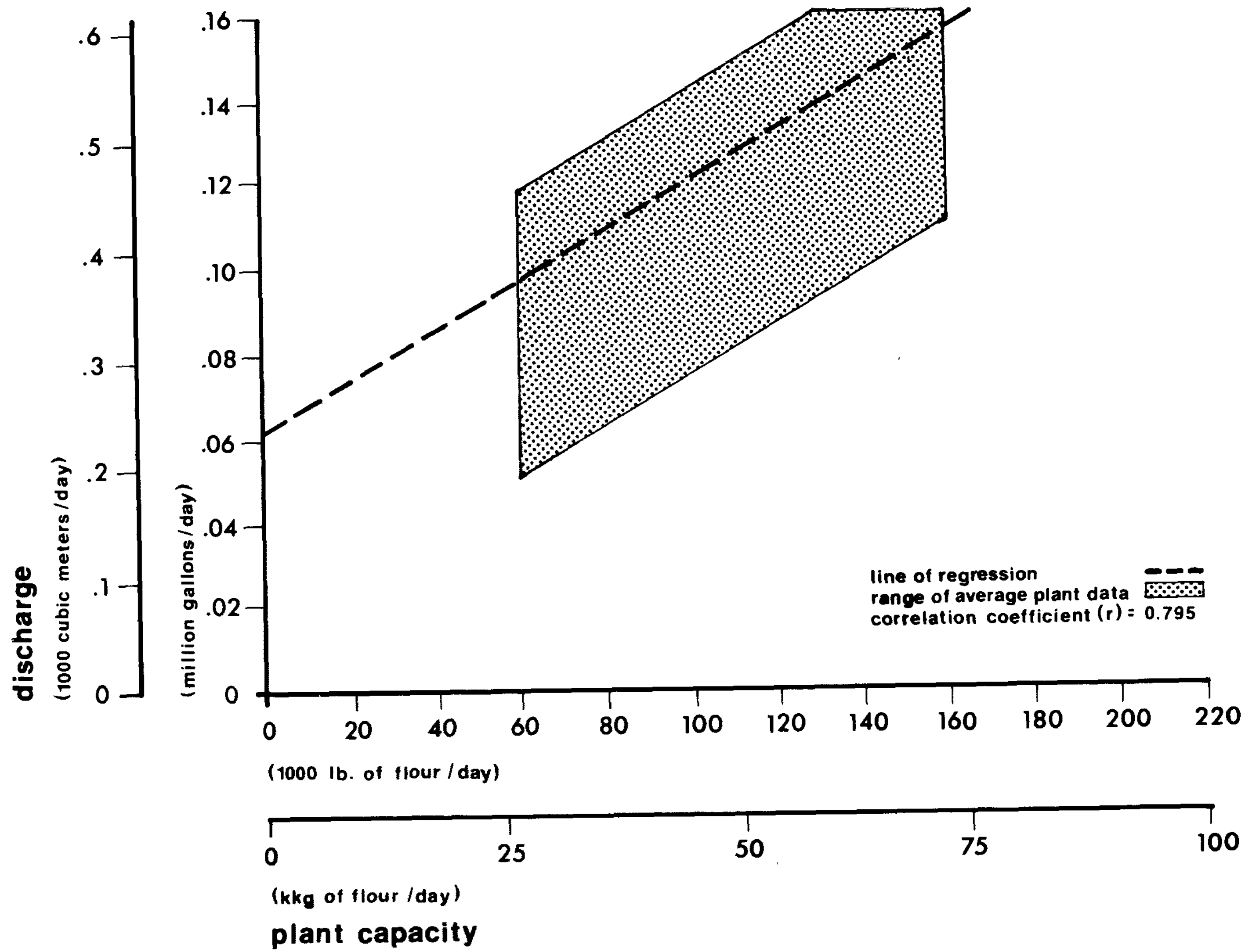


FIGURE 19

WASTE WATER DISCHARGE AS A FUNCTION OF WHEAT STARCH PLANT CAPACITY

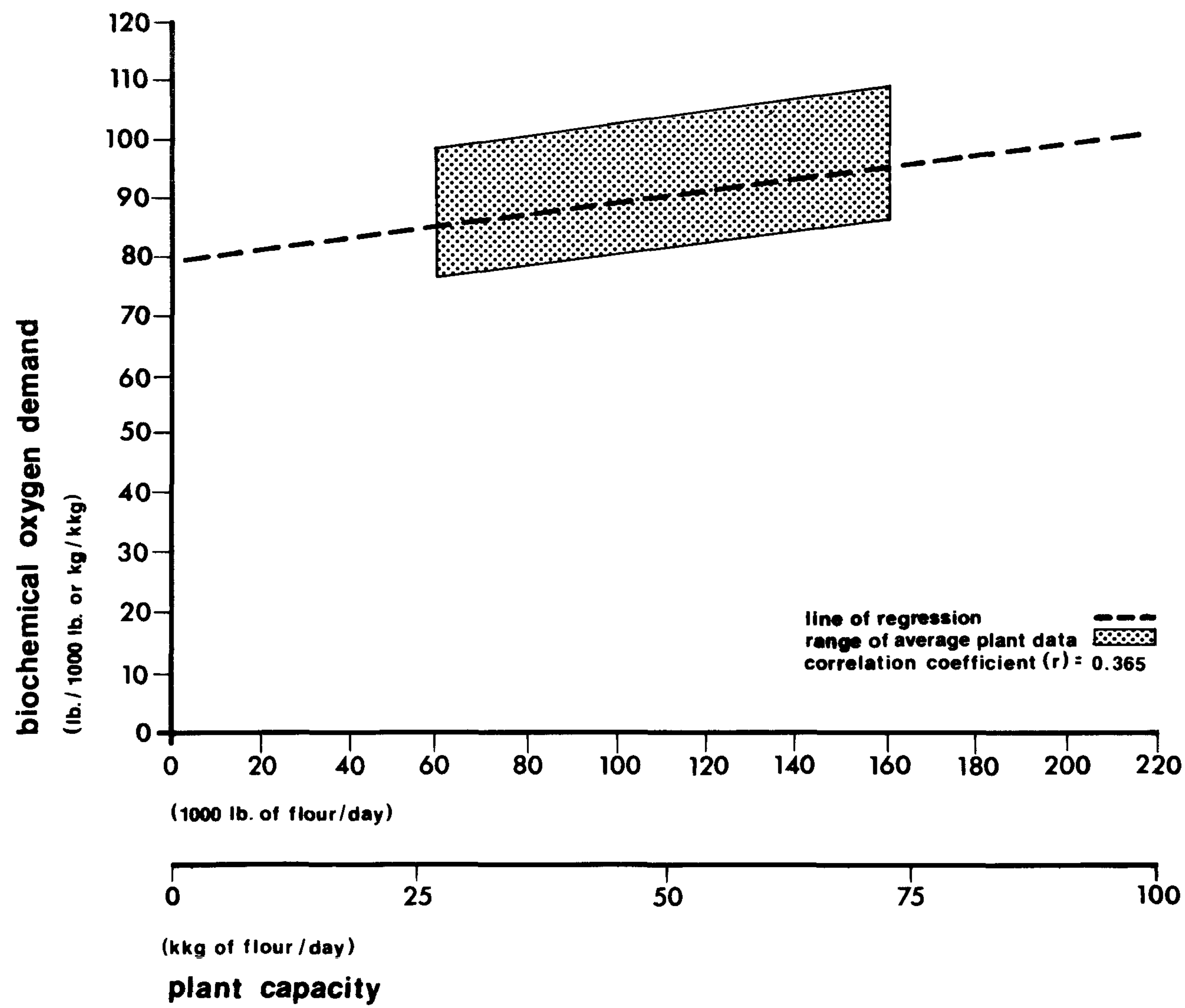


FIGURE 20

AVERAGE BOD DISCHARGED AS A FUNCTION OF WHEAT STARCH PLANT CAPACITY

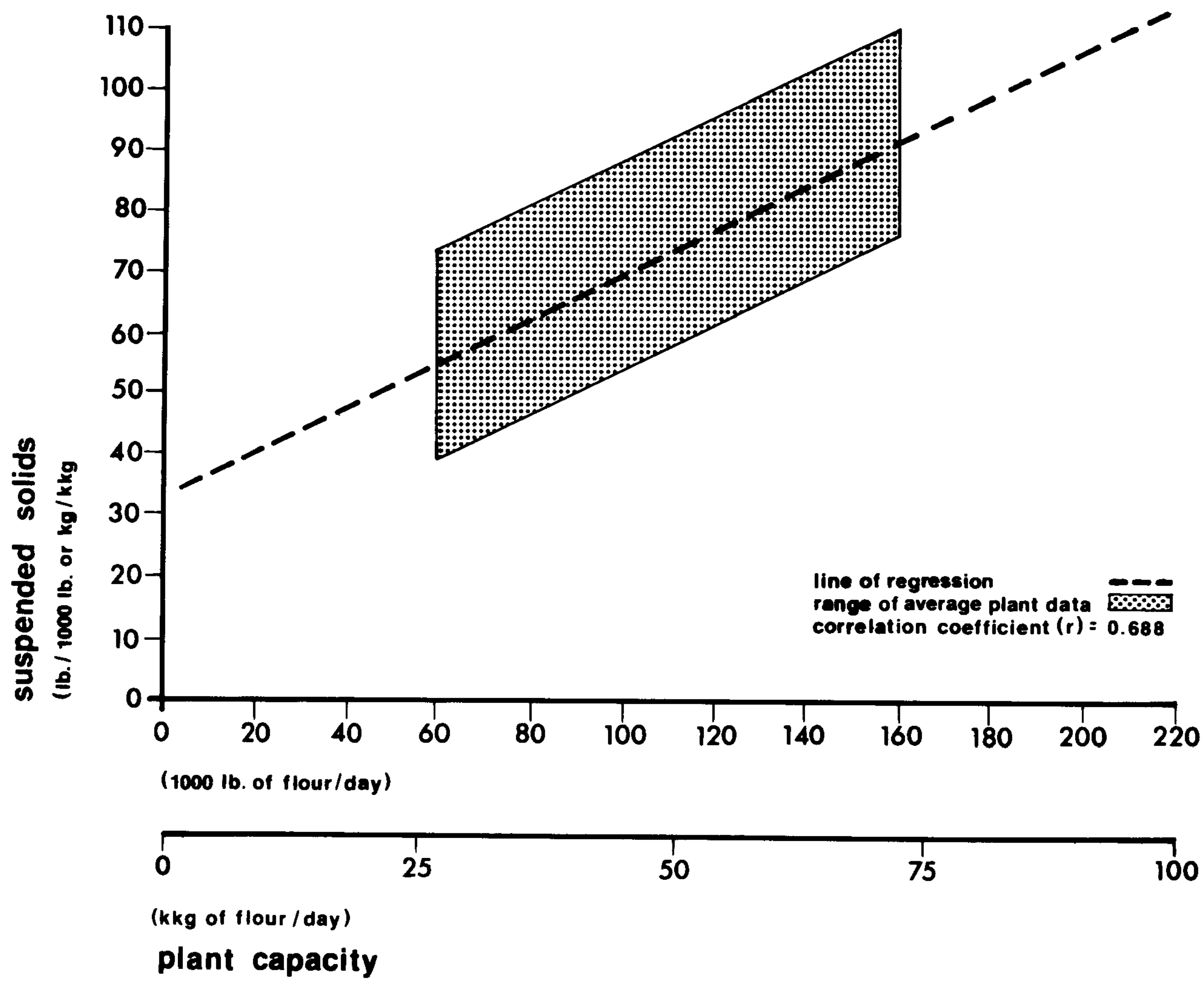


FIGURE 21

AVERAGE SUSPENDED SOLIDS DISCHARGED AS A FUNCTION OF WHEAT STARCH PLANT CAPACITY

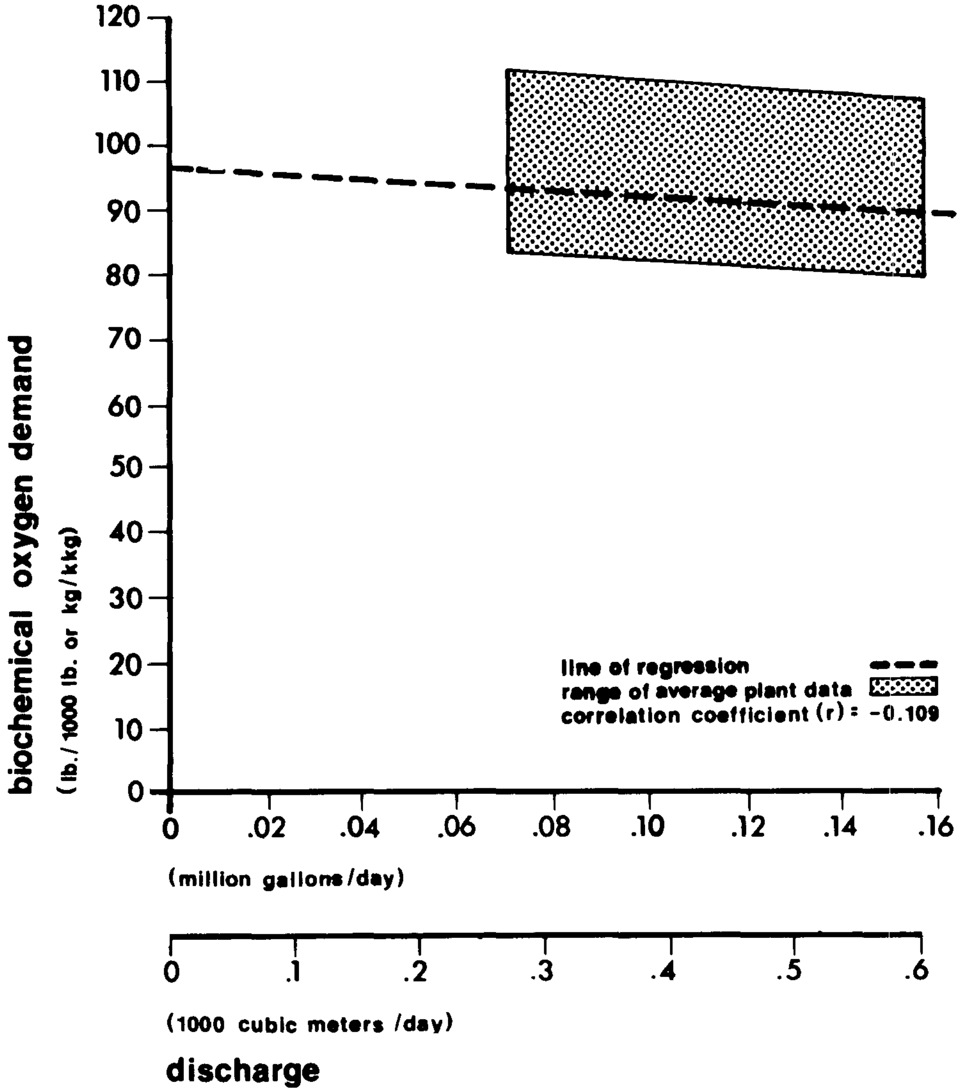


FIGURE 22

AVERAGE BOD DISCHARGED AS A FUNCTION OF WHEAT STARCH PLANT DISCHARGE VOLUME

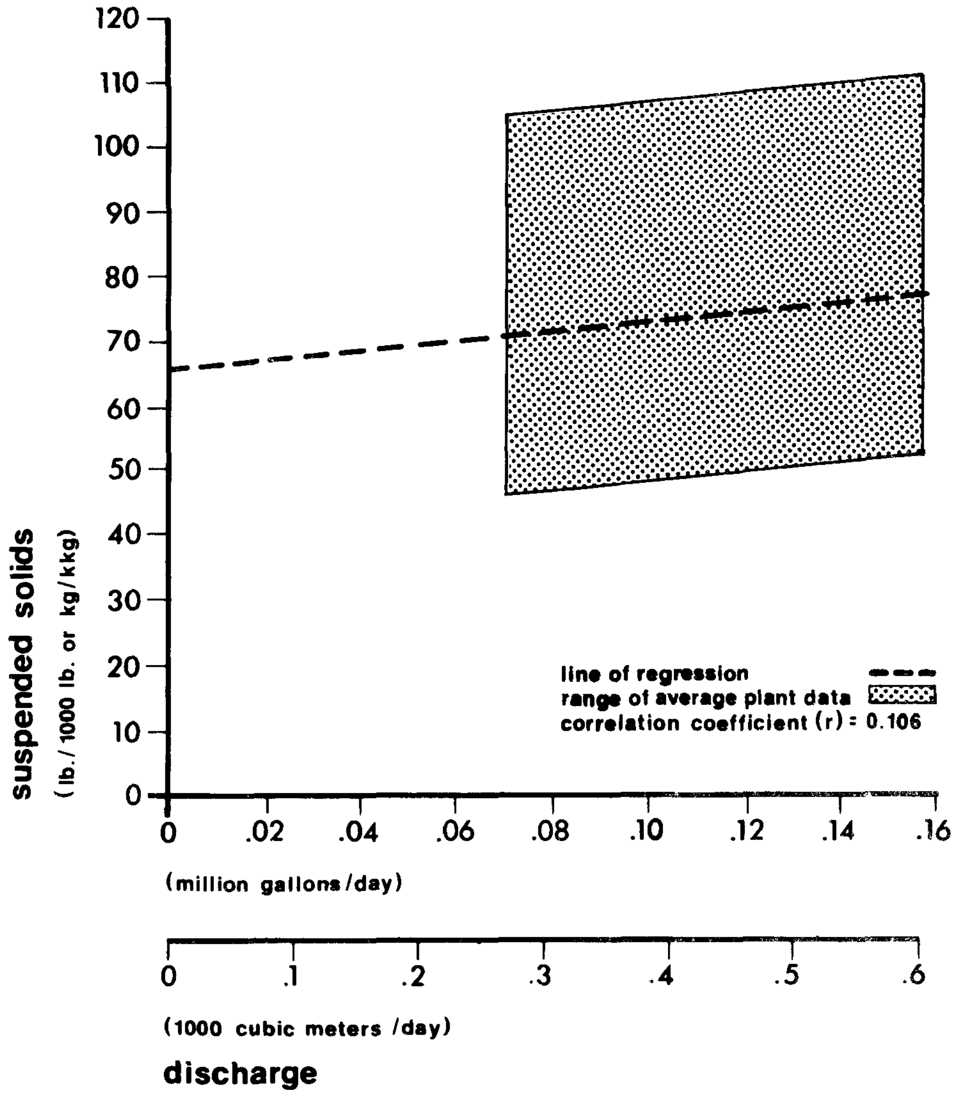


FIGURE 23

AVERAGE SUSPENDED SOLIDS AS A FUNCTION OF WHEAT STARCH PLANT DISCHARGE VOLUME

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The waste water parameters that can be used in characterizing the process waste waters from the cereal and wheat starch segments of the grain milling industry are as follows: BOD5 (5-day20°C biochmeical oxygen demand), suspended solids, pH, chemical oxygen demand (COD), dissolved solids, nitrogen, phosphorus, and temperature. These parameters are common to the entire industry, but are not always of equal importance. As described below, the selection of the waste water control parameters was determined by the significance of the parameters and the availability of data throughout each industry subcategory.

MAJOR POLLUTANT CONTROL PARAMETERS

The following selected parameters are the most important constituents of cereal and wheat starch manufacturing waste waters. Data collected during the preparation of this document, particularly from cereal plants, was limited in most cases to these parameters. Nevertheless, the use of these parameters adequately describes the waste water characteristics from virtually all plants in the industry. BOD5, suspended solids, and pH are, therefore, the parameters selected for effluent limitations guidelines and standards of performance for new sources for these two subcategories.

Biochemical Oxygen Demand (BOD5)

Biochemical oxygen demand (BOD5) is a measure of the oxygen consuming capabilities of organic matter. The BOD5 does not, in itself, cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD5, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are frequently reached where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD5 indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential to keep organisms living and sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in the young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely by suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the total lack of dissolved oxygen due to a high BOD5 can kill all inhabitants of the affected area.

If a high BOD5 is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

Many cereal and wheat starch plants or the municipalities that handle their waste waters routinely measure BOD5 in the plant waste waters. Typical BOD5 levels are moderate to high in the ready-to-eat cereal subcategory, ranging from several hundred to over 2000 mg/l. Wheat starch waste waters are quite high in BOD5, with values ranging from 6,000 to 14,000 mg/l and higher for large plants.

Suspended Solids

Suspended solids include both organic and inorganic materials. These materials may settle out rapidly, and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentrations to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems; and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances that are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and, therefore, decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Suspended solids concentrations are rather low (100 to 400 mg/l) in cereal manufacturing waste waters, but are quite high (5000 to 15,000 mg/l) in wheat starch effluents. Wet cleanup operations that wash product spillage into the sewer account for much of the suspended solids content of cereal waste waters. In wheat starch wastes, very fine starch particles pass through the refining operation and remain in suspension. This starch accounts for much of the organic load in the waste water and is essentially insoluble.

pH

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7.0, the hydrogen and hydroxyl ion concentrations are equal and the water is neutral. If pH values are below 7.0, acid conditions are indicated, while pH values above 7.0 indicate alkaline conditions.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7.0. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

The pH levels of ready-to-eat cereal plant waste waters vary over the production day, but generally average close to 7.0. Wheat starch waste waters tend to be acidic, in the range of 3 to 6. pH is an essential control parameter for treatment of this waste and regulation of the discharges.

OTHER POLLUTANT CONTROL PARAMETERS

Chemical Oxygen Demand (COD)

COD is a chemical measure of the organic content and, hence, oxygen demand of the waste water constituents. As with most food wastes, the COD of cereal and wheat starch wastes is considerably higher than the BOD_5, usually by a factor of 2.0 to 2.5. COD was not specified as a control parameter because of the limited availability of COD data. Due to the lack of data, no definitive relationship between COD and BOD_5 can be established at the present time. The fact that the chemical nature of the organics may differ from plant to plant may preclude the use of a uniform COD standard for each subcategory. Therefore, it was concluded that effluent limitations guidelines and standards of performance should not be based on COD.

Dissolved Solids

In natural waters, the dissolved solids consist mainly of inorganic compounds including calcium, magnesium, sodium, potassium, iron, and manganese and their associated anionic species of carbonates, chlorides, sulfates, phosphates, and possibly nitrates.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved solids, when no better water is available. Such waters are not very palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. Above 5000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with clearness, color, or taste of many finished products. High dissolved solids concentrations also tend to accelerate corrosion.

There are a number of sources of dissolved solids in the cereal and wheat starch subcategories. In cereal manufacturing, these sources include wastes from water treatment, cooling water blow-down, and various processes, particularly cleanup, within the plant. These sources can increase dissolved solids concentrations several hundred to a few thousand mg/l. Most of these dissolved materials are usually of an organic nature. Wheat starch wastes contain high levels of dissolved solids, most of which are probably unrecovered starch and gluten and thus constitute a high dissolved organic load.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development; warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in

organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that would otherwise be lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally to blue-green algae at high temperatures, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the aesthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Cereal plant wastes generally have temperatures ranging from 32 to 43 degrees C (90 to 110 degrees F). Much of the increase in temperature is due to discharge of spent cooling water and the use of hot water in cleanup operations. As mentioned previously, process wastes from shredded cereal cooking range in temperature from 71 to 77 degrees C (160 to 170 degrees F) and can elevate waste water temperatures at plants producing this type of cereal. Temperature levels in wheat starch wastes range from 21 to 27 degrees C (70 to 80 degrees F).

Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently a key element in stimulating excess algae growth.

When a plant population increases sufficiently to become a nuisance, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Excess algae growth can emit bad odors, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1.0 microgram per liter.

Phosphorus levels in ready-to-eat cereal waste waters tend to be quite low. Concentrations in plant effluents may be increased somewhat by the use of detergents in plant cleanup, but levels in the waste streams are generally too low to present a pollutional hazard. Limited data indicate that wheat starch wastes may contain significant phosphorus concentrations, on the order of 100 mg/l. This level may be necessary to achieve good biological waste treatment, in view of the very high BOD_5 concentrations present.

Nitrogen

Total nitrogen levels in ready-to-eat cereal plant waste waters are quite low, ranging from 5 up to 30 mg/l. Based on limited data, wheat starch wastes contain higher nitrogen levels, ranging from 350 to 400 mg/l. As with the phosphorus concentrations, these nitrogen levels based on present evidence are required to achieve effective biological treatment. Addition of nitrogen and phosphorus has been found necessary in effective biological treatment of ready-to-eat cereal manufacturing wastes.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

Since animal feed and hot cereal manufacturing plants generate no process waste waters, there is no need to include these subcategories in a discussion of control and treatment technologies. There has not been a great deal of attention given to either in-plant control or treatment of waste waters within the ready-to-eat cereal industry. Most of the cereal plants in the U.S. discharge medium strength wastes to large municipal systems which are capable of handling the industrial waste loads. Several plants within the subcategory provide screening and some settling of their wastes. One plant provides biological pretreatment, and two others are constructing pretreatment facilities to reduce waste loadings prior to municipal discharge.

Although there has been more attention given to waste treatment within the wheat starch industry, there has not been a great need for development of waste control and treatment technology within this subcategory since there are only a few plants and they all discharge to municipal systems. One plant operates a pretreatment facility and is attempting to develop a complete treatment system. Another plant will soon construct a biological pretreatment facility to reduce its organic waste loads prior to discharge to a small municipal system.

READY-TO-EAT CEREAL MANUFACTURING

Waste Water Characteristics

As detailed in Section V, ready-to-eat cereal plants generally produce moderate volumes of medium to high strength wastes. Higher BOD_5 concentrations result from plants that produce shredded cereals or a high percentage of sugar-coated cereals. Suspended solids concentrations are moderate, generally in the range of 100 to 400 mg/l. Treatment in the industry is limited; one known pretreatment facility and the design criteria for a pretreatment facility presently under construction are discussed in this section.

In-Plant Controls

Since most waste waters from ready-to-eat cereal manufacturing are generated by cleanup operations, it is not anticipated that the raw waste characteristics can be greatly influenced by in-plant controls. Separation and recycling of non-contact cooling waters or increased usage of spent cooling water rather than fresh water for such uses as cleanup would reduce waste volumes, but not waste loadings in terms of kilograms or pounds of pollutant per unit of production. Waste loads could be reduced in some plants if more dry-type cleanup operations, such as sweeping or vacuuming of spillage, were employed in place of wet washing methods.

Treatment Processes

Several plants provide minimal forms of pretreatment for their process wastes prior to discharge to municipal systems. This treatment usually consists of screening and occasionally settling and skimming. Solids collected are either dried and recovered as animal feed or disposed of by landfill.

One plant in the industry presently provides biological pretreatment prior to municipal discharge. The treatment system consists of a 0.51 hectare (1.25 acre) lagoon equipped with mechanical aerators and designed for 30-day detention. Nutrients in the form of ammonia and phosphoric acid are added to the high carbohydrate waste stream. The treatment facility handles all process and sanitary wastes from the plant, including shredded cereal cooking wastes. The facility was designed to handle a flow of 379 cu m/day (0.1 MGD), a BOD5 loading of 1135 kg/day (2500 lbs/day), and a suspended solids loading of 272 kg/day (600 lbs/day). Average influent and effluent characteristics over the past year are given below:

	Average Influent mg/l	Average Effluent mg/l
BOD5	2500	260
COD	4300	870
Suspended Solids	300	935
Total Solids	3000	2500
pH	6.9	7.1

The high effluent suspended solids concentrations reflect the production of biological solids dung aeration. These figures are averages over a year's time and do not reflect seasonal fluctuations which occur. During the warmer months, May through September, effluent BOD5 values vary from 100 to 200 mg/l, and suspended solids vary from 550 to 800 mg/1. Corresponding BOD5 and suspended solids removals range from 92-96 percent, and zero percent. In color weather, BOD5, concentrations increase to the 300 to 450 mg/l range. Similarly, suspended solids during winter vary from 900 to 1200 mg/l. BOD5 and suspended solids removals under winter conditicns ranged from 81 to 88 percent, and zero percent. Results of a sampling program conducted during the winter as a part of this study indicated BOD5 removals of 81 to 83 percent and an average effluent BOD5 of 450 mg/l. The addition of a final clarifier is anticipated to lower the suspended solids levels within municipal ordinance limits.

A second pretreatment facility is currently under construction that will handle combined process and sanitary wastes from a small ready-to-eat cereal plant. Presently the plant's total waste discharge has an average BOD5 concentration of 600 mg/l and an average suspended solids level of 175 mg/l. The facility will consist of two aerated lagoons in series with nutrient addition and provisions for recycling between the two lagoons. Design is based on an average flow of 284 cu m/day (75,000 gpd) and an average BOD5 loading of 408 kg/day (900 lbs/day). Anticipated effluent quality is shown below:

	mg/l	kg/day	lb/day	Percentage Removal
BOD5	200	41	90	88
Suspended solids	200	41	90	88
pH	7.5-9.0			

The municipal sanitary system will continue to handle the treated effluent.

WHEAT STARCH AND GLUTEN MANUFACTURING

Waste Water Characteristics

Waste waters from wheat starch and gluten manufacturing operations, as described in detail in Section V, are high in organic strength and suspended solids. Flows are moderate, in the range of 265 to 570 cu m/day (70,000 to 160,000 gpd). pH values are quite low, and phosphorus and nitrogen levels tend to be high. All plants in the U.S. discharge to municipal systems except one which uses its starch process wastes in a distillery operation and then discharges directly to receiving waters. Extensive treatment facilities for the distillery waste are under construction.

In-Plant Controls

It is doubtful that any major reductions in waste loads can be achieved through in-plant controls or modifications at existing starch plants. Since product yield is economically crucial to wheat starch and gluten plants, most manufacturers already attempt to maximize solids recovery in the starch refining operations by thickening and centrifugation. Wash down water only amounts to between 5 and 10 percent of the total process waste water contribution.

Two new plants will commence full scale production of wheat starch and gluten in the near future, and both anticipate the generation of much lower volumes of waste water than existing plants. One plant will accomplish this by drastically reducing water requirements, while the other hopes to employ a total recycle system. These plants are constructed primarily for recovery of proteinaceous material from the wheat raw material.

and are suspected to employ methods and processes which may be quite uncharacteristic as compared to historical processes.

Treatment Technology

Pretreatment operations and pilot plant studies substantially support that the process waste water from wheat starch and gluten manufacturing is readily biodegradable and treatable by conventional biological treatment systems.

One pretreatment facility is in operation in the wheat starch industry, reducing the organic strength of the starch waste prior to municipal system disposal. The facility handles 530 cu m/day (140,000 gpd) of high-strength wastes from a medium sized starch and gluten plant. The treatment sequence consists of a steel mixing tank where the waste is heated to 29°C 85°F, three anaerobic filters operated in parallel, and a chlorine contact tank. Ammonia gas and sodium bicarbonate are continuously added in the mixing tank to stabilize the pH between 6.5 and 7.5. The treated waste can be recycled at rates from 0 to 100 percent. That portion that is not recycled enters the chlorine contact tank, where chlorine is introduced for control of odor and potential sewer corrosion by reducing hydrogen sulfide levels. Waste gas produced by the filters contains sufficient methane to be combusted readily in a gas burner, and is a potential energy source.

A comparison of average influent and effluent characteristics during seven months of operation is shown below:

	Average Influent			Average Effluent		
	mg/l	kg/day	lb/day	mg/l	kg/day	lb/day
BOD_5	6500	3175	7000	2940	1406	3100
COD	8800	4309	9500	3170	1542	3400
Suspended Solids	2650	1270	2800	1460	703	1550

This data indicates average reductions of 55, 64, and 45 percent for BOD_5, CCD, and suspended solids, respectively. More recent plant sampling indicates COD removals ranging from 18 to 59 percent and averaging 33 percent over the past year, however.

One wheat starch plant has been experimenting with a full scale complete treatment system for some time. The system employs a vapor recompression evaporator which, in theory, should effect 98 to 99 percent solids recovery. The plant has not been able to operate the system successfully on a continuous basis. The plant has been operated successfully for intermittant periods of a week or more, and experimental efforts to the process are continuing. This type of treatment system definitely cannot yet be considered as demonstrated technology at the present time.

One other plant in the wheat starch industry is planning to construct a pretreatment facility. The facility will incorporate extended aeration and final clarification after which the wastes will be discharged to the municipal system. A chemical feed unit will be capable of adding lime and alum to the wastes either prior to or after aeration. Design flow is 409 cu m/day (108,000 gpd), and the detention time will be 5.0 days in the aeration unit. Effluent BOD_5 levels are estimated at 190 mg/l, representing a 95 percent reduction. It should be emphasized that the attainment of this effluent level has not been demonstrated in a full scale treatment facility.

Extensive pilot plant studies were run on the starch waste prior to design of the above pretreatment facility. The pilot system included a 15,140 liter (4000 gallon) aeration and settling tank, to which were later added a 1325 liter (350 gallon) rotating biological disc and a 3217 liter (850 gallon) polishing pond. The pilot system handled 2.7 cu m/day (720 gpd) of waste over a five-month period. During that time, BOD_5 reductions averaged 86 percent through the aeration unit alone, 88 percent through the aeration unit and disc, and 98 percent through the entire system including polishing pond. Average effluent BOD_5 concentrations were 680, 578, and 84 mg/l, respectively, from the three components of the pilot treatment system.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

This chapter presents detailed cost estimates for the various treatment alternatives and the rationale used in developing this information. Data have been developed for investment, capital, operating and maintenance, depreciation, and energy costs using various sources, including contractor's files, literature references 6 and 9, and information from individual plants within the industry. The cost data from industry were quite limited and, therefore, the cost estimates are based principally on data developed by the contractor and the references cited.

REPRESENTATIVE PLANTS

Because of the variations in plant operation, waste water characteristics, and treatment systems, it was impractical to select one existing plant as typical of each of the industry subcategories. Therefore, hypothetical plants were developed (or synthesized) for purposes of developing cost data.

In the ready-to-eat cereal subcategory, there is such a wide range of plant production capacities that it was decided to choose three hypothetical plants of different sizes. The plant capacities chosen were 90,700 kg/day (200,000 lb/day), 226,800 kg/day (500,000 lb/day), and 544,300 kg/day (1,200,000 lb/day). Although the waste water characteristics of ready-to-eat cereal plants vary considerably, there is no apparent correlation with plant capacity, as shown in Figures 14 and 15 in Section V of this report. Thus, flow and waste water characteristics were selected to reflect average values for existing plants in the industry as reported in Section V.

The seven wheat starch and gluten plants exhibit a fairly narrow range of plant capacities and waste water characteristics. A hypothetical plant with an average daily raw material capacity of 45,360 kg (100,000 lbs) of flour was chosen for cost estimating purposes. Since flow and waste water characteristics are fairly uniform for the industry, average values for existing plants as reported in Section V were utilized.

TERMINOLOGY

Investment Costs

Investment costs are defined as the capital expenditures required to bring the treatment or control technology into operation. Included, as appropriate, are the costs of excavation, concrete, structural steel, mechanical and electrical equipment installed, and piping. An amount equal to 15 percent of the total of the above is added to cover engineering design services, construction supervision, and related costs. Because most of the control technologies involve external, end-of-plant systems, no cost is included for lost time due to installation. It is believed that the interruptions required for installation of control technologies can be coordinated with normal plant operating schedules. The cost of additional land required for treatment facilities is included, using an estimating figure of $10,000 per acre.

Capital Costs

The capital costs are calculated, in all cases, as 8 percent of the total investment costs. Consultations with representatives of industry and the financial community lead to the conclusion that, with the limited data available, this estimate is reasonable for this industry.

Depreciation

Straight-line depreciation for 20 years, or 5 percent of the total investment cost, is used in all cases.

Operation and Maintenance Costs

Operation and maintenance costs include labor, materials, solid waste disposal, effluent monitoring, added administrative expense, taxes and insurance. When the control technology involves water recycling, a credit of $0.30 per 1,000 gallons is applied to reduce the operation and maintenance costs. Manpower requirements are based upon information found in References 6 and 9. A total salary cost of $10 per man-hour is used in all cases.

Energy and Power Costs

Power costs are estimated on the basis of $0.025 per kilowatt-hour.

Annual costs are defined as the total of capital costs, depreciation, operation and maintenance, and energy and power costs as accrued on an annual basis.

COST INFORMATION

The investment and annual costs, as defined above, associated with the alternative waste treatment control technologies are presented below. In addition, a description of each of the control technologies is provided, together with the effluent quality expected from the application of these technologies. All costs are reported in terms of August, 1971 dollars.

Ready-to-Eat Cereal Manufacturing

As a basis for developing control and treatment cost information, three different ready-to-eat cereal plants were synthesized to cover the broad range of plant capacities within the industry.

The waste water characteristics used to describe these plants reflect actual industry practice based on average data received from existing plants. The values employed are as follows:

Flow	2.7 liters/lb of cereal (0.7 gal/lb)
BOD5	6.6 kg/kkg (lbs/1000 lbs) or 1130 mg/l
Suspended Solids	1.4 kg/kkg (lbs/1000 lbs) or 240 mg/l

The production and waste water characteristics of the three hypothetical cereal plants are summarized below:

Plant A:		
Production	90,700 kg/day	(200,000 lb/day)
Flow	529 cu m/day	(140,000 gpd)
BOD5	635 kg/day	(1400 lb/day
Suspended Solids	127 kg/day	(280 lb/day)
Plant B:		
Production	226,800 kg/day	(500,000 lb/day)
Flow	1325 cu m;day	(350,000 gpd)
BOD	1588 kg/day	(3500 lb/day)
Suspended Solids	318 kg/day	(700 lb/day)
Plant C:		
Production	544,300 kg/day	(1,200,000 lb/day)
Flow	3179 cu m/day	(840,000 gpd)
BOD5	3810 kg/day	(8400 lb/day)
Suspended Solids	762 kg/day	(1680 lb/day)

A number of alternative treatment systems are proposed below to handle the waste waters from these plants. These systems are presented in terms of increasing effluent quality. The investment and annual cost information for each alternative, and the resultant effluent qualities are presented in Tables 8, 9, and 10 for the three hypothetical ready-to-eat cereal plants.

Table 8

Water Effluent Treatment Costs
Small Ready-to-Eat Cereal Plant
(90,700 kg/day)

Alternative Treatment or Control Technologies:	A	B	C	D	E	F
	(Thousands of Dollars)					
Investment Costs	$448.9	527.9	629.9	563.3	777.5	960.7
Annual Costs:						
Capital Costs	35.9	42.2	50.4	45.1	62.2	76.9
Depreciation	22.4	26.4	31.5	28.2	38.9	48.0
Operating and Maintenance Costs	45.2	46.4	47.9	53.4	68.4	86.2
Energy and Power Costs	10.6	11.6	11.6	12.6	16.6	22.6
Total Annual Cost	114.1	126.6	141.4	139.3	186.1	233.7

Effluent Quality:

Parameters	Units	Raw Waste Load	Resulting Effluent Levels					
BOD	kg/kkg	7.0	0.58	0.44	0.18-0.35	0.12-0.18	0.03	0.03
Suspended Solids	kg/kkg	1.4	0.58	0.44	0.18-0.35	0.06-0.12	0.03	0.03
BOD	mg/l	1200	100	75	30-60	20-30	5	5
Suspended Solids	mg/l	240	100	75	30-60	10-20	5	5
Dissolved Solids	mg/l	-	-	-	-	-	-	500

Table 9

Water Effluent Treatment Costs
Medium-Sized Ready-to-Eat Cereal Plant
(226,800 kg/day)

Alternative Treatment or Control Technologies	(Thousands of Dollars) A	B	C	D	E	F
Investment Costs	$686.4	811.8	887.2	875.3	1247.3	1613.5
Annual Costs:						
Capital Costs	54.9	64.9	71.0	70.0	99.8	129.1
Depreciation	34.3	40.6	44.4	43.8	62.4	80.7
Operating and Maintenance Costs	67.9	70.0	71.8	83.9	109.9	142.1
Energy and Power Costs	22.0	23.7	23.7	25.4	32.3	42.7
Total Annual Cost	179.1	199.2	210.9	223.1	304.4	394.6

Effluent Quality:

Parameters	Units	Raw Waste Load	Resulting Effluent Levels					
BOD	kg/kkg	7.0	0.58	0.44	0.18-0.35	0.12-0.18	0.03	0.03
Suspended Solids	kg/kkg	1.4	0.58	0.44	0.18-0.35	0.06-0.12	0.03	0.03
BOD	mg/l	1200	100	75	30-60	20-30	5	5
Suspended Solids	mg/l	240	100	75	30-60	10-20	5	5
Dissolved Solids	mg/l	-	-	-	-	-	-	500

Table 10

Water Effluent Treatment Costs
Large Ready-to-Eat Cereal Plant
(544,300 kg/day)

Alternative Treatment or Control Technologies	(Thousands of Dollars) A	B	C	D	E	F
Investment Costs	$1062.1	1277.5	1441.5	1411.7	2040.9	2785.5
Annual Costs:						
Capital Costs	85.0	102.2	115.3	112.9	163.3	222.8
Depreciation	53.1	63.9	72.1	70.6	102.0	139.3
Operating and Maintenance Costs	96.7	100.3	102.7	123.2	167.1	237.3
Energy and Power Costs	44.9	47.8	47.8	50.7	62.4	80.0
Total Annual Cost	279.7	314.2	337.9	359.9	494.8	679.4

Effluent Quality:

Parameters	Units	Raw Waste Load	Resulting Effluent Levels					
BOD	kg/kkg	7.0	0.58	0.44	0.18-0.35	0.12-0.18	0.03	0.03
Suspended Solids	kg/kkg	1.4	0.58	0.44	0.18-0.35	0.06-0.12	0.03	0.03
BOD	mg/l	1200	100	75	30-60	20-30	5	5
Suspended Solids	mg/l	240	100	75	30-60	10-20	5	5
Dissolved Solids	mg/l	-	-	-	-	-	-	500

Figure 24 graphically depicts the investment costs of the six treatment alternatives as a function of cereal plant capacity. The specific treatment technologies are described in the following paragraphs.

Alternative A -- Activated Sludge

This alternative provides for grit removal, nutrient addition, primary sedimentation, complete-mix activated sludge, secondary sedimentation, chlorination, and solids dewatering. The treatment system does not include equalization. Effluent BOD_5 and suspended solids concentrations are expected to be about 100 mg/l. In terms of plant production, these values correspond to 0.58 kg/kkg (lbs/1000 lbs) for BOD_5 and for suspended solids.

Investment Costs:	Plant A	$ 448.900
	Plant B	$ 686,400
	Plant C	$1,062,100
Total Annual Costs:	Plant A	$ 114,100
	Plant B	$ 179.100
	Plant C	$ 279.700

Reduction Benefits: BOD_5 reduction of 92 percent and suspended solids reduction of 59 percent.

Alternative B -- Equalization and Activated Sludge

Alternative B includes an aerated equalization step with 18-hour detention ahead of the complete-mix activated sludge system and associated chemical feed, sedimentation, and sludge dewatering facilities outlined in Alternative A. Estimated BOD_5 and suspended solids levels are 75 mg/l for each parameter. This value corresponds to 0.44 kg/kkg (lbs/1000 lbs) of BOD_5 and suspended solids.

Investment Costs:	Plant A	$ 527,900
	Plant B	$ 811,800
	Plant C	$1,277,500
Total Annual Costs:	Plant A	$ 126,600
	Plant B	$ 199,200
	Plant C	$ 314.200

Reduction Benefits: BOD_5 reduction of 94 percent and suspended solids reduction of 69 percent.

Alternative C -- Equalization, Activated Sludge, and Stabilization Basin

This alternative adds a stabilization basin or lagoon after the secondary sedimentation step of the preceding treatment system, Alternative B. This lagoon will provide 10-day detention for

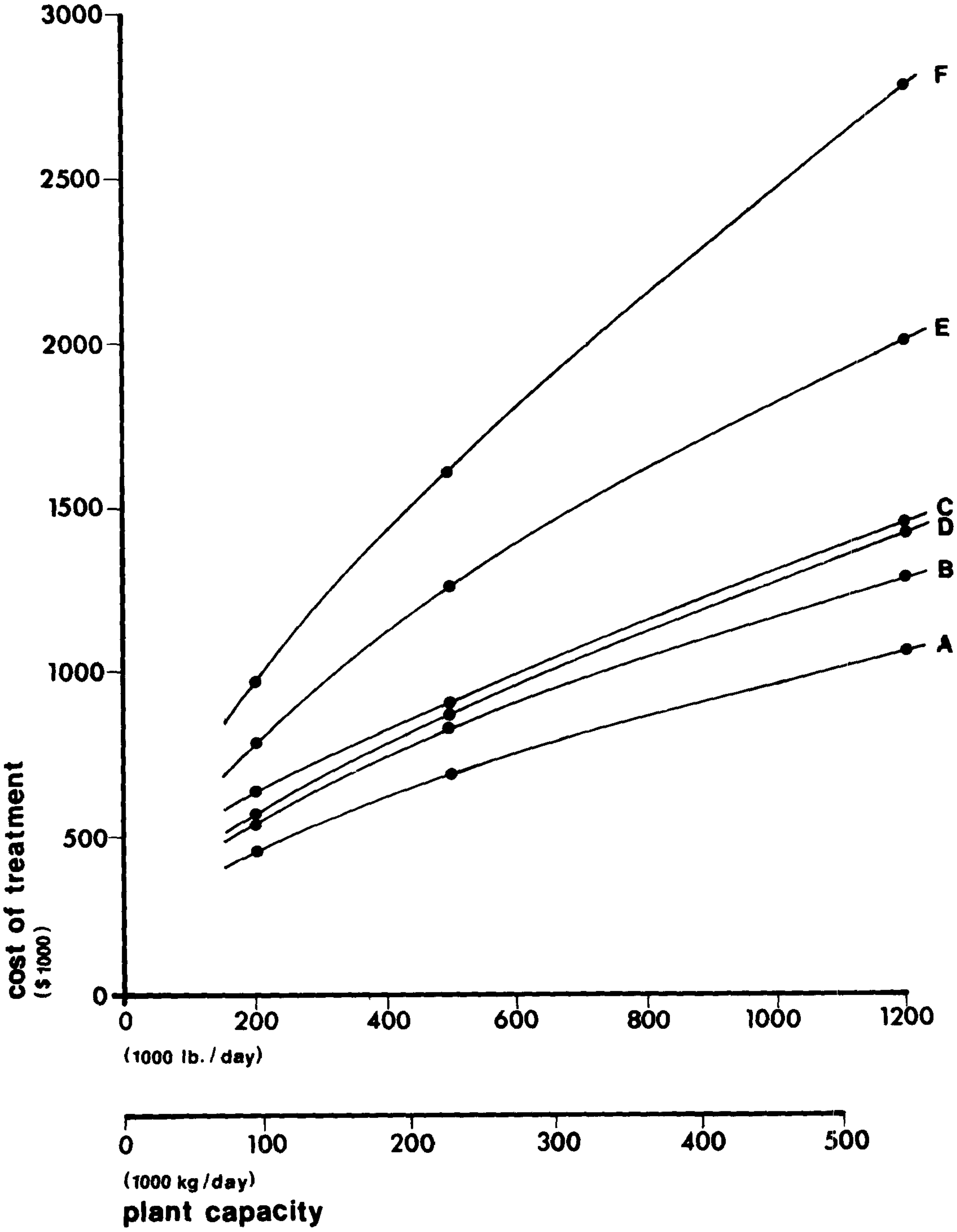


FIGURE 24
COST OF TREATMENT ALTERNATIVES VERSUS
CEREAL PLANT CAPACITY

stabilizing the remaining BOD5 and reducing the suspended solids concentration. Effluent levels of 30 to 60 mg/l of BOD5 and suspended solids are expected from Alternative C. Resultant waste loads per unit of production will be 0.18 to 0.35 kg/kkg (lbs/1000 lbs) for both BOD5 and suspended solids.

Investment Costs:	Plant A	$ 629,900
	Plant B	$ 887,200
	Plant C	$1,441,500
Total Annual Costs:	Plant A	$ 141,400
	Plant B	$ 210,900
	Plant C	$ 337,900

Reduction Benefits: BOD5 reduction of 95 to 97.5 percent and suspended solids reduction of 75 to 87 percent.

Alternative D -- Equalization, Activated Sludge, and Deep Bed Filtration

Alternative D includes deep bed filtration with the treatment steps proposed in Alternative B. BOD5 concentrations are anticipated to be 20 to 30 mg/l in the effluent and suspended solids are expected to be 10 to 20 mg/l. These concentrations correspond to effluent waste loads of 0.12 to 0.18 kg/kkg (lbs/1000 lbs) of BOD5 and 0.06 to 0.12 kg/kkg (lbs/1000 lbs) of suspended solids.

Investment Costs:	Plant A	$ 563,300
	Plant B	$ 875,300
	Plant C	$1,411,700
Total Annual Costs:	Plant A	$ 139,300
	Plant B	$ 223,100
Plant C	Plant C	$ 359,900

Reduction Benefits: BOD5 and suspended solids reductions of 97.4 to 98.3 percent and 91.4 to 95.7 percent, respectively.

Alternative E -- Equalization, Activated Sludge, Deep Bed Filtration, and Activated Carbon Filtration

In Alternative E, activated carbon filtration is added to the previous treatment scheme. The effluent concentrations are estimated to be 5 mg/l for both BOD5 and suspended solids. This level corresponds to waste loads of 0.03 kg/kkg (lbs/1000 lbs) for both BOD5 and suspended solids.

Investment Costs:	Plant A	$ 777,500
	Plant B	$1,247,300
	Plant C	$2,040,900
Total Annual Costs:	Plant A	$ 186,100

	Plant B	$ 304,400
	Plant C	$ 494,800

Reduction Benefits: BOD5 and suspended solids reductions of 99.6 and 97.9 percent, respectively. The effluent should be suitable for partial reuse or recycle.

Alternative F -- Equalization, Activated Sludge, Deep Bed Filtration, Activated Carbon Filtration, and Reverse Osmosis

This alternative includes reverse osmosis to reduce the total dissolved solids. Effluent levels will be comparable to those anticipated in Alternative E, but with a maximum dissolved solids concentration of 500 mg/l.

Investment Costs:	Plant A	$ 960,700
	Plant B	$1,613,500
	Plant C	$2,785,500
Total Annual Costs:	Plant A	$ 233,700
	Plant B	$ 394,600
	Plant c	$ 679,400

Reduction Benefits: BOD5 and suspended solids reductions equal to those expected in Alternative E, i.e., 99.6 and 97.9 percent, respectively. The effluent should be suitable for complete recycle.

Wheat Starch and Gluten Manufacturing

A hypothetical wheat starch and gluten plant of moderate size, i.e., 45,360 kg/day (100,000 lbs/day) of wheat flour input, was selected as a basis for developing cost data. The values of the waste water characteristics used to describe this plant reflect actual industry practice, as follows:

Flow	4.5 cu m/kkg (1.2 gal/lb) of flour
BOD5	90.7 kg/kkg (lbs/1000 lbs)
Suspended Solids	75.2 kg/kkg (lbs/1000 lbs)

The production and waste water characteristics of the hypothetical plant are summarized below:

Production	45,360 kg/day (100,000 lbs/day)
Flow	454 cu m/day (120,000 gpd)
BOD5	4114 kg/day (9070 lbs/day) or 9057 mg/l
Suspended Solids	3411 kg/day (7520 .bs/day) or 7509 mg/l

Proposed alternative treatment systems are described below. The investment and annual cost information for each alternative and the resultant effluent qualities are presented in Table 11.

Alternative A -- Activated Sludge

This first alternative includes pH neutralization, primary sedimentation, complete-mix activated sludge, secondary sedimentation, effluent chlorination, and sludge dewatering. Anticipated effluent levels are 200 to 400 mg/l of BOD_5 and 100 to 400 mg/l of suspended solids. These levels correspond to waste loads of 2.0 to 4.0 kg/kkg (lbs/1000 lbs) of BOD_5 and 1.0 to 4.0 kg/kkg (lbs/1000 lbs) of suspended solids.

Investment Cost: $ 892,500

Total Annual Cost: $ 240,700

Reduction Benefits: BOD_5 reduction of 95.6 to 97.8 percent, suspended solids reduction of 94.7 to 98.7 percent.

Alternative B -- Equalization and Activated Sludge

This alternative includes 18 hours of aerated equalization ahead of the complete-mix activated sludge system described in Alternative A. Average effluent levels are estimated at 150 to 300 mg/l for BOD_5 and 100 to 300 mg/l for suspended solids. These concentrations represent waste loads of 1.5 to 3.0 kg/kkg (lbs/1000 lbs) for BOD_5 and 1.0 to 3.0 kg/kkg (lbs/1000 lbs) for suspended solids.

Investment Cost: Incremental costs are approximately $71,800 over Alternative A for a total cost of $964,300.

Total Annual Cost: Incremental costs are approximately $11,500 over Alternative A for a total annual cost of $252,200.

Reduction Benefits: BOD_5 reduction of 96.7 to 98.3 percent and suspended solids reduction of 96.0 to 98.7 percent.

Alternative C -- Equalization, Activated Sludge, and Stabilization Lagoon

Alternative C adds a stabilization basin with 10-day retention to the preceding treatment system. BOD_5 levels in the effluent are anticipated to be 100 to 150 mg/l, and suspended solids levels of 75 to 150 mg/l are expected. These values correspond to 1.0 to 1.5 kg/kkg (lbs/1000 lbs) for BOD_5 and 0.75 to 1.4 kg/kkg (lbs/1000 lbs) for suspended solids.

Table 11

Water Effluent Treatment Costs
Typical Wheat Starch and Gluten Plant

Alternative Treatment or Control Technologies:	(Thousands of Dollars) A	B	C	D	E	F
Investment Costs	$892.5	964.3	1014.6	996.0	1191.7	1350.4
Annual Costs:						
Capital Costs	71.4	77.1	81.2	79.7	95.3	108.0
Depreciation	44.6	48.2	50.7	49.8	59.6	67.5
Operating and Maintenance Costs	86.3	87.5	88.9	94.1	107.9	127.6
Energy and Power Costs	38.4	39.4	39.4	40.4	44.4	50.4
Total Annual Cost	240.7	252.2	260.2	264.0	307.2	353.5

Effluent Quality:

Parameters	Units	Raw Waste Load	Resulting Effluent Levels					
BOD	kg/kkg	90.7	2.0-4.0	1.5-3.0	1.0-1.5	0.3-0.5	0.05-0.15	0.05
Suspended Solids	kg/kkg	75.2	1.0-4.0	1.0-3.0	0.75-1.5	0.2-0.3	0.05-0.15	0.05
BOD	mg/l	9070	200-400	150-300	100-150	30-50	5-15	5
Suspended Solids	mg/l	7520	100-400	100-300	75-150	20-30	5-15	5
Dissolved Solids	mg/l	-	-	-	-	-	-	500

Investment Costs: Incremental costs of $50,300 over Alternative B for a total cost of $1,014,600.

Total Annual Costs: Incremental costs of $8000 over Alternative B for a total cost of $260,200.

Reduction Benefits: BOD5 reduction of 98.3 to 98.9 percent, suspended solids reduction of 98 to 99 percent.

Alternative D -- Equalization, Activated Sludge, and Deep Bed Filtration

In this proposed system, deep bed filtration is added to the treatment system outlined in Alternative B. The stabilization lagoon is deleted. BOD5 and suspended solids effluent levels of 30 to 50 mg/l and 20 to 30 mg/l, respectively, are anticipated These concentrations represent 0.3 to 0.5 kg/kkg (lbs/1000 lbs) of BOD5 and 0.2 to 0.3 kg/kkg (lbs/1000 lbs) of suspended solids.

Investment Costs: Incremental costs of $31,700 over Alternative B for a total cost of $996,000.

Total Annual Costs: Incremental costs of $11,800 over Alternative B for a total cost of $264,000.

Reduction Benefits: BOD5 reduction of 99.4 to 99.7 percent, suspended solids reduction of 99.6 to 99.7 percent.

Alternative E -- Equalization, Activated Sludge, Deep Bed Filtration, and Activated Carbon Filtration

For Alternative E, activated carbon filtration is added to the previous treatment system in Alternative D. Effluent concentrations of 5 to 15 mg/l are expected for both BOD5 and suspended solids. These levels correspond to 0.05 to 0.15 kg/kkg (lbs/1000 lbs) for both parameters.

Investment Costs: Incremental costs of $195,700 over Alternative D for a total cost of $1,191,700.

Total Annual Costs: Incremental costs of $43,200 over Alternative D for a total cost of $307,200.

Reduction Benefits: BOD5 and suspended solids reductions of 99.8 to 99.9 percent. The effluent should be suitable for at least partial recycle.

Alternative F -- Equalization, Activated Sludge, Deep Bed Filtration, Activated Carbon Filtration, and Reverse Osmosis

This alternative includes reverse osmosis to reduce the total dissolved solids. Effluent levels of 5 mg/l for both BOD5 and suspended solids are anticipated, with a maximum dissolved solids concentration of 500 mg/l.

Investment Costs: Incremental costs of $158,700 over Alternative E for a total cost of $1,350,400.

Total Annual Costs: Incremental costs of $46,300 over Alternative E for a total cost of $353,500.

Reduction Benefits: BOD5 and suspended solids reductions of 99.9 percent. The effluent should be suitable for complete recycle.

NON-WATER QUALITY ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

Air Pollution Control

With the proper operation of the types of biological treatment systems presented earlier in this section, no significant air pollution problems should develop. Since the waste waters from the breakfast cereal and wheat starch segments of the grain milling industry have a high organic content, however, there is always the potential for odors. Various methods of odor control are available and have been extensively applied in the biological treatment of waste water. These methods include aeration, chorination, lime and other chemical addition, odor masking agents, and modified operating procedures. Odors as they may result from biological treatment of wheat starch and ready-to-eat cereal waste are technological control. No significant odors would result above existing conditions. Care should be taken in the section, design, and operation of biological treatment systems to prevent anaerobic conditions and thereby eliminate possible odor problems.

Solid Waste Disposal

The treatment of waste waters from cereal and wheat starch plants will give rise to substantial quantities of solid wastes, particularly biological solids from activated sludge or comparable systems. Conventional methods for handling biological solids are applicable to these wastes such as digestion, dewatering, landfill, or incineration. Disposal of this solid material as not to contribute to pollution of ground or surface waters is necessary.

Energy Requirements

The treatment technologies presently in use or proposed in this document do not require any processes with exceedingly high energy requirements. Power will be needed for aeration, pumping, centrifugation, and other unit operations. These requirements, generally, are a direct function of the volume treated and the waste strength. Thus, the greatest energy demands will occur in large ready-tc-eat cereal plants.

For the hypothetical treatment systems described previously in this section, the power requirements are in the range of 75 to 370 kw (100 to 500 hp) for cereal plants and 150 to 220 kw (200 to 300 hp) for wheat starch plants. This level of demand is generally less than one percent of the total energy requirements of a typical ready-to-eat cereal or wheat starch plant. It was concluded that the energy needs for achieving needed waste water treatment constitute only a small portion of the energy demands of the entire industry, and these added demands can readily be accommodated by purchased and in-house power sources.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved by July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the best practicable control technology currently available. The best practicable control technology currently available is generally based upon the averages of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category or subcategory. This average is not based on a broad range of plants within the grain milling industry, but on performance levels achieved by a combination of plants showing exemplary in-house performance and those with exemplary end-of-pipe control technology.

Consideration must also be given to:

a. the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the processes employed and product mix;

d. the engineering aspects of the application of various types of control techniques;

e. process changes; and

f. non-water quality environmental impact (including energy requirements).

Also, best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process, but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry. A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction of installation of the control facilities. However, where pollution control and abatement technology as presently applied in an industry is judged inadequate, effluent limitation guidelines for the industry category or subcategory may be based upon the transfer of technology to reasonably achieve the effluent limitations and standards as established.

In establishing the level of technology and effluent limitation guidelines for the breakfast cereal, and wheat starch segment of the point source category, it is recognized that present plants, with only few exceptions, discharge the untreated or partially treated waste water to municipal sewage systems. Therefore, since no direct discharge to navigable waters result from the operation of industry-owned treatment measures, effluent guidelines would have no direct application in these instances. However, the need for effluent guidelines for the ready-to-eat cereal and wheat starch manufacturing subcategories is evident where any plant modifications or changes in existing practices would result in discharge of process waste waters directly to navigable waters.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based on the information presented in Sections III through VIII of this report, it has been determined that the effluent reductions attainable through the application of the best practicable control technology currently available for these subcategories are those presented in Table 12. These values represent the maximum allowable waste water effluent loading for any 30 consecutive calendar days. Excursions above these levels are to be permitted with a maximum daily average of 3.0 times the average 30-day values listed below. The variances for maximum daily average are necessary to consider variation in production, plant operation, shock waste loads, and variable waste contributions.

Table 12

Effluent Reduction Attainable Through the Application of Best Practicable Control Technology Currently Available*

Subcategory	BOD5 kg/kkg (lbs/1000 lbs)	Suspended Solids kg/kkg (lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process waste water pollutants		
Hot cereal manufacturing	No discharge of process waste water pollutants		
Ready-to-eat cereal manufacturing	0.40	0.40	6-9
Wheat starch and gluten manufacturing	2.0	2.0	6-9

*Maximum average of daily values for any period of 30 consecutive days.

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The best practicable control technology currently available for the subcategories of the grain milling industry covered in this document generally consists of equalization, biological treatment (e.g. activated sludge), and effective solids separation. The specific technological means available to implement the specified effluent limitations are presented below for each subcategory.

Animal Feed Manufacturing

Animal feed manufacturing requires little process water and generates no waste waters. Hence, the effluent limitation of no discharge of process wastes is already being met.

Hot Cereal Manufacturing

The manufacture of hot cereals generates no process wastes. Thus, the effluent limitation of no discharge of process wastes is already being met.

Ready-to-Eat Cereal Manufacturing

Waste waters from ready-to-eat cereal plants are generated primarily in cleanup operations. Although waste volumes can be reduced by in-plant modifications, substantial reduction in the waste load from the plant is not an immediate possibility and treatment of the entire waste stream is necessary. Treatment includes:

1. Collection and equalization of flow
2. Primary sedimentation
3. Nutrient addition
4. Biological treatment using activated sludge or a comparable system
5. Secondary sedimentation.
6. Additional biological treatment and/or solids removal

Wheat Starch and Gluten Manufacturing

Wheat starch manufacturing plants generate moderate volumes of high strength waste waters. Substantial reductions in the total waste load by means of in-plant modifications are not presently practical under present manufacturing methods, and treatment of the entire waste stream is required as follows to meet the effluent limitations:

1. Collection and equalization of flow

2. pH neutralization

3. Primary sedimentation

4. Biological treatment using activated sludge or a comparable system

5. Final separation of solids by sedimentation prior to discharge. Addition filtration may be required or desirable.

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Animal Feed Manufacturing

Since no process waste waters are generated in the manufacture of animal feed, an effluent limitation of no discharge is specified.

Hot Cereal Manufacturing

As with animal feed manufacturing, no waste waters are generated in the manufacture of hot cereal, and again an effluent limitation of no discharge is specified.

Ready-to-Eat Cereal Manufacturing

Cost of Application

Data developed on the cost of applying various treatment technologies are presented in Section VIII. Costs were developed for three ready-to-eat cereal plants of different sizes. For a small plant producing 90,700 kg/day (200,000 lbs/day), the investment cost for implementing the best practicable control technology currently available is about $527,900 and the total annual cost is $126,600. For a medium sized plant producing 226,800 kg/day (500,000 lbs/day), the investment cost is $811,800 and the total annual cost is $199,200. For a large plant producing 544,300 kg/day (1,200,000 lbs/day), the investment cost is $1,277,500 and the total annual cost is $314,200.

Age and Size of Production Facilities

The plants in this subcategory range in age from four to over 70 years. The chronological age of the original buildings, however, does not accurately reflect the degree of modernization of the production facilities. Periodic changes in the types of cereal produced frequently involve new production methods and equipment. As a result, it is not possible to differentiate between the basic production operations at the various plants on the basis of age.

Similarly, waste water characteristics from the ready-to-eat cereal plants cannot be classified according to plant age. Of the newer plants, several generate low raw waste loads in terms of BOD_5 and suspended solids per unit of product and several yield rather high waste loads. At the same time, several older plants have low raw waste loads. The data graphically presented in Section V clearly demonstrate the absence of any practicable and reliable correlation based on plant age. Accordingly, it is concluded that the age of the plant is not a direct factor in determining the best practicable control technology currently available.

The size of the plant does have a direct influence as expected on the total amounts of contaminants discharged. In general, the larger the plant the greater the waste load. The effluent limitations presented herein have been developed in terms of unit of finished product, i.e., kg/kkg or lbs/1000 lbs of cereal, in order to reflect the influence of plant size. The control technologies discussed in Section VIII, however, are applicable to all plants regardless of size.

Production Processes

Although the manufacturing processes employed in ready-to-eat cereal plants vary depending on the type of cereal being produced, the basic unit processes are standard across the industry. These unit processes, as discussed in Section IV, include various combinations of mixing, cooking, extrusion, flaking, shredding, puffing, toasting, and packaging. Production processes within the industry do not provide a basis for subcategorization, nor are they a factor in determining the best practicable control technology currently available.

Product Mix

As mentioned previously in describing the ready-to-eat cereal industry, a wide variety of different types of cereal is produced at the various plants throughout the country. Furthermore, the product mix at a given plant may vary significantly on a monthly, weekly, and even daily basis. Attempts were made to correlate raw waste loads with type of cereal produced, such as flaked, puffed, extruded, coated, and non-coated. The available data did not indicate a correlation between waste loads and variation in product mix. One possible relationship was indicated, that being the variation of organic waste load with the percentage of cereals being sugar-coated, but this relationship could not be quantitatively defined and in practice would be administratively difficult to interpret. There is no evidence to suggest that the waste waters generated from any specific cereal manufacturing process so affect the character of the total plant waste stream as to substantially reduce the ability of the plant to implement the best practicable control technology currently available.

Engineering Aspects of Application

The engineering feasibility of achieving the effluent limitations using the technology discussed has been examined. None of the ready-to-eat cereal plants provide extensive waste water treatment with discharge directly to the receiving waters. The best practicable control technology currently available does not represent current practice of any cereal plant. All plants presently discharge their process waste water, with or without partial treatment, to municipal sewage systems with one exception. The one plant now discharging directly to receiving waters anticipates connection to a municipal sewage system in the near future. The availability of municipal systems has not necessitated the development and the application of available treatment measures for specific use in the ready-to-eat cereal industry. The technology as presently demonstrated in the industry is inadequate, and transfer of technology for similar wastes is appropriate. The effectiveness of these technologies for treatment of ready-to-eat cereal waste has been satisfactorily indicated through pilot plant and prototype operations as described in Section VII of this document. Data from one pretreatment plant clearly indicate that this type of waste water is amenable to biological treatment. Accordingly, the treatment technology recommended is considered to be a practicable means for achieving the specific effluent limitations. The treatment technology is readily available. On an overall industry basis, these effluent limitations will result in a BOD_5 reduction of approximately 95 percent and a suspended solids reduction of about 69 percent.

Based on present waste water volumes in the industry, the average treated effluent resulting from the application of these effluent limitations will contain about 75 mg/l of BOD_5 and suspended solids.

Non-Water Quality Environmental Impact

In terms of the non-water quality environmental impact, the only item of possible concern is the increased energy consumption to operate the waste water treatment facilities. Relative to the production plant energy needs, this added load is small and not of significant impact. For example, the power requirements for waste handling and disposal in the application of the best practicable control technology currently available to a medium sized ready-to-eat cereal plant are estimated to be 100 kilowatts (135 hp). This demand represents less than one percent of the plant's total power usage.

Wheat Starch and Gluten Manufacturing

Cost of Application

The investment and annual costs for implementing various control technologies were presented in Section VIII. To implement the best practicable control technology currently available in order to meet the specified effluent limitations, the costs for a typical medium sized wheat starch plant were estimated to be $964,300 for investment and $252,200 in total annual costs.

Age and Size of Production Facilities

The plants in this subcategory range in age from three to over 30 years. As with the cereal industry, the age of the original plant building does not, however, reflect the degree of modernization of the production facilities. Since the plants continually incorporate new production techniques, no reliable generalizations between the basic production operations employed at various plants and the age of the plant can be made.

Available data indicates a possible relationship between plant age and raw waste loads. On the basis of Figures 17 and 18 in Section V, BOD_5 and suspended solids loads show some correlation with wheat starch plant age, and a general trend of increasing waste loads with increasing age was indicated. It is important however to note that the older wheat starch plants also tend to be it may be reasonably concluded that the larger plants. Thus, the indicated correlations may be strongly influenced by other factors the most important of which is likely plant capcity.

The size of the plant as expected has a direct influence upon the total amounts of contaminants discharged. The effluent limitations presented herein for the wheat starch and gluten manufacturing subcategory have been developed in terms of unit of raw material input, i.e., kg/kkg or lbs/1000 lbs of wheat flour, in order to reflect the influence of plant size. Available data does indicate a possible relationship between suspended solids and plant size or capacity, but no relationship between BOD_5 and plant size. A narrow range of raw waste load values exists per unit of raw material input. The control technologies discussed in Section VIII are judged applicable to all wheat starch plants regardless of size.

Engineering Aspects of Application

As with the ready-to-eat cereal subcategory, none of the wheat starch and gluten plants provide extensive waste water treatment with direct discharge to receiving waters. One wheat starch and gluten manufacturing plant does provide substantial pretreatment of the plant waste water prior to discharge to a municipal sewage system. The best practicable control technology currently available does not represent the current practice at any wheat starch and gluten manufacturing plant. As noted previously, current practice is to discharge the process waste water, either without treatment or with partial treatment, to municipal sewage systems. Because of the proximity to municipal systems and the ready acceptance of this waste by municipal facilities, a great deal of research and experimentation for separate treatment of wheat starch and gluten manufacturing wastes has not been necessitated. Specific application for treatment of wheat starch wastes has been principally limited to one operational pretreatment facility and pilot plant study. The technology as currently demonstrated in the industry is inadequate where direct discharge of process waste waters to navigable waters may result. Under the circumstances, a transfer of technology is establishing effluent limitations is appropriate.

Available information from full-scale pretreatment, and pilot plant studies firmly establishes the ready biodegradability of the wastes without the addition of nutritional additions. Present knowledge of waste treatability and efficiency of removal of pollutants with available unit process waste water treatment sequences, reasonably establishes the predictability of overall pollutant removal efficiency to be attained through additional and/or alternate physical, chemical, and biological treatment processes.

The transfer of technology ahs been adopted on the basis of anticipated end-of-pipe treatment of process waste water, even though it is well recognized that in-plant control measures (water conservation and waste water recycling) and land application has promises of offering a practical and effective means of waste load reduction in many instances, and may effectively complement end-of-pipe treatment measures. High pollutant reduction levels (BOD_5 and suspended solids) are necessitated particularly in the wheat starch and gluten manufacturing subcategory because of the extrmeely high initial raw waste load characteristic of this industry. Technology exists to effectively reduce the effluent load limitations to the specific level. Attainment of this level of technology is judged practical, and is currently available. The final effluent concentrations to be realized by applying the specified control technologies will be about 200 mg/l of BOD_5 and suspended solids.

Non-Water Quality Impact-

The non-water quality environmental impact is restricted to the increased power consumption required for the treatment facility. This power consumption is quite small compared to the total energy requirements for a wheat starch plant and, therefore, the impact of the control facilities is considered insignificant.

LIMITATIONS ON THE APPLICATION OF THE EFFLUENT LIMITATIONS GUIDELINES

The effluent limitation guidelines presented above can generally be applied to all plants in each subcategory of the grain milling industry covered in this report. Special circumstances in individual plants, however, may warrant careful evaluation.

Also, it must be recognized that the treatment of high strength carbohydrate wastes, notably from wheat starch plants, is difficult. Upset conditions may occur that result in higher BOD_5 and suspended solids discharges than normal. While the treatment sequence defined as best practicable control technology currently available will minimize these upsets, they may still occur. The allowance in the effluent limitations guidelines to reflect maximum daily values properly considers the momentary variations in waste load and treatment efficiency which are expected to occur.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved by July 1, 1983 are to specify the degree of effluent reduction attainable through the application of the best available technology economically achievable. This control technology is not based upon an average of the best performance within an industrial category, but is determined by identifying the very best control and treatment technology employed by a specific plant within the industrial category or subcategory, or readily transferable from one industry process to another.

Consideration must also be given to:

a. the total cost of application of this control technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the processes employed;

d. the engineering aspects of the application of this control technology;

e. process changes;

f. non-water quality environmental impact (including energy requirements).

Best available technology economically achievable also considers the availability of in-process controls as well as end-of-process control and additional treatment techniques. This control technology is the highest degree that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants.

Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, this control technology may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, this control technology may necessitate some industrially sponsored development work prior to its application.

In establishing the level of technology and effluent limitation guidelines for the breakfast cereal, and wheat starch segment of the grain mills point source category, it is recognized that present plants, with only few exceptions, discharge untreated or partially treated waste water tc municipal sewage systems. While direct discharge to municipal systems are the result, effluent guidelines as applicable to discharge to navigable waters from industrial guidelines for the ready-to-eat and wheat starch manufacturing subcategories is apparent where any plant modifications or changes in existing practices would result in discharge of process waste waters directly to navigable waters.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based on the information contained in Sections III through VIII of this document, it has been determined that the effluent reductions attainable through the application of the best available technology economically achievable are those presented in Table 13. The values presented in Table 13 represent the maximum allowable waste water effluent loading for any 30 consecutive calendar days. To allow for variances, excursions above these levels are permitted for a maximum daily average of 3.0 times the average 30-day values. These standards are based on unit weight of pollutant per unit weight of raw material (wheat starch) for the wheat starch and gluten subcategory, and per unit weight of finished cereal product for the ready-to-eat cereal subcategory.

Table 13

Effluent Reduction Attainable Through the Application of Best Available Technology Economically Achievable

Industry Subcategory	BOD kg/kkg(lbs/1000 lbs)	Suspended Solids kg/kkg(lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process wastes		
Hot cereal manufacturing	No discharge of process wastes		
Ready-to-eat cereal manufacturing	0.20	0.15	6-9
Wheat starch and gluten manufacturing	0.50	0.40	6-9

IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

For the segments of the grain milling industry covered in this document, the best available technology economically achievable for those subcategories with waste water discharges comprises improved solids separation following activated sludge or comparable biological treatment. Improved solids separation can be represented best by deep bed filtration and/or carbon filtration although alternative systems may be available. It is anticipated that the technology of removing biological solids by filtration will improve rapidly with the increased use of such treatment processes in many industries and municipalities.

Improved stability and performance of the biological treatment processes is a significant factor in the successful application of deep bed filtration. At present, upsets do occur in activated sludge systems handling high strength waste waters and might be expected to result in some efficiency and effectiveness loss of deep bed filtration. A reasonable allowance must be made in the established effluent guidelines limitations to accoutn for variance in daily effluent quality with best operation.

RATIONALE FOR THE SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Ready-to-Eat Cereal Manufacturing

Cost of Application-

As presented in Section VIII, the investment costs for providing the best available technology economically achievable are $563,300 for a small cereal plant (90,700 kg/day), $875,300 for a medium sized plant (226,800 kg/day), and $1,411,700 for a large plant (544,300 kg/day). Total annual costs for the three size ranges are $139,300, $223,100, and $359,900, respectively.

Age, Size, and Type of Production Facilities-

As discussed in Section IX, differences in age or size of production facilities in the ready-to-eat cereal manufacturing subcategory do not significantly affect the application of the best available technology economically achievable. Likewise, the production methods employed by the different plants are similar and do not affect the applicability of this technology.

Engineering Aspects of Application

As similarly discussed for best practicable control technology currently available in Section IX, the control technologies specified herein have not been specifically demonstrated for process waste water from ready-to-eat cereal plants. The basic treatment rpocesses in attaining the specified level of effluent load limitations have received industrial and municipal application in recent years with successful production of a high quality effluent.

Present process waste water treatment technology demonstrated in the industry is jduged inadequate. A transfer of available technology is necessary where process waste waters are to be treated with direct discharge to navigable waters. The technology utilized in attaining the stipulated effluent limitations is readily transferrable. This technology may be substantially aided by in-process control such as reduction of water use and pollutant contributions from clean-up operations. The technology is judged economically and technologically feasible. Biodegradability of the process waste water with nutrient addition has been demonstrated and fully established through an existing full-scale pretreatment facility now in operation. The technology has strong premise of producing an effluent of 30 mg/l of both BOD5 and suspended solids.

Process Changes

No basic process changes will be necessary to implement these control technologies. Substitution of dry clean-up for wet clean-up operations can substantially reduce pollutant loads from the industry.

Non-water Quality Environmental Aspects

The application of the best available technology economically achievable will not create any new sources of air or land pollution, or require significantly more energy than the best practicable control technology currently available. Power needs for this level of treatment technology were estimated to be about 115 kw (155 hp) for a medium sized plant as defined in Section VIII. This demand is small when compared to the total production plant power requirements.

Wheat Starch and Gluten Manufacturing

Cost of Application-

The investment cost of applying the best available technology economically achievable, defined above, to a moderate-sized wheat starch and gluten plant has been estimated in Section VIII to be $996,000. Total annual costs are estimated at $264,000.

Age, Size, and Type of Production Facilities

As discussed in Section IX, the application of this level of control technology is not dependent upon the size or age of the plants. Production methods employed by the different plants are similar and do not affect the applicability of this technology.

Engineering Aspects of Application

As previously discussed in relation to ready-to-eat cereal plants, the specified treatment technology has not been specifically demonstrated for wheat starch and gluten manufacturing process waste waters. However, these processes are readily available, transferrable from other treatment applications and economically and technically feasible. Technology as now practiced is judged inadequate where direct discharge of treated process waste water to navigable waters result. The technology may be aided by reduction of in-plant clean-up water use (generally representing 5 to 10 percent of the total process waste water flow), and recycling of process water in the production operation. Biodegradability of the waste has been firmly established by results at one operational pretreatment facility, and pilot plant studies. High organic removals are necessitated by the extraordinarily high pollutant potential of the representative waste water. The technology will result in effluent concentrations of 100 mg/l of BOD_5 and suspended solids.

Process Changes

No basic changes are necessary to implement these control technologies. Reduction in water use, and recycling of water for production purposes can reduce the reliance upon end-of-pipe treatment technology.

Non-water Quality Environmental Aspects

Power requirements for the prescribed treatment system are small compared to the overall production demands. The estimated energy requirement for waste treatment at a typical wheat starch plant is 185 kw (250 hp). Other environmental considerations will not be affected by the application of this control technology.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

Standards of performance are presented in this section for new sources. The term "new source" is defined to mean "any source, the construction of which is commenced after the publication of the proposed regulations prescribing a standard of performance." These standards of performance are to reflect higher levels of pollution control that may be available through the application of improved production processes and/or treatment techniques.

Consideration should be given to the following factors:

a. the type of process employed and process changes;

b. operating methods and in-plant controls;

c. batch as opposed to continuous operations;

d. use of alternative raw materials;

e. use of dry rather than wet processes; and

f. recovery of pollutant as by-products.

The new source performance standards represent the best in-plant and end-of-process control technology coupled with the use of new and/or improved manufacturing processes. In the development of these performance standards, consideration must be given to the practicability of a standard permitting "no discharge" of pollutants.

NEW SOURCE PERFORMANCE STANDARDS

The performance standards for new sources in the subcategories of the grain milling industry covered in this document are presented in Table 14. Standards (BOD and suspended solids) are given in terms of unit weight of pollutant per unit weight of raw material (wheat flour) for the wheat starch and gluten subcategory and per unit weight of finished cereal product for the ready-to-eat cereal subcategory.

Table 14

New Source Performance Standards*

	BOD kg/kkg(lbs/1000 lbs)	Suspended Solids kg/kkg(lbs/1000 lbs)	pH
Animal feed manufacturing	No discharge of process wastes		
Hot cereal manufacturing	No discharge of process wastes		
Ready-to-eat cereal manufacturing	0.20	0.15	6-9
Wheat starch and gluten manufacturing	1.0	1.0	6-9

*Maximum average of daily values for any period of 30 consecutive days.

The values given in Table 13 reflect the maximum allowable waste water effluent loading for any 30 consecutive calendar days. To allow for variances, excursions above these levels are permitted for a maximum daily average of 3.0 times the average 30-day levels.

RATIONALE FOR THE SELECTION OF NEW SOURCE PERFORMANCE STANDARDS

Ready-to-Eat Cereal Manufacturing

The performance standards for new sources in the ready-to-eat cereal subcategory are identical to the effluent limitations prescribed as attainable through the application of the best available technology economically achievable as presented in Section X.

The specific control technologies to meet the new source performance standards are not presented in this document. The end-of-process treatment is to be equivalent to that suggested for the best control technology economically achievable. Recognizing that this level of waste water treatment has not been demonstrated in this segment of the grain milling industry, it is nonetheless felt that this technology will meet the new source standards. Factors considered in developing these standards are summarized in the following discussion.

Production Processes-

The basic production methods employed in ready-to-eat cereal manufacturing are not likely to be altered significantly in the future. Although new types of equipment are constantly being developed and incorporated into the manufacturing operations, the basic process will probably remain largely in its present form. Furthermore, since most waste waters from a ready-to-eat cereal plant are generated in cleanup operations, it is not anticipated that changes in production processes will significantly alter waste characteristics and waste water flow volumes contributed by this industry.

Operating Methods and In-Plant Controls

As discussed in Section VII, in-plant controls are not anticipated to have a major effect on waste loads from ready-to-eat cereal plants. New plants do offer the possibility of incorporating controls such as dry-collection systems for product spillage, but significant usage of water in wet cleanup operations may still be expected.

By-Product Recovery

At present, most plants in this segment of the grain milling industry recover substantial amounts of product spillage in a dry form for use in animal feed. These recoveries might be increased at new plants by implementing improved collection methods and systems, but no new recovery methods are presently anticiapted.

Wheat Starch and Gluten Manufacturing

The new source performance standards for the wheat starch and gluten manufacturing subcategory fall between The technology required to meet the effluent limitations guidelines established for the best practicable control technology currently available and the best available technology economically achievable. these standards includes biolcgical treatment, final sedimentation, and a further solids removal step such as a stabilization basin or deep bed filters. Two factors properly influence the selection of the proposed new source performance standard. One is the extremely high organic strength and suspended solids concentrations of the process waste water from wheat starch plants, which make waste load reductions beyond conventional secondary treatment quite difficult. A second factor is that the degree of pollutant reduction required by end-of-process treatment has not been specifically demonstrated at any full-scale plant, even though reliable technology is available and transferrable. Water reuse and conservation offer alternatives to reducing waste loads through in-plant controls, and together with end-of-pipe treatment, may be the most effective means of pollutant reduction. Several new plants now under construction are incorporating such in-plant measures for substantial reductions in water use and waste loads.

The production processes at existing wheat starch plants are basically the same throughout the industry. It is known that two new plants, presently under construction, anticipate major reductions in water usage and waste loads. These waste load reductions have yet to be demonstrated, however. If improved waste water characteristics do result at these plants, re-evaluation of the proposed new source performance standards may be warranted.

SECTION XII

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SECTION XIII

REFERENCES

1. "Battle Creek - Cereal Capital of the World", *Inside Battle Creek*, Battle Creek Public Schools Brochure No. 6, 1965.

2. "Breakfast Cereals, Part of Modern Life", *Cereal Institute Publication*, February, 1973.

3. Brody, Julius, *Fishery By-Products Technology*, AVI Publishing Company, Inc., Westport, Connecticut, 1965.

4. Dyer, Irwin A., and O'Mary, C. C., *The Feedlot*, Lea & Febiger, Philadelphia, Pennsylvania, 1972.

5. Eynon, Lewis, and Lane, J. Henry, *Starch, Its Chemistry, Technology, and Uses*, W. Heffer and Sons Ltd., Cambridge, 1928.

6. Koon, J. H., Adams, Carl E., Jr., Eckenfelder, W. Wesley, Jr., "Analysis of National Industrial Water Pollution Control Costs", submitted to U.S. Environmental Protection Agency, Office of Economic Analysis, Washington, D. C., May 21, 1973.

7. Matz, Samuel A., *Cereal Technology*, AVI Publishing Company, Inc., Westport, Connecticut, 1970.

8. Matz, Samuel A., *The Chemistry and Technology of Cereals as Food and Feed*, AVI Publishing Company, Inc., Westport, Connecticut, 1959.

9. Patterson, W. L., and Banker, R. F., Black & Veatch Consulting Engineers, "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities", Report for the Office of Research and Monitoring, Environmental Protection Agency, October, 1971.

10. Radley, J. A., *Starch and Its Derivatives*, Chapman & Hall Ltd., London, 1940.

11. Reece, F. N., "Design of a Small Pushbutton Feed Mill for Research Stations", *Feedstuffs*, pp. 39-40, September 24, 1973.

12. Riggs, J. K., "Fifty Years of Progress in Beef Cattle Nutrition", *Journal of Animal Science*, Volume 17, 981-1006, 1958.

13. Sanford, F. Bruce, "Utilization of Fishery By-Products in Washington and Oregon", Fishery Leaflet No. 370, U.S. Department of the Interior, Fish and Wildlife Service, March, 1950.

14. Schaible, Philip J., Poultry: Feeds and Nutrition, AVI Publishing Company, Inc., Westport, Connecticut, 1970.

15. Seyfried, C. F., "Purification of Starch Industry Waste Water", Proceedings of the 23rd Industrial Waste Conference, Purdue University, Lafayette, Indiana, May 7-9, 1968.

16. Shannon, L. J., Gorman, P. G., Epp, D. M., Gerstle, R. W., Devitt, T. W., Amick, R., "Engineering and Cost Study of Emissions Control in the Grain and Feed Industry", Environmental Protection Agency, Research Triangle Park, North Carolina.

17. Sherwood, Ross M., The Feed Mixers' Handbook, Interstate Publishers, Danville, Illinois, 1956.

18. Whistler, Roy L. and Paschall, Eugene F., Starch: Chemistry and Technology, Volume I, Fundamental Aspects, Academic Press, New York, 1965.

19. Whistler, Roy L. and Paschall, Eugene F., Starch: Chemistry and Technology, Volume II, Industrial Aspects, Academic Press, New York, 1967.

METRIC TABLE

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier