The
Food Processing Residual Management Manual

Robin C. Brandt
Senior Engineer
Geo Decisions, Inc.
A Subsidiary of Gannet Fleming, Inc.
State College, Pennsylvania

and

Kelli S. Martin
Senior Research Technologist
Department of Agricultural and Biological Engineering
The Pennsylvania State University
University Park, Pennsylvania

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Department of Environmental Protection

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PURPOSE:	The purpose of this document is to provide instructions and operating procedures for FPR waste source reduction, recycling, and disposal.
APPLICABILITY:	This guidance applies to all persons, municipalities, and counties who operate a food processing facility and are exempt from acquiring a permit under 25 Pa Code Chapter 287.
DISCLAIMER:	The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures will affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
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CREDITS

Working Group Chairman, *William F. Pounds*, Pennsylvania Department of Environmental Protection
Marcie A. Bahn, Consultant, Hershey Foods Corporation
Robin C. Brandt, P.E., Geo Decisions, Inc.; a subsidiary of Gannett Fleming, Inc.
Karl R. Girton, President, Girton Sales Co., Inc.
Christian R. Herr, Director, Bureau of Agricultural Development, Pennsylvania Department of Agriculture
Paul W. Hess, Ph.D., Consultant, Hershey Foods Corporation
Cyrus A. Karper, Environmental Manager, Knouse Foods
Curtis N. Kratz, Farmer Representative; Member, Pennsylvania Farmers Association
Kelli S. Martin, Senior Research Technologist, Department of Agricultural and Biological Engineering, The Pennsylvania State University
Paul D. Robillard, Ph.D., Associate Professor, Department of Agricultural and Biological Engineering, The Pennsylvania State University
Stephen M. Socash, Pennsylvania Department of Environmental Protection
George E. Witmayer, Environmental Affairs Director, Moyer Packing Company

Working Group Assistant *Holly Dugan*, Pennsylvania Department of Environmental Protection

Technical Advisors Coordinator *Paul D. Robillard*, Ph.D.
Young D. Hang, Ph.D., Professor, Food Science & Technology, Cornell University
Larry D. Hepner, M.S. Associate Professor, Agronomy & Environmental Science, Delaware Valley College
Lewis M. Naylor, Ph.D., Director, Technical Services, International Process Systems, Ithaca, New York
William F. Ritter, Ph.D., Professor, Agricultural Engineering, University of Delaware

Reviewers Industry Review Coordinator *Karl R. Girton*
Robert Alexander, Philadelphia Electric
Paul W. Hess, Ph.D.
Cyrus A. Karper
Ann Savolainen, Food Industry Council of Pennsylvania
George Sechrist, III, Pennsylvania Association of Meat Processors
George E. Witmayer
Regulatory Review Coordinator *Stephen M. Socash*
Max A. Van Buskirk, Jr., V.M.D., Director, Bureau of Animal Industry, Pennsylvania Department of Agriculture
Melanie G. Cook, Chief Counsel, Pennsylvania Department of Environmental Protection
Earl M. Hass, Chief, Division of Agronomic Services, Pennsylvania Department of Agriculture
Gary L. Hepford, Water Quality Management, Pennsylvania Department of Environmental Protection
Michele M. Moses, Chief Counsel, Pennsylvania Department of Environmental Protection
Michael R. Steiner, Field Operations Deputate, Pennsylvania Department of Environmental Protection
Richard D. VanNoy, Ag Advisory Board, Pennsylvania Department of Environmental Protection
Ronald Buchanon, Solid Waste Advisory Committee
Curvin Snyder, III, Solid Waste Advisory Committee

Additional Reviewers
Hershel A. Elliott, Ph.D., Professor, Department of Agricultural and Biological Engineering, The Pennsylvania State University
Harold W. Harpster, Ph.D., Associate Professor, Dairy and Animal Science, The Pennsylvania State University
Gerald P. Vogler, P.E., Gannett Fleming, Inc.

Editors *Krista M. Weidener* and *David L. Lehning*

Design and Layout *Marcie A. Bahn* and *Kelli S. Martin*

Typists *Patti L. Burns, C. Christine Butts, Marsha L. Hull*, and *Joan M. Potter*

Cover Design *Diedier Masson*

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DISCLAIMER

Acknowledgements

During development of *The Food Processing Residual Management Manual*, we found information on this topic to be widely dispersed, making it time-consuming and cumbersome to access.

For the first time, information on food processing residuals (FPR) management is compiled in one manual, in the context of the *FPR Utilization and Disposal Hierarchy*. The hierarchy is a systematic yet flexible organization tool for management strategies that incorporate cost minimization or maximum return.

Development of this manual provided an opportunity for the open exchange of ideas within a working committee of industry, regulatory, and academic contributors. We believe this forum led to a more balanced regulatory posture regarding FPR management in Pennsylvania. The manual is by no means the last word on FPR management. Rather, it is a necessary step toward a comprehensive resource base. It is our hope that all public sectors strive toward continued progress in training, education, technology transfer, research, and balanced regulatory policies. Toward this end, the FPR manual is designed to be periodically supplemented to incorporate new technological advances and subjects of interest.

Many individuals and organizations have generously contributed their time and talents to make this guidance tool possible. We wish to gratefully acknowledge and thank each contributor so listed on the credits page. With the efforts of so many individuals, we believe that the processing industry will continue to thrive as we work to manage our valuable environmental resources.

Robin C. Brandt
Kelli S. Martin
June 1994

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Acronyms in FPR Manual

AAFCO	Association of American Feed Control Officials
ADF	Acid Detergent Fiber
API	Activity Production Index
ASTM	American Society for Testing Materials
BOD5	Biochemical Oxygen Demand (five day test)
BTU	British Thermal Units
BLRWM	Bureau of Land Recycling and Waste Management
C:N	Carbon Nitrogen Ratio
CCD	County Conservation District
CCE	Calcium Carbonate Equivalent
CEC	Cation Exchange Capacity
COD	Chemical Oxygen Demand
CP	Crude Protein
D/T	Dilutions to Threshold
DAF	Dissolved Air Flotation
DE	Digestible Energy Concentration
DM	Dry Matter
EC	Electrical Conductivity
ED	Effective Dilutions
FDA	Food and Drug Administration
FPR	Food Processing Residual
GPD	Gallons Per Day
LAS	Land Application System
MALR	Maximum Allowable Loading Rates
ME	Metabolizable Energy Concentration
MGD	Million Gallons per Day
MSDS	Materials Safety Data Sheets
NDF	Neutral Detergent Fiber
NEg	Net Energy of Gain
NEl	Net Energy of Lactation
NeM	Net Energy of Maintenance
NIWE	Northeast Industrial Waste Exchange
NMP	Nutrient Management Plan
OD	Odor Unit
OM	Organic Matter
PADEP	Pennsylvania Department of Environmental Protection
PAGS	Pennsylvania Geological Survey
PCB	Polychlorinated Byphenols
PDA	Pennsylvania Department of Agriculture
PFA	Pennsylvania Farmers Association
PFRP	Process Further Reduces Pathogens
PLA	Polylactic Acid
PSRP	Process Significantly Reduces Pathogens
RCRA	Resource Conservation Recovery Act
RO	Reverse Osmosis
SAR	Sodium Absorption Ratio
SCP	Single Cell Protein
SCS	Soil Conservation Service
SHWT	Seasonal High Water Table
SRS	Source Reduction Strategy
SS	Suspended Solids
TCLP	Toxic Characteristics Leaching Procedure
TDN	Total Digestible Nutrients
TDS	Total Dissolved Solids
TOC	Threshold Odor Concentration
TOX	Total Organic Halogens
TSS	Total Suspended Solids
UF	Ultrafiltration
USDA	United States Department of Agriculture
USGS	United States Geological Survey

Preface

The food processing industry plays a vital economic role in Pennsylvania. According to 1986 data, more than 2,300 food processing companies operate in the Commonwealth. As the fourth largest employer, Pennsylvania food processors employ approximately 90,000 workers. The industry accounts for nearly 9% of all manufacturing jobs in the state and ranks third in new job contributions. The increased market value of raw agricultural commodities – total value added – for the industry in Pennsylvania is estimated at $6.5 billion. Clearly, the food processing industry is essential to prosperity in Pennsylvania.

The industry's prominence extends beyond state boundaries. Because the Keystone State is in the hub of Northeastern population centers and abundant regional agricultural products, Pennsylvania food processors have a significant competitive edge over other Northeastern processors. Millions of consumers depend on the consistent, high quality food supply faithfully provided by Pennsylvania processors.

Incidental residual materials are necessary consequences of processing agricultural commodities. Combined Pennsylvania food processing residuals (FPRs) and packaging wastes are estimated to approach 4.8 million tons annually. This estimate is conservative; many processors are uncertain about the quantities of FPRs generated. FPRs, once inexpensively dumped at local landfills, now generate a variety of concerns. Environmental protection standards are becoming more stringent, and disposal costs continue to escalate. Therefore, we need to take a new look at alternatives – FPRs must be minimized and recycled. By implementing successful FPR management strategies, the Pennsylvania food processing industry can remain strong.

PA DEP has had comprehensive residual waste regulations (RWR) since 1992. As a part of these RWR, the use of food processing wastes or food processing sludges can occur as part of normal farming operations. All industries operating within the Commonwealth are also responsible for developing comprehensive source reduction and management programs. FPR generators have numerous possibilities for beneficial use due to the unique nature of FPRs. A multi-disciplinary work group was formed to develop a guidance document to assist individuals involved in managing food processing residuals. This document is a result of the collaborative efforts of representative regulatory, industry, and university group members.

The objective of the *Food Processing Residual Management Manual* is to provide a framework for developing FPR source reduction, recycling, and disposal programs through the FPR utilization and disposal hierarchy. The main emphasis is on source reduction and recycling. FPR disposal (e.g., landfilling) is viewed only as a last resort when no practical, cost effective beneficial use can be found.

Every attempt has been made to present information in a concise, easy-to-read format. While the manual is not intended to be the sole reference for FPR management, it will be a valuable guide for developing effective FPR programs. The principles presented apply to all food processing groups. The potential for source reduction and beneficial applications for FPRs are limited only by our imagination and willingness to explore innovative solutions.

Introduction

Food processing management professionals have extensive experience in production technologies, market development, and competitive strategies in their market. However, managers find that keeping pace with stringent and changing waste management regulations and escalating costs is a challenging task – made even more difficult by unfamiliar technical terminology and overlapping regulatory agency mandates. Even regulators find it difficult to keep abreast of current policies and programs required by sister agencies.

Food Processing Residual (FPR) Defined

An FPR is an incidental organic material generated by processing agricultural commodities for human or animal consumption. The term includes food residuals, food coproducts, food processing wastes, food processing sludges, or any other incidental material whose characteristics are derived from processing agricultural products. Examples include: process wastewater from cleaning slaughter areas, rinsing carcasses, or conveying food materials; process wastewater treatment sludges; blood; bone; fruit and vegetable peels; seeds; shells; pits; cheese whey; off-specification food products; hides; hair; and feathers.

The term Food Processing Residual (FPR) was chosen specifically for this manual to recognize incidental materials generated during preparation of food products as resources, not wastes. For FPRs to be an asset rather than a liability, we must make a conscious commitment to this concept. FPR source reduction and reuse will not occur by accident, but rather through a concentrated effort including thorough familiarity with specific FPRs and management options.

The *Food Processing Residual Management Manual* was prepared as a guidance manual for the reader who has limited knowledge of FPR management. The manual is user friendly, with language gauged toward those with little or no background in the subject. Where possible, extended technical discussions are avoided. Readers desiring more information are directed to Additional Resources at the back of the manual or to other publications when appropriate.

The objectives of this document are to:

- introduce use of the Food Processing Residual Utilization and Disposal hierarchy as a guidance strategy for FPR management
- provide a guidance manual for regulatory agencies responsible for review of FPR programs in accordance with current *Pennsylvania Residual Waste Regulations* (Title 25, Ch. 287-299)
- provide a standard, but flexible, step-by-step methodology for developing an FPR management program
- provide a basic reference and guideline resource for FPR managers
- provide examples of successful FPR management programs

Using this Manual

As shown in Figure I.1, the manual is subdivided into three major parts with supporting information sections. Refer to Figure I.1 as you read the description of each section.

Part I: Assessing your Food Processing Residuals explains how to quantify and characterize FPRs. Chapter 1 guides the reader through an initial seven-step review of existing in-house data describing current FPR management practices. Chapter 2 provides a standardized format for developing FPR flow diagrams. Chapters 3 and 4 provide basic information on important physical, chemical, and nuisance characteristics. FPR sampling, analysis, and interpretation of results are also covered.

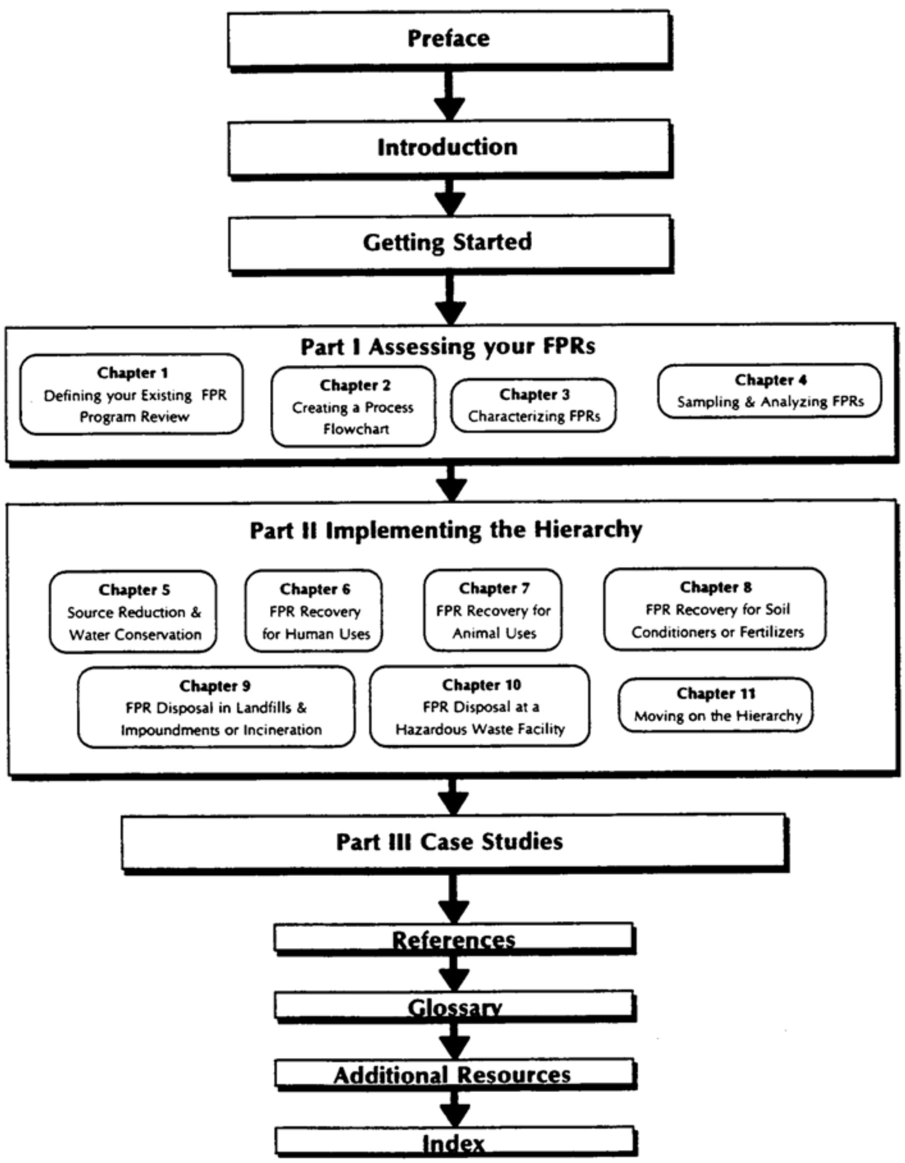
Part II: Implementing the Hierarchy addresses FPR utilization and disposal alternatives. Chapter 5 reviews FPR minimization and water conservation strategies. Chapters 6, 7, and 8 provide detailed information about the three beneficial use strategies. Chapters 9 and 10 are devoted to disposal options. Chapter 11 closes Part II of the manual with a discussion of strategies used to increase the value of FPRs. A brief section covering economic analysis of FPR management alternatives is also included.

Part III: Case Studies provides reviews of successful FPR management programs and innovative strategies from several food processing plants.

References provides a list of all sources cited in the manual.

The Glossary is included to assure that the terminology used in the manual is uniformly interpreted. Definitions provided in the glossary are consistent with those contained in the most current Pennsylvania laws and regulations.

Figure I.1. FPR manual outline



Additional Resources presents detailed supplemental information and includes lists of analytical laboratories, sample preservation and storage protocols, and regulatory agency contacts.

PADEP Intent Statement

If the use of food processing waste or food processing sludge in the course of normal farming operations is not hazardous, you are not required to obtain a permit, comply with the bonding or insurance requirements, or comply with duties of generators. A person managing food processing waste shall implement best management practices. This manual identifies best management practices for the management of food processing residuals and may approve additional best management practices on a case-by-case basis. If a person fails to implement best management practices for food processing waste, the Department may require compliance with the land application, composting, and storage operating requirements of Chapter 291, 295, and 299.

An **Index** is provided to assist readers in locating topics of interest. This tool will be particularly helpful to infrequent users of the manual as a reference source.

This manual is intended to be an evolving document. The work group decided that provisions for updating the document periodically should be a primary consideration when selecting the manual format. Because the manual covers a broad spectrum of topics, certain sections may become outdated yearly. A three-ring binder format for the manual was selected so that individual pages, or even sections, can be updated periodically. In this way the manual will remain current as new and innovative FPR management approaches evolve or as regulations change.

GETTING STARTED

With a complex issue like FPR management, you might be asking yourself, "Where do I begin?" The FPR Utilization and Disposal Hierarchy is an excellent starting point. Originally developed by R.J. Shober (1989), the hierarchy graphically illustrates that careful reduction and management of FPRs benefit your company. The multi-level sieve shown in Figure I.2 illustrates the hierarchy concept. Management strategies on the screen's upper levels yield the greatest benefit to the facility, environment, and society. For example, when material losses and water consumption are reduced, fewer FPRs are generated.

As you progress down the hierarchy, the relative benefit to your facility and the environment decreases. This is noted along the right column in the figure. The sieve order in the hierarchy assumes that FPRs intended for human uses have greater value than those recovered for animal uses. Land-applied FPRs that act as a soil conditioner or plant nutrient supplement have less benefit than human and animal uses. Options below land application are liabilities with increasing costs.

You can apply the hierarchy concept to every FPR in your facility. As the concept develops, you will see that such an approach is a valuable tool for exploring and setting goals, and establishing priorities for FPR use.

The following sections define these hierarchy terms, discuss FPR management constraints, and provide you with an FPR management goal.

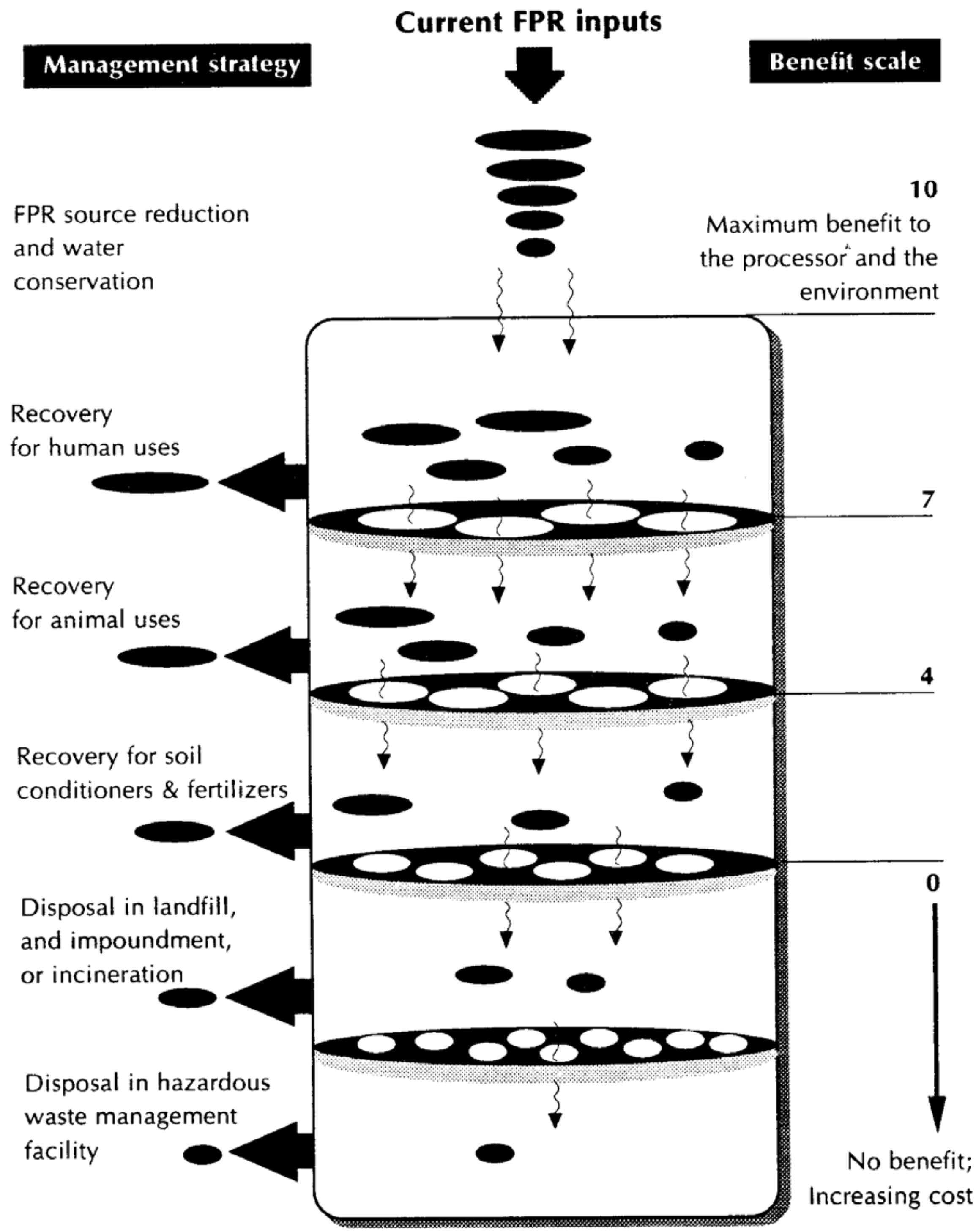
The FPR Hierarchy

Each level in the hierarchy has a corresponding chapter in Part II devoted to that particular management strategy. However, it is important that you become familiar with the hierarchy concept early in the manual. The following paragraphs introduce the hierarchy levels.

FPR Source Reduction and Water Conservation.

This management strategy reduces excessive FPR production. All processing plants practice this technique to one degree or another. However, even more significant savings can be achieved through a concerted effort. This may be accomplished by reducing material loss, conserving and reusing water, and preventing spills.

Figure I.2: FPR utilization and disposal hierarchy



FPR Recovery for Human Uses

This management strategy recovers FPRs for human ingestion, personal care, home use, or commercial/industrial use. Some examples of FPR human uses are thermally modified whey proteins used as food additives, cosmetic additives, incense, and starch-based biodegradable packaging materials.

FPR Recovery for Animal Uses.

This management strategy uses FPRs primarily for animal consumption. Examples include pet food, livestock feed, and animal bedding.

FPR Recovery for Soil Amendments or Fertilizer (Land Application)

Often viewed as a disposal option, properly managed land application programs strive to replenish soil organic matter and nutrients that are depleted through cropping. The objective is to replace conventional soil supplements with FPRs, which are recycled through the soil back into a new crop. Nutrient management programs prevent accumulation of substances that may inhibit plant growth or permanently limit future use of a site. Crop harvest and attention to site productivity in this management option distinctly set it apart from disposal practices. Examples include the land application of snack food and meat processing plant wastewater sludges.

FPR Disposal via Landfill, Impoundment, or Incineration.

This disposal strategy has no benefit to society other than to capture, contain, and control the release of potentially harmful contaminants. At this point on the hierarchy, the residuals are waste. The manager's objective is to find the least expensive, environmentally responsible alternative. All disposal options involve an extensive evaluation of waste characteristics since the type of facility required for disposal depends on these characteristics. An FPR possessing high heating value may be more appropriately viewed as a recovery for human use management approach when incinerator heat is captured and put to beneficial use.

FPR Disposal via Hazardous Waste Management Facility.

Any FPR material that has been mixed with a listed hazardous waste, or exhibits hazardous characteristics (e.g., ignitability, corrosivity, reactivity, or toxicity) must be handled as a hazardous waste. An FPR becomes a hazardous waste only under unusual circumstances. However, such situations may arise. One example would be a spill of toxic cleaning agent that was washed into an FPR stream. The entire contaminated FPR stream would require handling as a hazardous waste. A brief coverage of this topic is provided in Chapter 10.

Understanding FPR Terms

To understand the remainder of this manual, you need to be familiar with FPR terms. This section introduces FPR terms and provides examples where appropriate. Legal definitions are provided in the Glossary.

Agricultural Waste

This term includes manure and residual material generated in the production and marketing of agricultural commodities. Residual materials generated during production, harvesting, and marketing of agronomic, aquacultural, horticultural, and silvicultural crops are included as long as they are not hazardous. Examples include livestock manure, fishery manure, soil residue dislodged from harvested crops, waste animal feed, plant parts, and livestock washwater.

Beneficial Use

This term applies to the use or reuse of residual material for beneficial purposes. The use must not threaten public health or the environment. Examples include returned bakery, confectionery, or dairy products used in animal feeds; composted FPRs used as a soil amendment or fertilizer.

Coproduct

A coproduct is an incidental material generated during production that can be substituted for another commercially available product or raw material. A coproduct must be similar in physical character and chemical composition to the product for which it is substituted and be used for land application or energy recovery. Coproducts must not present a greater risk to human health and the environment than the original product or raw material. Examples include nutshells, bone, blood, fats, and hides.

Expended Material

This FPR has exceeded its useful lifetime and can no longer be used effectively without processing or treatment. Examples include process wastewater or additives that have been exposed to unsanitary conditions.

Food Processing Residual (FPR)

An FPR is an incidental organic material generated by processing agricultural commodities for human or animal consumption. The term includes food residuals, food coproducts, food processing wastes, food processing sludges, or any other incidental material whose characteristics are derived from processing agricultural products. Examples include: process wastewater from cleaning slaughter areas, rinsing carcasses, or conveying food materials; process wastewater treatment sludges; blood; bone; fruit and vegetable peels; seeds; shells; pits; cheese whey; off-specification food products; hide; hair; and feathers. Note that only those materials that are wastes are regulated by the Pennsylvania Department of Environmental Protection (PADEP).

Food Processing Sludge

Generated by a food processing water treatment or wastewater treatment facility, this sludge may contain additives like detergents, dispersal agents, flocculants, disinfectants, or biological agents. Examples include: process wastewater clarifier solids and skimmings; dissolved air flotation skimmings; and chemically conditioned dewatered solids.

Food Processing Waste

In the context of this manual, a food processing waste is a waste and includes: expended materials; products or co-products if they are abandoned or disposed; or contaminated soil, water, or other residue that are generated during the processing of commodities for human or animal consumption and are not immediately reused by the generator or employed as a beneficially useful co-product. These commodities include seafood, milk, meat, eggs, poultry, fruit, vegetables, and crops.

This term is formally defined in Title 25, Chapter 287 of the *Residual Waste Regulations*, and is included in the Glossary of this manual. However, it must be noted that the representation of the term in this manual is specifically limited to those materials that have no redeeming value.

Normal Farming Operations

This term refers to accepted practices routinely used in the nurturing and production of agronomic, aquacultural, horticultural, livestock, poultry, or silvicultural commodities. Normal farming operations must be conducted in compliance with applicable laws that govern public health and environmental protection. Examples include: land application of FPRs as soil amendments or fertilizer; use of FPRs in livestock or fish feed; and use of FPRs as bedding.

Product

A product is the sole or primary intended result of a manufacturing or production process. Materials that do not meet industry or manufacturing quality specifications are not considered to be products.

Residual Waste

This is a broad term that includes non-hazardous garbage, refuse, and discarded material from industrial, mining, or agricultural operations. Industrial, mining, or agricultural sludges from water supply treatment, wastewater treatment, and air pollution control facilities are considered residual wastes as long as they are not hazardous.

Source Reduction

Source reduction refers to lessening or eliminating the generation of wastes or their undesirable characteristics. Source reduction is achieved through changes in the production process. The term does not include dewatering, compaction, waste reclamation, or the use or reuse of waste. Examples include: process modifications, feedstock substitutions, improved feedstock purity, shipping and packing modifications, housekeeping and management practices, and improved process efficiency.

Waste Exchange

In some instances you will not have the technology and resources available to recycle certain FPRs. You are faced with the problem of marketing a material that has some value but not to your plant. Ideally, you would like to find someone who does have the resources to convert the FPR into a cash value product: The concept of waste exchange was developed to match waste generators with waste users. In some cases, waste exchanges yield profits because the user is willing to pay for the material. In such arrangements, the generator profits by avoiding disposal costs and by receiving a fee for the material. The user benefits by acquiring a needed product for less cost. Chapter 11 further explores the value of waste exchange programs.

FPR Management Constraints

As an FPR manager you are faced with a series of constraints that limit practical FPR use possibilities. You need to be aware of the constraints in your particular situation. Any FPR program must function within these limitations, which will vary from plant to plant, even when the same product is being produced. Six general categories of constraints follow:

- Physical Plant: What is your plant size, location, age, and level of technology?
- Financial Resources: Are adequate funds available to resolve regulatory issues, explore alternatives, and develop new technologies?
- Human Resources: What is the current level of training, experience, and worker cooperation at your plant? Are individuals assigned specific FPR management responsibilities? Is there one individual who has overall responsibility and control for FPR management?
- Regulatory Issues: What federal, state, and local agencies have jurisdiction over the plant and what are the current regulatory requirements?
- Technical Information: Do you have access to current information concerning available technologies, waste exchange opportunities, and expert consultation?

- Public Perception: What is your relationship with the local community? Have you been a good neighbor or the target of nuisance complaints?

This manual will help processors identify, work within, and in some cases, overcome these management constraints.

Where to Begin

Effective FPR management begins with a thorough evaluation of the current FPR handling/disposal method at your plant. Look at all process lines, FPRs, and waste streams. Ask yourself the following questions and consider how you may go about finding answers.

- What FPRs are being generated?
- How much of each FPR is generated?
- Where do FPRs go after they are removed from the process line?
- What are current FPR recycling and disposal costs?
- Who controls the FPR management program?
- Is the current FPR management strategy in compliance with federal, state, and local environmental regulations?

The answers to these questions should be readily available. If your plant is like most facilities, a rigorous examination of existing plant records and practices is needed. You need to know what you have to work with in order to develop an effective FPR management program. This manual will help you to determine whether or not your current program is in compliance with state and federal regulations. Since local concerns may vary significantly, inquire at your municipality about its FPR requirements. We will explore how to define your program in Chapter 1.

Your Goal

Effective FPR management does not happen by accident. It takes a focused plan of action with clear objectives and individual accountability. Companies with effective FPR management programs share several basic characteristics. These programs:

- satisfy regulatory requirements
- operate as a separate enterprise with one or more individuals devoting their full time to FPR management and a separate management budget
- maintain flexibility to take advantage of new FPR uses
- incorporate cost-effective strategies and planning

PART I: ASSESSING YOUR FOOD PROCESSING RESIDUALS

Without exception, all FPR use and disposal options are contingent on the specific properties of the material. For example, a clean FPR exposed to unsanitary conditions renders the FPR unsuitable for both human and animal use. FPRs containing broken glass or other sharp objects may eliminate all beneficial use options and necessitate landfill disposal. In the worst case, contaminating FPRs with a toxic material results in a greater hazardous waste disposal problem.

It is essential that you assess your FPR resources. The first step is to identify and characterize all FPRs. A careful program evaluation also identifies opportunities to reduce FPR generation and to maintain or improve FPR quality. The characteristics of your FPR will largely determine where your particular material(s) fit into the hierarchy. Improving the quality of your FPR may provide new options for a higher return on beneficial uses.

Chapter 1: Defining Your Existing FPR Program

This chapter guides you through a review of the current plant FPR handling strategies, practices, characteristics, and costs. This involves locating and assembling all available data to create an accurate picture of your current situation. Detailed analysis of specific FPR flows is not addressed at this point in your evaluation. Focused evaluations should wait until all the basic facts about various FPRs are gathered.

The following **Seven Step Program Review** provides the basic facts needed to assess the existing FPR program at your plant. A program review describes the baseline situation for your plant and stimulates consideration of innovative management strategies. Measure all future FPR management initiatives against this baseline to determine actual efficiency and cost savings.

Additional Resource A provides a set of blank worksheets to use for the seven-step program review.

1.1 Step 1: Create an Input Inventory

While this exercise may seem unproductive, creating an input inventory is the most important step toward effective FPR management. Documenting plant inputs verifies potential outputs as FPRs or residual waste materials. For example, if no toxic materials enter the plant, no hazardous (toxic) residual wastes will exit the plant. Careful documentation may eliminate the need for detailed waste characterization and thus costly waste analyses. You may also discover that you are hindering your own recycling efforts, by virtue of certain pollutants contained in one or more inputs.

Begin your inventory by listing all materials delivered to the plant and estimate their volumes. Walk through the facility and examine container labels, cleaning closets, and storage areas. Talk to shift supervisors and maintenance personnel. Show them your list and discuss any omissions. Don't forget to include people wastes (e.g. lavatory, lunchroom, office wastes) in your inventory. Collect all material safety data sheets (MSDS). File the input inventory and MSDSs together. After you have made the effort to create the inventory, invest the time to keep the list current.

1.2 Step 2: Create an Output Inventory

This inventory identifies all materials that are generated apart from your intended product. The output inventory must consider every plant output exiting via door, truck, pipe, or otherwise. This includes but is not limited to: FPRs, sanitary sewer discharges, garbage, trash, small pieces of the raw agricultural produce, sludges, manure, paunch material, and offal.

As you identify each output, make a preliminary estimate of the volume generated and record the properties of the material. Record the physical state (solid, liquid, or slurry), general appearance, any nuisance characteristics like odor, and known significant qualities (e.g., elevated temperature, extreme pH, fecal contamination). Gather current flow monitoring, volume measurement, or laboratory analyses for each plant output.

1.3 Step 3: Connect Inputs and Outputs

Comparing the material types, composition, and quantities in the input and output inventories will identify obvious inconsistencies. If a specific input does not show up in products or output streams, something is wrong. Conversely, if an output stream exhibits qualities that are inconsistent with the listed input materials, you have missed an important input. This initial connection of inputs with outputs will serve as the skeleton for detailed flow diagrams discussed in Chapter 2. The worksheet included in Additional Resource A provides space to list each input and output and draw lines to connect them. Figure 1.1 illustrates this process and shows the level of detail that should be considered.

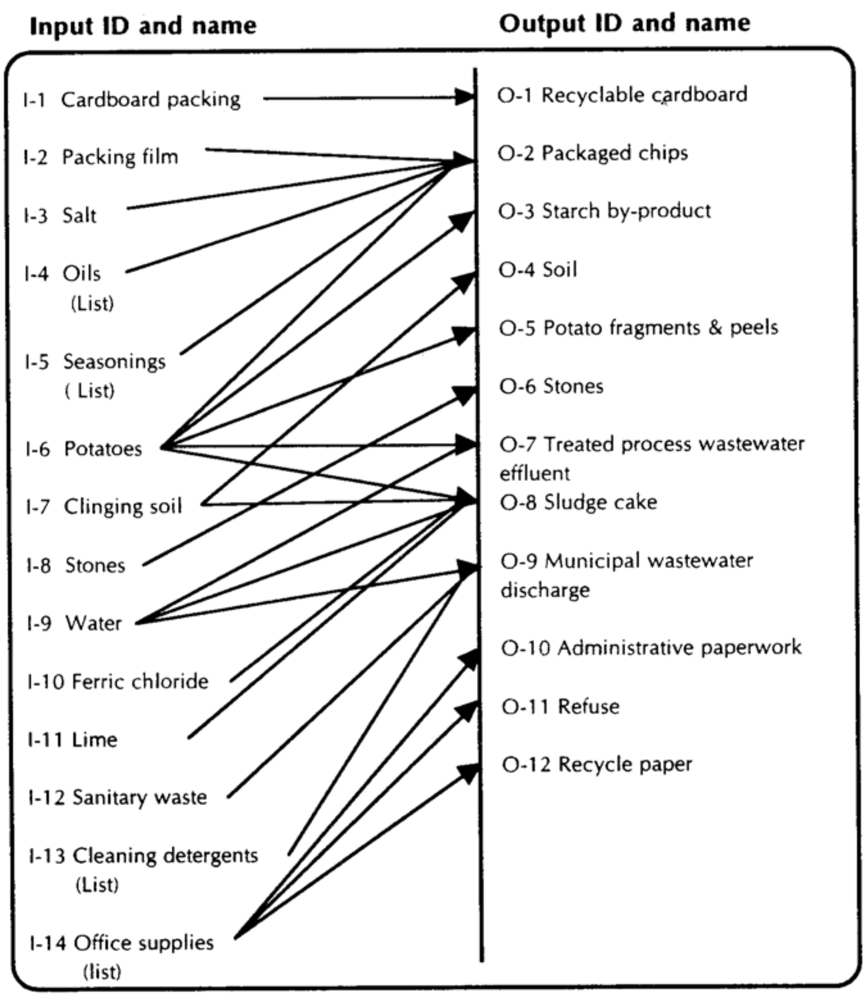
1.4 Step 4: Identify Current FPR Management Practices

Identify how all plant outputs are conveyed, reused, or disposed. Find answers to the following questions.

- How is each material transported to the disposal/reuse site?
- Who transports it?
- Where does it go?
- How is it recycled or disposed?
- What are the minimum quality criteria required by the user?
- Where are pipelines and connection points for liquid FPRs located?
- What is the capacity of the pipe?
- What is the wastewater treatment facility capacity, and how is the material being treated?
- Is the wastewater treatment facility in compliance with environmental regulations?

What is the status of your discharge quality with respect to the wastewater treatment facility pretreatment standards?

Figure 1.1: Connecting FPR inputs and outputs for a potato chip processer



Note: Step 3 of the 7-step program review.

1.5 Step 5: Identify Limiting FPR Characteristics

Based on information gathered in Steps 1 through 4, consider the principle limiting factors of each output. For example, one restroom hookup or an unmonitored floor drain that enters an FPR collection line limits all further potential uses for that FPR. When a sanitary waste enters the FPR flow, it becomes sewage. The sanitary waste becomes the limiting factor in this example. A caustic peeling FPR may have high pH and soluble salt levels as limiting factors. Certain slaughterhouse wastes likewise have high soluble salt levels. For fruits and vegetables, storability limits FPR uses for animal feeds. Odors resulting from storage or land application of FPRs place severe limitations on these activities.

An understanding of limiting factors will focus further waste characterization efforts and indicate where your FPR fits into the hierarchy.

1.6 Step 6: Estimate Current FPR Management Costs

At this step you must consider all the costs and receipts of FPR management. Include energy costs, transportation costs, disposal tipping fees, penalty fees (e.g., municipal wastewater treatment facility discharges exceeding pretreatment standards), chemical costs, in-plant labor costs, capital amortization, coproduct sales, and any other factors affecting costs and receipts.

To determine the optimum (lowest cost) FPR management options you need to evaluate several alternatives. All other things being equal, the lowest cost alternative is the option of choice. The cost savings realized over other alternatives may also be viewed as a "cost avoidance" factor. Chapter 11 discusses cost analysis considerations in greater detail.

If FPR management is not a separate enterprise in the overall plant management strategy, estimating FPR costs may be a formidable task. However, without an economic baseline you have no actual measure of improvements or increased efficiency. All optimization problems boil down to an economic comparison of the alternatives. FPR management is no exception.

1.7 Step 7: Brainstorm the Alternatives

With information from Steps 1 through 6 in hand, you can now brainstorm how the limiting factors may be altered to reduce the overall FPR management costs. For example, a rigorous examination of water use in the plant may identify locations where flow restricting nozzles or modified dry clean up could eliminate the need to expand wastewater treatment facilities. Running raw product through a waterless soil removal device before processing may significantly reduce solids in the wastewater treatment facilities. Uncontaminated soil dislodged from potatoes, for instance, is considered an agricultural waste, which is subject to less rigorous regulation. In the lavatory sewer hook-up example, you may eliminate one restroom connection for $20,000 in capital improvements. In return, the on-site wastewater treatment facility sludge may now be managed as an FPR rather than as sewage sludge. While first-year sludge management cost savings may be less than the cost of eliminating the restroom hook-up, successive years will more than make up for the expenditure. In addition, the FPR sludge has greater potential for beneficial use, thus moving this FPR up on the FPR hierarchy. In some cases, combining similar FPRs may result in a composite FPR that may be handled more efficiently. The combined FPRs could have superior qualities to the individually handled FPRs.

Brainstorming alternative FPR management strategies will set the stage for Chapters 3 and 4, which describe FPR characterization, sampling, and analysis.

Chapter 2: Creating a Process Flowchart

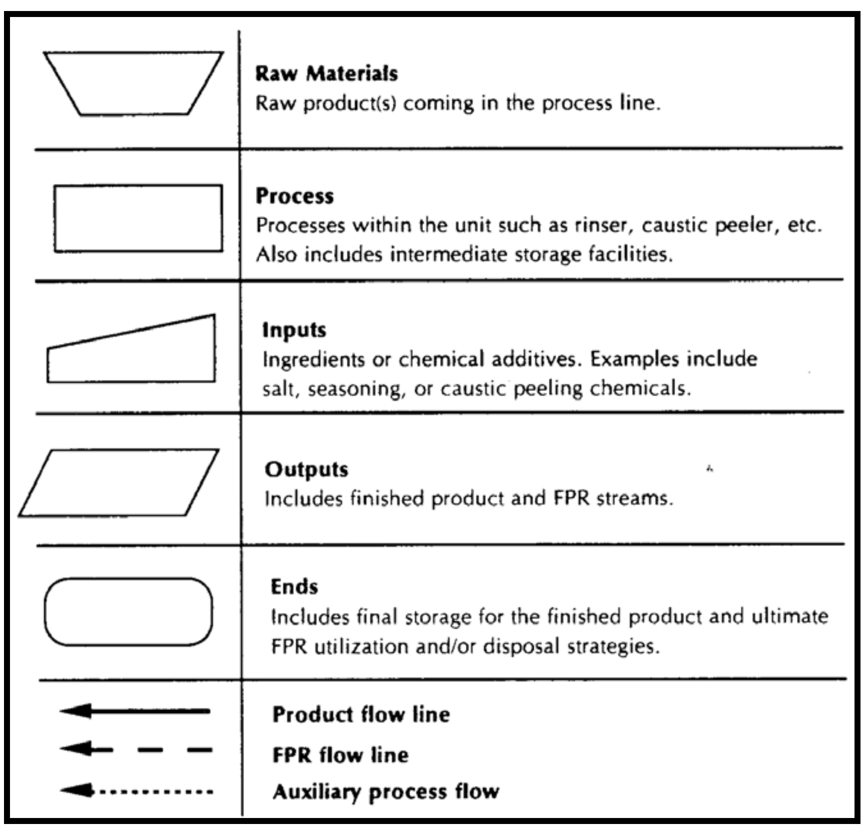
In Chapter 1, FPRs were characterized from a broad perspective. Now it's time to answer specific questions about each FPR. Where is it generated? What potential inputs may have altered characteristics during processing? How is the FPR processed? A process flowchart is an FPR management tool that can answer these questions. In this chapter, we will explore how to create your own consistent flowcharts for each process within your plant. These flowcharts will become the basis for determining FPR hierarchy placement and utilization options discussed in later chapters.

2.1 What Is a Flowchart?

A flowchart is a powerful tool for FPR management because it compiles considerable amounts of information into a consistent format. It identifies important steps within each process unit and identifies where FPRs are generated. Once you have created the basic flowchart, you can then add the information you glean from Chapters 3 and 4 about flows, volumes, and FPR characteristics. At this point, the chart can be used to develop material balances – a balance of mass input with mass output and mass accumulated. This concept was described in Chapter 1. By diagramming such information you determine where losses are occurring in the system and where to concentrate reduction efforts. It cannot be stressed enough that the creation of an accurate and comprehensive FPR flowchart can in itself be the basis for a number of FPR management decisions.

A good flowchart will use consistent symbols that provide specific information about a process or flow. Figure 2.1 identifies these symbols and their definitions. Within each symbol you write the name of the component and later on, after completing Chapters 3 and 4, you can fill in flow volumes and characteristics of interest. We will examine these flowchart components in detail but first we need to identify unit processes.

Figure 2.1 Flowchart components



2.2 Defining Unit Processes

Before making the flowcharts, first identify all unit processes of interest. Remember that FPR treatment (e.g., wastewater, drying, etc.) is also a process that generates outputs. Assign a name to each unit process and create a separate file for each one. Compile all available information on these units and the raw product that they process. The following are some potential sources of information:

- existing process line diagrams
- standard operating procedures and operating manuals
- raw material purchase records
- batch makeup records
- plant personnel
- product specification sheets

Gain an understanding of each process. Talk with personnel in the plant who can clarify exactly how equipment works, where pipes connect and discharge, and what inputs are added on the process line. Draft rough flowcharts by spending some time in the plant when lines are running. Refer back to the worksheets from Chapter 1 to make sure that you have covered all-important processes. Now you are ready to use the flowchart components in Figure 2.1 to refine the charts and make them consistent for each process.

2.3 Compiling Flowchart Components

Step 1: Connect Unit Processes

Start to draft the flowchart by putting the raw material in its symbol – the first symbol in Figure 2.1. Next, put processes in the rectangular symbols and order them according to flow, connecting each process to the subsequent one with solid arrow lines. This is the path that raw materials follow to become a finished product.

For example, potatoes for a chipping process are washed, peeled, sliced, fried, cooled, and bagged.

Step 2: Add Inputs

Process inputs may include chemicals, process water, ingredients, seasoning, and steam. You should have gleaned this information from the purchasing records and batch makeup records. Put each input in the appropriate flowchart symbol and connect it to the process where the input occurs.

For example, at the potato chip plant, a caustic might be added at the peeler, oil at the fryer, and salt at the cooling stage.

Step 3: Add Outputs

This step identifies outputs. Give each output a specific name and put it in the parallelogram symbol. Outputs can be primary products, coproducts, FPRs to be reused, and waste to be disposed. Be sure to gather all output information from waste manifests and shipping papers, production records, and wastewater treatment. For FPRs coming off of a process, use a dashed line to connect it to the process. For products and coproducts coming off of the production line, use a solid arrow line.

For example, final outputs from a chipping operation might include potato chips; chip pieces skimmed from the fryer; wastewater from the peeler, washer, and cooker; and skins from the peeler.

Step 4: Indicating Use and Disposal Methods

At this point, you are ready to put "ends" on the flowchart. These are final uses and disposal methods for all outputs coming off of the various processes. Sometimes these may only be storage facilities or coolers in the case of the finished product or, for wastewater, an end might be the wastewater treatment plant. (Of course, the wastewater treatment plant would then have its own process flowchart.)

For example, potato chips would go to the warehouse; chip pieces from the fryer and potato skins might go to animal feed; wastewater would go to a treatment lagoon.

Step 5: Account for Auxiliary Process Features

Now that you have the skeleton of the flowchart – from raw material to ultimate use and disposal – you must now incorporate auxiliary process features. Not directly related to production, these features might include cleanup cycles, recycled water, or makeup water. Although this information may be difficult to obtain, it is very important to collect data or estimates of wastewater flow volumes added to process lines. Label these outside of the actual flow chart and use a dotted line to show their flow.

For example, water used to wash peeled potatoes might be recycled to the intake flumes to wash incoming raw potatoes before it is discharged to the wastewater treatment plant.

Step 6: Add Flow Volumes

This step is really the key to the material balance principle. By adding input and output volumes to your flowchart, you will have all the weapons you need to pinpoint problem areas and material losses, and make economic decisions about recycling, utilization, and treatment.

You will complete this step after you read about flow measurements in Chapter 3, but here are two points to consider before you add any numbers to the flowchart: First, what level of detail do you want to include in the flowchart? When you first start flowchart development, you may only want to incorporate volumes for known problem areas. However, attention to detailed flow measurements at this stage of the management process will make it easier to assess waste reduction opportunities later. Second, what units will you use to determine volumes? You can measure flows by the minute, hourly, daily, weekly, or even monthly. You can also measure average values over a given period of time. Whichever you choose, make sure that all flow measurements added to the flowchart are measured over the same time period.

Step 7: Add FPR Characteristics

A final piece of information to add to the flow chart is flow characteristic data. Refer to Chapter 4 to learn how to obtain this data. While it is not necessary to add all analyses to the flowchart, you may want to write in a characteristic of concern.

Figure 2.2 provides an example of a completed flowchart. Figure 2.3 shows a process flowchart for a wastewater treatment facility at a potato chip plant. By adding flow volume and waste characteristic data, you now have a fairly accurate and detailed assessment of the unit process __ all on one flowchart. As you will see in Part II, you've created a very powerful tool for assessing your management alternatives.

Figure 2.2 Sample flowchart of potato ship processing

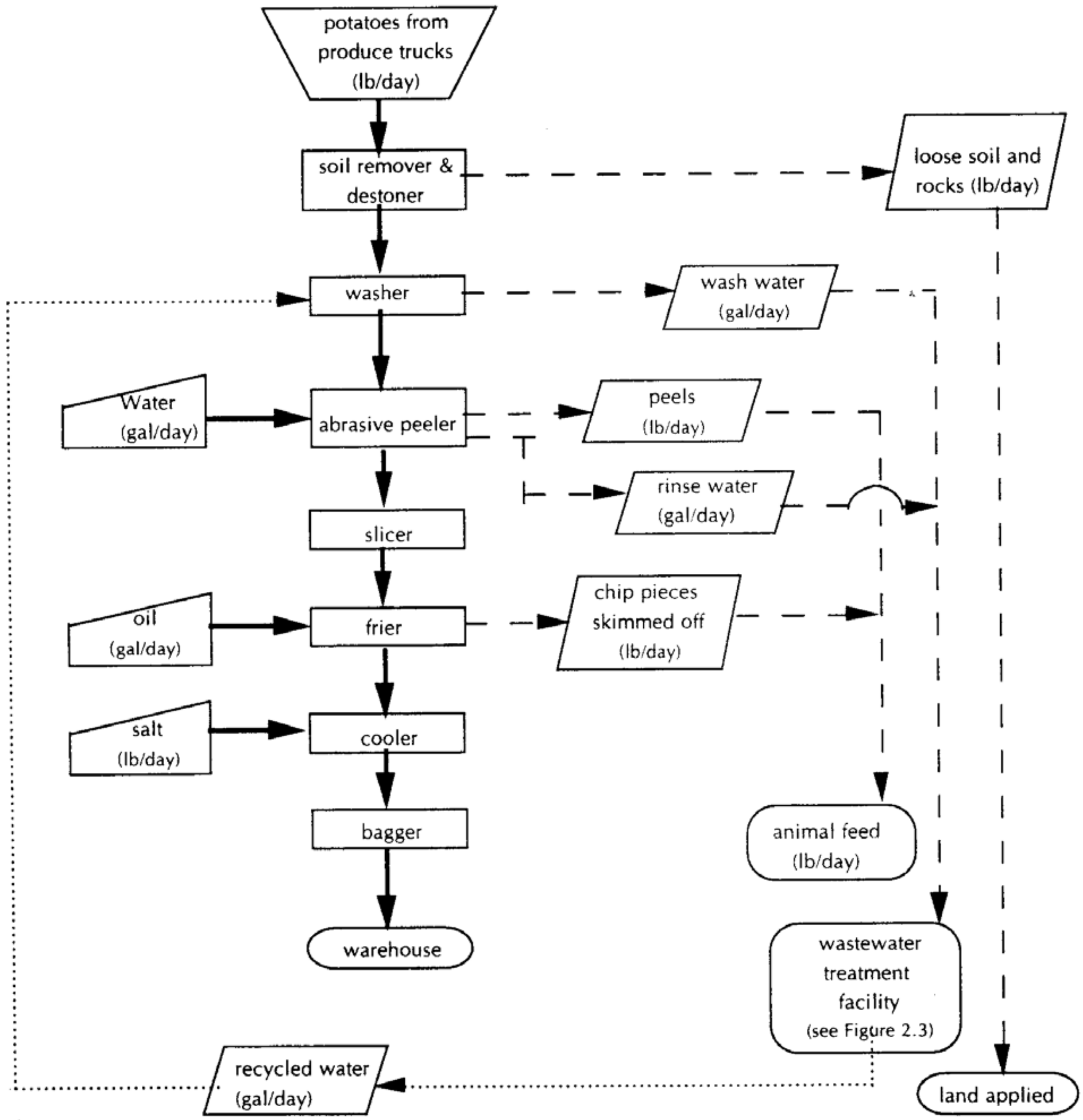
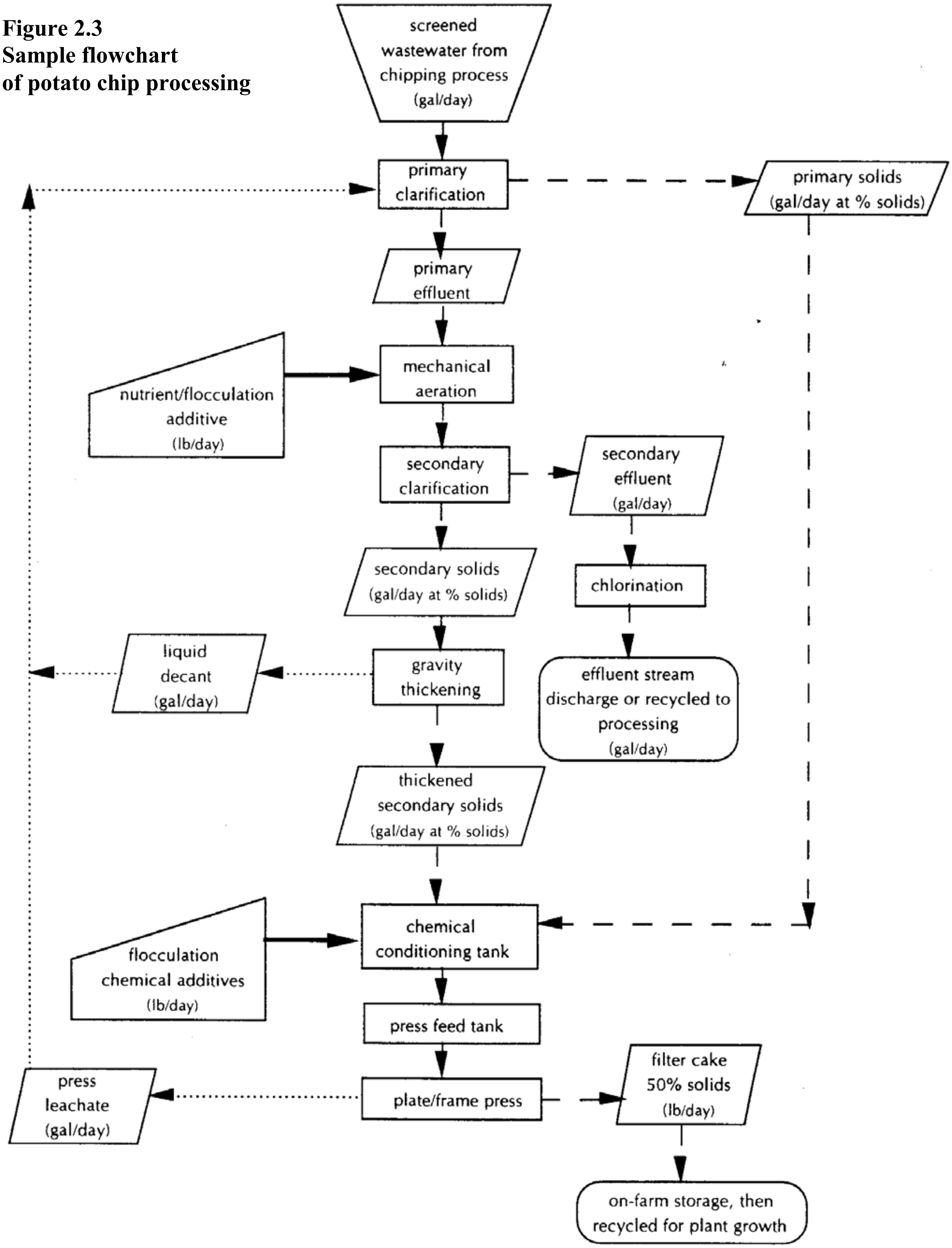


Figure 2.3
Sample flowchart
of potato chip processing



Chapter 3: Characterizing Food Processing Residuals

Previous chapters introduced the concept of using the hierarchy as a tool to formulate strategies for effective FPR management and collect data describing current programs and facilities. Regardless of the type of FPR you generate and the method you employ for reuse or disposal, thorough characterization is essential. In this chapter we will examine the issues related to characterization. FPR properties of importance and types of analyses are introduced. A more detailed discussion of FPR properties is reserved for Part II of the manual where specific test values and interpretations are covered. To characterize your FPR, you need to ask the following strategic questions.

3.1 Is Your FPR a Waste?

Food processing wastes and food processing sludges are considered wastes unless they meet the exemption provided in the waste definition, Section 287.1 of the residual regulation, qualified as *coproduct* (Sections 287.1 & 287.8), or are materials from the slaughter and preparation of animals that are used in manufacturing of products. The definition of waste does not include materials directly returned to the original process from which they were generated without first being reclaimed, or materials from the slaughter and preparation of animals that are used in the manufacturing of products.

A coproduct is a material generated by a manufacturing process that is not the product but can be used as a substitute for land application or energy recovery in lieu of a product or raw materials. <u>A coproduct is not a waste and is therefore not regulated under the PADEP Residual Waste Regulations (Title 25, Ch. 287-289).</u> Accordingly, coproducts are exempt from all PADEP requirements noted in this manual. If you make the claim that you are producing a coproduct, you bear the burden of proof that the material is in fact a coproduct. Accordingly, thorough chemical and physical characterization is necessary.

3.2 Is Your FPR a Liquid or a Solid?

FPRs are frequently high in moisture content. Unless fluid material is conveyed by pipe to its ultimate recycling, utilization, or treatment location, high moisture content is an obstacle for FPR management. Excess water means increased volume or weight and, in most cases, significantly increased transport costs. For example, consider a 1% solids wastewater treatment plant sludge that is land applied. For every pound of solid material applied, 99 pounds of water is applied. Increasing sludge solids content to 2% yields a striking reduction in the amount of water being applied. In this case for every pound of solid material applied, 49 pounds of water was applied. Table 3.1 illustrates how reducing FPR water content affects the total amount of material requiring handling.

As Table 3.1 shows, dewatering can reduce FPR volumes dramatically. Dewatering FPRs to the point where no free draining liquids are present offers storage advantages since liquid containment is not necessary. The absence of free draining liquids is also a very important consideration for landfill disposal. Generally, drier material can be stored longer and offers the greatest flexibility for alternative recycling uses. Heat dried material is best suited to pile storage and least susceptible to odor emission.

Dewatering technology and sophistication unfortunately requires additional costs and expertise. Also, chemical-conditioning agents used in dewatering must be selected carefully so that they do not introduce other use limitations. When considering these limitations, always establish water conservation practices (Part II, Chapter 5) as a top priority.

When you consider FPR dewatering, the bottom-line question is, Will the reduced transportation costs, storage longevity, and flexibility, and reduced odor problems offset the increased costs associated with construction, operation, and maintenance of dewatering facilities? This question can be answered only by carefully evaluating your options and FPR management constraints.

Table 3.1 Impact of FPR dewatering on the amount of material handled.

Solids content %	Water handled for each lb of solids (lb)	Example of applicable technology
1	99	Clarification
2	49	Gravity thickening
5	19	Dissolved air flotation
20	4	Belt filter press
50	1	Recess chamber press
95	<1 oz.	Heat drying/pelletizing

Note: Technology examples are provided only to illustrate that commonly available methods are capable of achieving listed solids contents for certain materials. Applicability or effectiveness of listed methods is dependent on specific properties of the FPR. Numerous other technologies are also available.

3.3 How Much FPR Do You Have?

Volume estimation of variable flows such as those typically experienced in food processing plants is not an easy task. It usually involves a substantial amount of labor and/or sophisticated equipment. Start by planning a detailed strategy that will yield the best estimate with a reasonable level of effort. During the data collection period identify factors that may contribute to data bias. Finally, after data collection, you must consider whether the information you gathered is truly representative of the time period for which you intend to use it. The decisions you make during this process are among the most difficult you will face. A seemingly minor error in volume estimation can mushroom into a serious problem if, for example, FPR handling, storage, or treatment facilities are undersized.

Solid FPR estimates are usually based on volumetric (cubic yards) or weight (tons) measurements. The preferred method of measurement is by weight since this measure is not influenced by container size and capacity. Solid FPR generation rates are easily estimated. Simply combine the number of containers or the weight of materials shipped from the plant in a given period. Select a time frame that will yield the best information for your program. This may be based on one shift, a full workday, or a week.

To estimate slurry and semisolid FPR volumes use gallons or wet tons with an accompanying solids content value. For example, the term 5,000 gallons at 5% solids provides a basic description that relays considerable information. Even if you have not personally observed the material, you can judge that a 5% solids material is probably fluid. You can also determine the approximate wet and dry weights of the FPR (assume 8.5 lb per gallon). Measuring these FPRs requires either full pipe flow metering devices, open channel flume or weir measurement methods, or batch volume estimations. For example, you may need to calculate the number of fixed known volumes processed in a given period of time.

Express liquid FPRs – generally <0.5% solids – in gallons. Gallons per day (gpd) or million gallons per day (mgd) are common ways of expressing the discharge rate per unit time for liquid FPRs. Measuring also employs various full pipe flow, open channel flow, and batch volume methods. For more information on pipe flow and open channel flow measurement considerations, refer to Additional Resource B at the back of this manual. A concise review of flow measurement technology used for wastewater treatment is presented. This paper is applicable to most FPR needs.

Use the flow diagrams you created in Chapter 2 to locate appropriate locations for volume measurement. When evaluating FPR volume generation data, be sure to consider rate fluctuations. Continuous flow recording devices are well suited for this purpose. Adjust projections in accordance with product output for that period. Viewing the amount of FPRs generated per unit of production is a useful way of expressing the FPR generation rate.

3.4 Is Your FPR Variable?

One important characteristic of FPRs is that they are highly variable in nature. It is not unusual for several processing lines to contribute to a common underfloor FPR collection system. The combined flow is then treated as a single FPR. A change in any one of the processing lines, therefore, affects the composite. Week-to-week or even day-to-day fluctuations in FPR are the rule rather than the exception.

FPR properties change due to the seasonal nature of agricultural commodities and daily shift changes. Production line changeovers to successive, different crops (as they reach maturity) dramatically affect FPR characteristics. Water consumption and waste strength observed during the cleanup shift will obviously be different from that observed during other times of the day. The challenge to the FPR manager is to develop an FPR management strategy that accounts for these variables.

3.5 What Characteristics Best Describe Your FPR?

Representative characterization means that the description you use to classify your material truly represents the FPR from your plant. If the FPR does not meet the specifications made in your claims, a representative characterization was not made. This is especially important for beneficial use or disposal options. Higher levels in the hierarchy generally have tighter specifications.

Typical FPR characteristics reported in the literature provide some guidance concerning expected properties. However, you must not assume that your FPR is typical. Textbook values cannot be the foundation for your management program because they do not reflect the specific processes of your plant. Each food processing plant faces unique circumstances. Effective management begins with a thorough understanding of your FPR. This means that you must take the extra steps necessary to understand composition and how it varies over time.

A representative FPR characterization considers seasonal and daily fluctuations in the process line operation. Continuous monitoring of flow rates is practical in some situations, using automatic flow recording devices. When continuous monitoring is not practical, rely on carefully planned periodic measurements to represent FPR characteristics over time. This may be a daily, weekly, monthly, or seasonal undertaking.

No one is better qualified to design your basic characterization program than the people who handle FPRs daily. Even outside consultants would have to rely heavily on feedback from plant personnel. However, one clear advantage that an outsider brings is a fresh perspective. As with anything else, daily contact sometimes blinds you to things that may be obvious to an onlooker.

3.6 Is Your FPR a Potential Source of Odor?

More than any other factor, odor is listed as the most common source of complaints in FPR management programs. Two common sources of nuisance odors are land application fields and FPR storage areas. (Land application odor problems are more fully addressed in Chapter 8.) However, odor complaints also arise from wastewater treatment facilities, composting facilities, FPR animal feeds (e.g., ensiled cannery FPR or wet whey), and some food processing operations themselves. Hence, a general overview of odor perception and measurement is appropriate.

Environmental odors are not pure compounds, but rather complex mixtures of ammonia, hydrogen sulfide, skatole, indol, amines, and mercaptans. Despite advances in analytical procedures, most odors are so complex and detectable at such low concentrations that isolating them is impractical. The ultimate odor-testing device is the human nose. Hence, odor detection remains a qualitative measurement. Odor perception has four dimensions: detection, intensity, character, and acceptability (also called hedonic tone).

Detection

This dimension is measured by finding the number of dilutions (with odorless air or water) required to elicit a 50% positive response from a panel of test subjects exposed to a particular sample. Results from the detection evaluation are expressed by several equivalent terms: threshold odor concentration (TOC), odor unit (OU), dilutions to threshold (D/T), or effective dilutions (ED).

Perhaps the most often used term, ED50 means that 50% of panelists could detect an odor. A relatively low ED50 value such as 2 indicates that a given volume of odorous air (say one cubic foot) requires dilution with two cubic feet of odorless air to reach threshold where the odor is detected by one-half of the population. An ED50 of 1000 indicates that the odor sample had to be diluted 1000 times to reach the same threshold point.

The detection threshold is the point at which test subjects become aware of the presence of an added substance but do not necessarily recognize an odor sensation. The recognition threshold is the point at which subjects recognize a characteristic odor. At this point, a specific odor quality description such as ammonia may be attributed.

Intensity

This dimension categorizes the perceived strength of an odor by comparing various odor concentrations with a reference odor. The n-butanol intensity scale, based on standard n-butanol solution concentrations, provides the reference odor. The test determines the rate at which intensity decreases as concentration decreases. This relationship is then used to predict concentration reductions needed to bring the intensity down to an acceptable level. Some odors require many dilutions for dissipation. Examples of these include hydrogen sulfide, butyl acetate, and the amines. Ammonia and aldehydes require less dilution.

Character

Character refers to what a substance smells like. One scale developed categorizes odor character with 146 descriptors. The scale includes such terms as fishy, hay, nutty, rancid, sewer, ammonia, etc. Character assessment is useful in determining the source and describing it to others. For a condensed list of the 146-odor character descriptors see Additional Resource C.

Acceptability

The last dimension of odor characterization is acceptability, also called hedonic tone. This trait is a subjective judgment of the relative pleasantness or unpleasantness of an odor. Odor frequency, character, and intensity all play an important role in determining its acceptability. Even a pleasant fragrance can become objectionable over time, so acceptability assessment is irrelevant to air pollution evaluation work.

3.7 How Do You Control FPR Odors?

For odor to be detected down wind from a source, it must be formed, released into the environment, and transported to the location of interest (e.g., your nearest neighbor). To control odors you must inhibit one of these processes. FPR odors arise during material decomposition. Measures that limit this biological activity can, therefore, directly affect and minimize odor formation. Limitation and minimization are the best controllers.

Low technology FPR odor control practices for diffuse sources include the following:

- moisture reduction
- aerobic condition maintenance
- pH adjustment
- shelter to reduce dissipation
- water sprays to scrub the air
- barriers to promote turbulent air mixing and dilution
- appropriate site location
- observance of local weather conditions
- timing of land application activities
- subsurface injection and incorporation

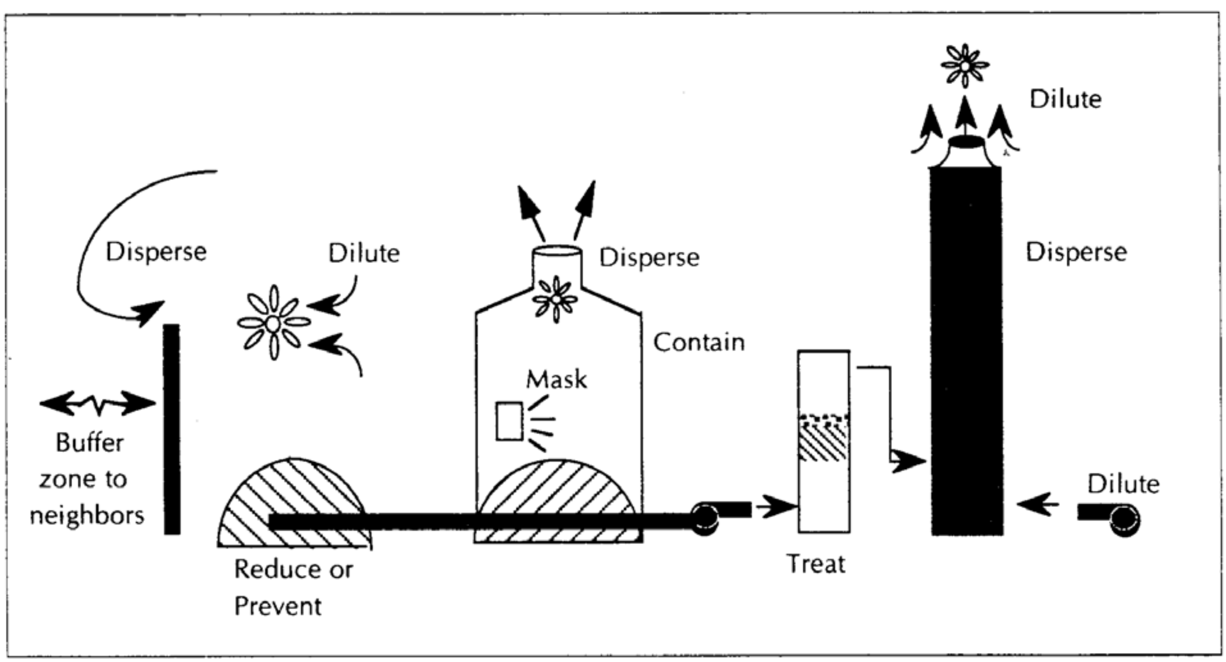
Odor control chemicals such as masking agents, odor counteractants, odor absorption chemicals, and enzymatic biological inhibitors can also be used. However, little data are available concerning chemical control effectiveness.

More sophisticated odor control solutions, normally considered for point sources such as cookers, wastewater treatment facilities, dryers, and ventilation exhausts, include the following:

- improved air dispersion (stacks)
- process modification
- ventilation modification
- add-on controls, including wet scrubbing, dry scrubbing, condensation, incineration, biofiltration
- chemical oxidation with chlorine or ozone

The various elements of odor control are identified in Figure 3.1. Chapter 8 provides additional information concerning odor control practices for land application programs.

Figure 3.1 Elements of odor control



Source: After Haug, 1990.

3.8 What are the Nuisance and Environmentally Significant Properties of Your FPR?

More than any other industrial residual, FPRs present consistently benign qualities that allow for innovative management solutions. Typical FPRs contain no toxic organics and have no more heavy metals than natural soil. After all, FPRs are derived from food grade materials that have undergone thorough inspection. Principal components of FPRs include water, carbohydrates, proteins, and fats. They are often similar to the raw agricultural product. Having said this, however, we must keep in mind that even food products can pose a hazard to human health and to the environment if they become contaminated or are not properly stored or disposed.

Nuisance and environmental FPR characteristics affect four areas of interest during production and management:

- human health and safety
- animal health
- plant growth and productivity
- general environmental degradation (e.g., odors, dust, noise, etc.)

These categories are interconnected. Clearly, environmental pollution may have a direct impact on human health. Vegetation that has been exposed to toxic materials may show no visible contamination, but may severely affect animals who consume it. An ingested pollutant may pass from plants to animals to humans, or directly from plants to humans with no apparent negative effect until toxic levels accumulate. This study of potential pollutant routes and impacts on human health is called risk pathway analysis. Risk pathway analysis is currently receiving much attention by environmental scientists.

Environmental regulations set maximum allowable levels of potential pollutants. Because environmental pollution has serious consequences, regulators often establish seemingly conservative cutoff values. However, to err on the conservative side is more acceptable than underestimating the pollutant hazard.

Table 3.2 provides a list of FPR characteristics significant for management planning. The list contains many parameters or qualities, which typically are not present in your FPR. However, a thorough review of important characteristics must at least consider hazardous waste qualities, parameters important for landfill disposal, land application parameters, and animal feedability potential. The table is not all - inclusive. If you know about important qualities or parameters not contained on the list, you should assess their beneficial and environmental properties before implementing the strategies described in Chapters 5-10.

This list may appear overwhelming at first sight, but you can eliminate many parameters if you have thorough knowledge of FPR sources and can substantiate your claims. This applies particularly to hazardous waste qualities. If you have no intent to pursue animal feed recycling, the feedability parameters can also be deleted from consideration.

Table 3.2
Select FPR parameters of importance

Human Health and Safety	
Listed hazardous wastes	Chromium
Ignitability	Lead
Corrosivity	Mercury
Reactivity	Nitrate nitrogen
Toxicity	Phenolics
Total organic halogens (TOX)	Cyanide
Cadmium	Floride
Pathogens	
Animal Health	
Dry matter	Aluminum
Digestible energy concentration	Boron
Metabolizable energy concentration	Calcium
Net energy of maintenance	Copper
Net energy of gain	Iron
Energy of lactation	Magnesium
Crude protein	Manganese
Fiber (crude) in animal feed	Phosphorous
Acid detergent fiber	Potassium
Fat	Sodium
Microbiological (pathogens)	Zinc
Sharps (glass, metal, etc.)	Pathogens
Plant Growth and Productivity	
Sodium absorption ratio (SAR)	Zinc
Calcium carbonate equivalent (CCE)	Kjeldhahl nitrogen
Plant pathogens (bacteria, nematodes, etc.)	Ammonia nitrogen
Carbon nitrogen ration (C:N)	Nitrate nitrogen
Soluble salts	Organic nitrogen
Sodium	Total nitrogen
Chlorides	Phosphorous
Copper	Potassium
Nickel	
General Environmental Degradation[a]	
Oil & grease (or petroleum hydrocarbons)	Sulfate
Pathogen reduction	Biochemical oxygen demand
Storability (how well does the FPR store?)	Chlorine residual
Total solids	Dust, noise
Suspended solids	Vector attraction
Volatile solids	Free liquids
Dissolved solids	PH
Fixed solids	Odor

a.) Parameters not otherwise listed which are useful for wastewater treatment, landfill disposal, & nuisance assessment.

Chapter 4: Sampling and Analyzing Food Processing Residuals

After completing Chapters 1-3, you should have a general idea of where your FPRs fit in the hierarchy. Now your position will be further narrowed through representative sampling and appropriate methods of analysis.

Chapter 3 listed a number of qualities and analytical parameters that can be used to assess FPRs. In this chapter we examine what constitutes a good sample and introduce some of the basic laboratory methods used for analyses. What these results mean in the context of the hierarchy is also considered. A thorough discussion of analysis interpretation is reserved for Part II of the manual where specific beneficial uses and disposal alternatives are addressed.

A list of Pennsylvania laboratories by county is provided in Additional Resource D. Additional Resource E provides a table summarizing required sample containers, preservation protocols, and methods of analysis.

4.1 Sampling Procedures

Accurate sampling produces a representative volume of material small enough to conveniently handle and transport to the laboratory. Test results are no better than the sample upon which they are run. Your sample must reflect proportionate volumes and concentrations of the FPR being evaluated. After collection, the sample is preserved to insure that characteristics remain stable before analysis. Remember, when you submit a sample to a laboratory for analysis, you are responsible for the validity of the sample. The appropriate use of analytical results is possible only when sample collection and preservation conditions are known.

Prior to sampling, contact the laboratory. Discuss the specific tests you desire and request special instructions for sample collection and preservation. For example, some analytical procedures require that suspended matter or turbidity be filtered from liquid samples during sampling. Request sample bottles, appropriate preservatives, bottle labels, chain of custody paperwork, and an ice chest if samples are to be refrigerated. Inform the laboratory when you expect to deliver your samples so that they can schedule testing for any parameters which require minimum storage before analysis. For example, biological and nitrate-N samples should be analyzed as soon as possible.

The lab will chop or grind solid/semisolid samples prior to sub-sampling for analysis. Generally, laboratories sub-sample and analyze liquids accurately. They tend to be less successful at sub-sampling and analyzing heterogeneous, bulky samples. If you prepare the sample by chopping or grinding, take care that you do not introduce foreign contaminants (certain metals, particularly lead, can invalidate the sample). When searching for a laboratory that performs bulky sample analysis, inquire about the number of tests they perform daily/weekly on the type of material you desire analyzed. Ask about their sub-sampling and grinding protocol and the size of the analysis sample. A one-gram sample may be too small for certain FPRs. When possible, laboratory procedures using large samples for analysis are recommended (e.g. use the macro-Kjeldahl method for nitrogen analysis rather than the semi-micro-Kjeldahl method).

Maintain a record of every sample collected. This includes location of the sample point, time, date, name of the sampler, and other information necessary to define sampling conditions (e.g., temperature, flow conditions, process being conducted, etc.). Do not rely on memory. Your recorded sampling information should provide enough direction for another person to secure a similar sample without personal guidance.

Sampling protocol depends on what you are sampling -- no fixed procedure applies to all situations. For example, before collecting samples from a water distribution system, allow water to run long enough to assure sufficient flushing. Representative groundwater samples require that the well be pumped long enough to displace water standing in the casing with fresh groundwater. You should also record the flow rate and the duration of flushing in these cases. The sampling of open channel flows may require sampling at varying depths or even across the channel if it is very wide. Lagoon sampling, or other large contained volumes, also requires care in selecting sample location, depth, and frequency. Avoid sampling surface scum unless that is your specific intent.

Be mindful of the general laboratory procedures to be used and the purpose for sampling. Do not underestimate the importance of good representative sampling. Accurate sampling lays the foundation for a successful FPR program.

4.2 Sample Types

Three basic types of samples are commonly recognized: grab or catch samples, composite samples, and integrated samples.

Grab samples

Grab samples are just what the term implies – a single sample representing a specific place or time in the FPR stream. Grab samples are adequate for sources with consistent composition over a considerable period of time, or over substantial distances in all directions. Examples of such sources include water supplies and some surface waters. Don't use a grab sample to characterize a wastewater stream; such streams vary too much.

Composite samples

Composite samples are a series of grab samples blended into a single sample to represent the average concentration over a given time or space. Time-composite sampling involves obtaining grab samples at a fixed location, at a predetermined frequency, and mixing them as a single sample. A sub-sample from the mixture is then used for analysis. Sampling frequency may be once a day, after each work shift, or every few hours.

Time composites may be either a blending of constant volume grab samples or the combination of individual grab samples having volumes proportional to flow. The latter case is called fixed time - flow weighted sampling. This type of composite is essential for representative sampling of many liquid FPR streams. Figure 4.1 shows how this type of sample is taken.

In liquid containment facilities such as digesters, lagoons, or tanks, a representative sample should have at least four grab samples. Grab samples should be composited over a 24-hour period. Each sample should be from different depths and locations in the unit. After sampling, thoroughly mix the grab samples in a single container and obtain a sub-sample for analysis.

Representative composite samples of stored solid materials, drying bed solids, or piles should contain at least ten grab samples. The recommended procedure involves creating an imaginary grid over the area to be sampled and obtaining grab samples from the center of each grid block. Grab samples should be thoroughly mixed and sub-sampled for analysis.

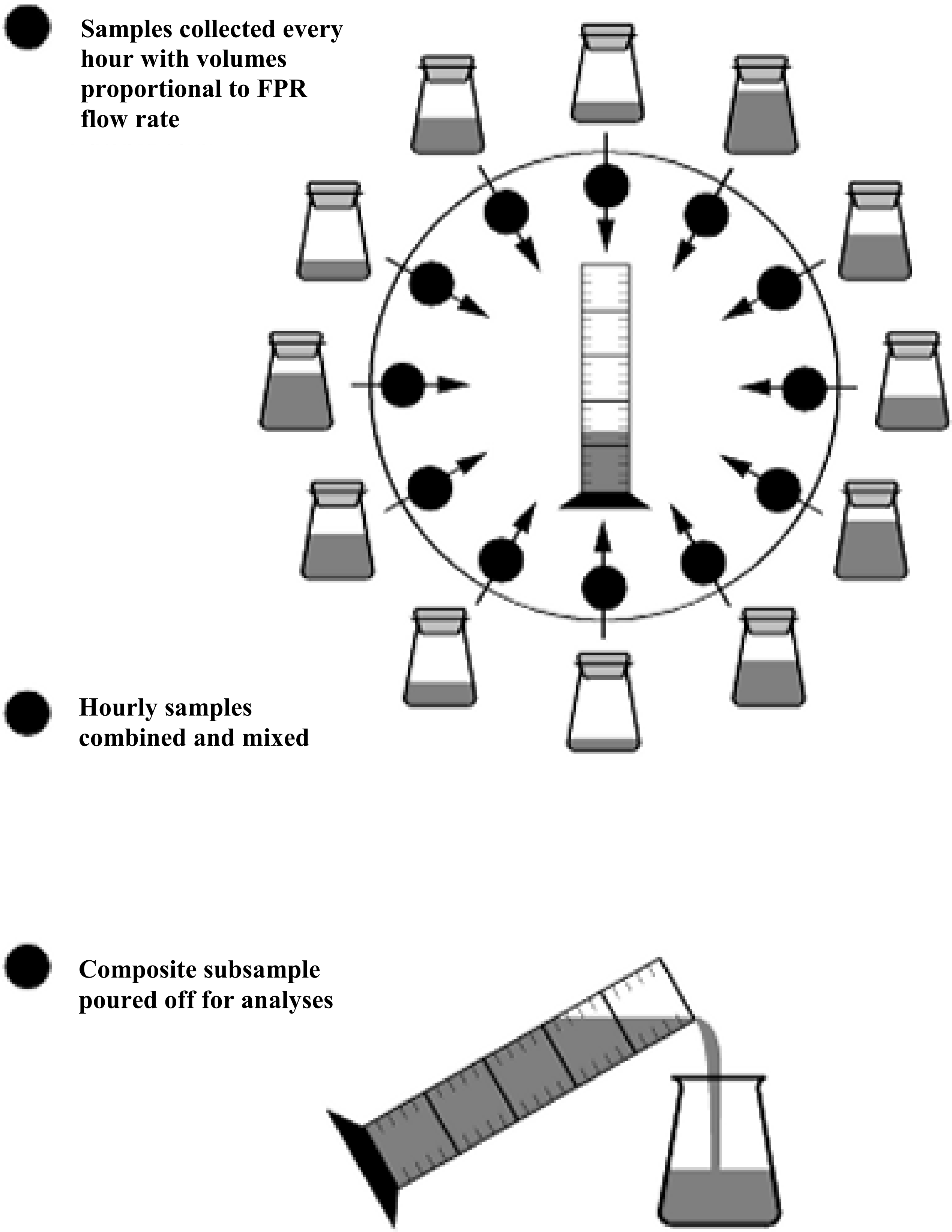


Figure 4.1 Fixed-time flow weighted sampling

Soil sampling, shown in Figure 4.2, is a good example of spatial composite sampling. Individual composite soil samples used for fertility management or soil chemistry monitoring should not represent more than ten acres. It is usually best to sample on a field basis since this is the way the farmer manages his operation. Fields greater than ten acres, or those containing two or more significantly different soil types require more samples. A composite soil sample should contain at least fifteen grab samples for a ten-acre field, and no fewer than ten grab samples for small fields. Normally, samples are secured from the plow layer (6 -11 in deep) and blended in a container. A representative sub-sample is then removed for analysis.

As illustrated above, it is not possible to establish universal rules for all sampling situations since circumstances vary. Representative sampling of most FPRs requires making composites of individual samples over a period of time or at numerous sampling points. Because of FPR variability, large sample composites are usually recommended. For any sampling procedure (grab, composite, integrated) be sure to follow the same procedure during repeat sampling to insure that data can be compared.

When sampling for characteristics that change during storage, composite sampling may not be appropriate. For example, the analyses for dissolved oxygen, residual chlorine, temperature, or pH may be invalidated by storage. These analyses should be performed as soon as possible after collection, preferably at the sample point.

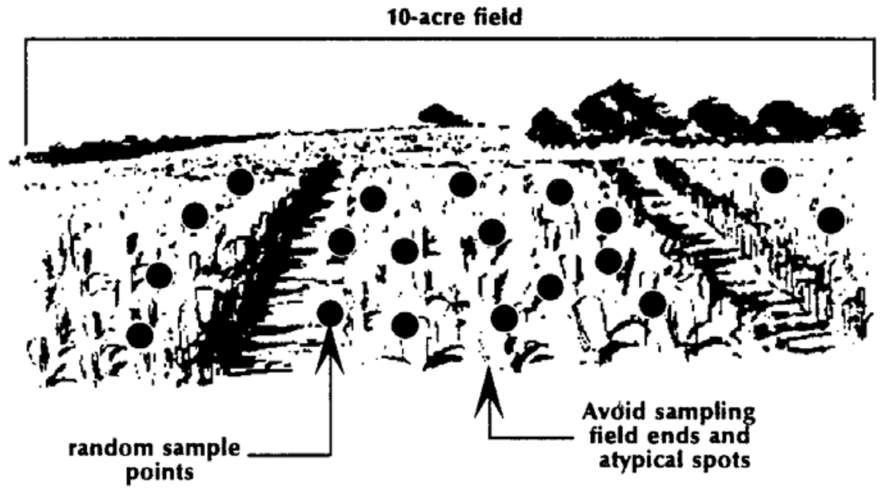
Integrated sampling

Integrated sampling involves mixing simultaneous grab samples from different points. One application would be for several separate FPRs that may be treated as one. An estimate made without sampling the combined mixture would be inaccurate. An integrated sample would better predict composition and treatability. Composite procedures can also be used at each point if differences in space and time are of concern. Each composite then becomes part of the integrated sample.

Figure 4.2 Typical soil sampling procedures

Step 1
Collect Grabs

- Obtain individual soil sample grabs from topsoil (6"±).
- Each grab should be of the same approximate size.
- Take a minimum of 10 individual samples. For a 10-acre field , collect 15 grabs.

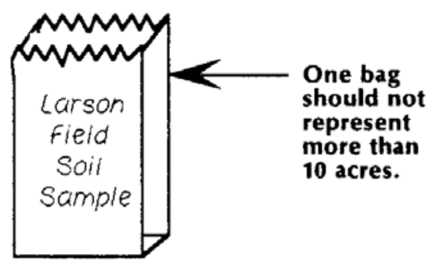


Step 2
Composite Grabs

- Combine all grab samples in one container (e.g., a bucket)
- Break soil clumps up
- Remove organic debris
- Mix thoroughly

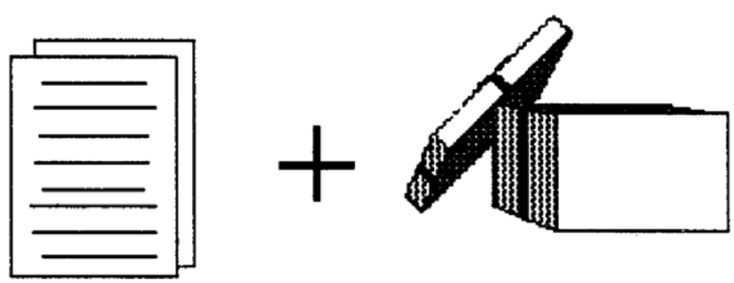
Step 3
Take Representative Subsample

- Take a representative subsample from the composite sample
- Put subsample in a bag



Step 4
Complete Sample Logging

- Fill out the appropriate paperwork
- Mail or deliver to the laboratory



Note: Become familiar with specific soil sampling recommendations provided by the laboratory performing your analyses.

4.3 Sample Collection, Size, and Preservation

You can collect samples either manually or with automatic sampling devices. Manual collection of time composite samples is labor-intensive. Occasional manual sampling can be performed by personnel working in the immediate area; however, it is not usually economical for routine sample collection. Automatic samplers are being used increasingly because they are effective and reliable, and they greatly increase sampling frequency. When considering the use of automatic sampling devices, you should consult with several manufacturers to select the unit you need for the specific job.

Due to the variability of FPRs, very large composite sample volumes are usually needed. This is particularly true for solid materials. A two-liter subsample is sufficient for most physical and chemical analyses of liquid FPRs. One-kilogram subsamples are needed for a representative solid FPR. See Additional Resource E for specifics on minimum sample size for individual tests. Since sample collection methods for biological, chemical, and microscopic analyses are different, separate samples are required for each. Also, it is generally a good policy to maintain a duplicate sample of material sent to the laboratory. This sample can serve as a backup if laboratory results reveal unusual findings or if the sample is lost.

Effective preservation methods are usually limited to pH control, chemical addition, refrigeration, and freezing. These methods are intended to retard biological activity and chemical changes. However, we must recognize that sample changes during storage are inevitable. Complete sample stability is impossible. When you minimize the time of storage prior to analysis you will usually obtain more reliable results.

4.4 Types of Analyses

The types of analyses required to characterize an FPR adequately depend on the intended use. In this section, we will introduce applicable test methods and specialized analytical procedures. Further discussions on interpreting test results are presented in Part II. Additional Resource D provides guidance for locating laboratories that perform these tests.

Animal feedability profile

This test series assesses the nutrient value of animal feed materials. The analysis array of tests and data interpretations to give a measure of ten characteristics that describe the estimated energy, fat, fiber, and protein values, eleven minerals, and a microbiological involves an assessment. The animal feedability profile is discussed in detail in Chapter 7.

General water chemistry

Analyses falling into this category determine characteristics of process water or wastewater. Test parameters include: ammonia, nitrate, Kjeldahl nitrogen, organic nitrogen, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), heavy metals, microbiological (coliform), oil and grease, pH, phosphorus, solids (all types), soluble salts, etc.

Hazardous wastes

All wastes must be evaluated for hazardous qualities. A material is considered hazardous if it is produced by a hazardous-waste-generating process, or exhibits hazardous characteristics, such as corrosivity, ignitability, reactivity, or toxicity. FPRs can become hazardous through contact with a hazardous substance although, this occurs only under unusual circumstances. A thorough input inventory and accurate FPR flow charts can provide justification for exemption from hazardous waste determination testing. Hazardous waste determination and disposal is discussed briefly in Chapter 10.

Leaching tests

Leaching tests are analyses performed on solid or semisolid materials in order to anticipate the potential for compounds to migrate to surface waters or groundwater. The Toxic Characteristics Leaching Procedure (TCLP) and the American Society for Testing Materials (ASTM) water leaching test are used to make this assessment.

The TCLP test employs a slightly acidic leaching solution to simulate a condition where waste is exposed to an acidic environment, as in a landfill. The TCLP test is recognized as the accepted methodology for determining hazardous waste toxicity. The standard test involves examining 39 parameters including various heavy metals and synthetic organic compounds. The TCLP test series costs about $1000 per sample.

The ASTM water leaching test (Method A) simulates conditions where the residual material is the dominant factor in determining the pH of the extract. This represents the condition where rain or surface water come in contact with the material. Parameters requiring examination in the leachate depend on the intended reuse or disposal method. The standard range of tests includes COD, total solids, oil and grease, and ammonia-nitrogen. Additional parameters of interest may include iron, manganese, total organic halogen, total nitrogen, organic nitrogen, and ammonium.

Leaching tests are considered when land application recycling or landfill disposal are proposed. These tests may be unnecessary if you can document that your FPR does not produce a leachate that exhibits excessive concentrations of the selected parameters. You can use your input inventory and flow diagrams to substantiate this case. Chapters 8 and 9 provide additional information regarding these tests and their interpretation.

Sludge/solids analyses

Sludge/solids analyses are distinguished from animal feedability tests, which were addressed above. Testing solid and semisolid materials involves the use of concentrated acid to extract compounds for analysis. This strong acid extraction is called digestion. Results from sample preparation by digestion are called total concentrations. Typical digestion test parameters include heavy metals, primary nutrients, secondary nutrients, micronutrients, and trace elements.

As noted above, leaching procedures are commonly employed to evaluate solid and semisolid materials, including sludges. Leaching test results always have lower concentrations than total analysis reports since only a fraction of the compounds present are extracted in the weak acid leaching solution used.

Several special agriculturally significant tests are also performed when appropriate. Soluble salts, sodium absorption ratio, and chlorides present in the saturated extract of solid FPRs assist in defining certain use limitations. Analysis of FPR calcium carbonate equivalent (CCE) and the carbon/nitrogen ratio also apply to agricultural investigations.

Physical measures of solids content and bulk density are important characteristics when evaluating alternatives. The presence or absence of free draining liquids may be used to assess whether landfill disposal can be considered as a management strategy. The paint filter test, in which the material is placed on paint filter paper to drip drain, is used to define whether free draining liquids are present.

Sludge/solids analyses may be employed at any level of the hierarchy; however, these tests apply primarily to land application and landfill disposal discussed in Chapters 8 and 9. These chapters provide additional information regarding the sludge/solids analyses and their interpretation.

Soil chemistry and fertility

Soil chemistry testing and fertility analyses are used to manage land application programs. Soil chemistry detects plant growth problems caused by chemical imbalances, and it assesses the accumulation of heavy metals in soil. Routine soil chemistry testing is not necessary for most FPRs since elevated heavy metals are not present.

Soil fertility testing assesses the nutrient status of soil with respect to a proposed crop. The standard soil fertility test reports soil pH, phosphorus, potassium, magnesium, and calcium. Recommendations for fertilization, including nitrogen addition and liming, are provided. This information is essential for nutrient management decision making.

Nitrogen recommendations are based on the selected crop and projected yield. Soil nitrogen content is not normally analyzed at the laboratory because of difficulties in interpreting results. Use of soil chemistry and fertility testing is further discussed in Chapter 8.

Synthetic organics

Synthetic organic compounds include categories of hazardous waste materials such as organic solvents (e.g., trichloroethene), polychlorinated byphenols (PCBs), pesticides, trihalomethanes, etc. A number of the parameters analyzed in the TCLP leaching test fall into the synthetic organics group. The synthetic organics category, therefore, overlaps into the leaching and hazardous waste categories. Synthetic organics are distinguished separately from the other two categories because testing for these compounds requires sophisticated gas chromatograph/mass spectrometer analysis -- a method not available at many laboratories.

Synthetic organic compounds should not be a problem in normal FPRs. However, accidental contamination or insufficient documentation on FPR characteristics may lead to a need for testing.

Synthetic organic compounds covered in the TCLP test are listed in Chapter 8, where the use of this test is discussed.

4.5 Reporting Units

Laboratory analysis reports use standard units for reporting results. For liquid samples or leaching analyses, results are usually reported as milligrams per liter (mg/l). On occasion the term parts per million (ppm) is used interchangeably with mg/l. Analyses of solid or semisolid materials should be reported on a dry weight basis as milligrams per kilogram (mg/kg), micrograms per gram (µg/g), or ppm. Results expressed as ppm can be converted to percent (%) by simply moving the decimal point four places to the left.

4.6 Interpreting the Results

The interpretation of laboratory results depends on the nature and intended use of your FPR. Maximum permissible levels for certain constituents are established by regulatory agencies. Generally, the highest level in the hierarchy, *Recovery for Human Uses,* is regulated by the Food and Drug Administration (FDA). As you move down the hierarchy to *Recovery for Animal Uses*, the Pennsylvania Department of Agriculture (PDA) is involved in regulation. The PADEP becomes involved at *Recovery for Soil Amendments and Fertilizers*. All remaining disposal options on the hierarchy are regulated by the PADEP. In order to evaluate your FPR management alternatives, it is important to be aware of regulated cutoff values and the regulatory agencies involved.

To illustrate the use of cutoff values for data interpretation, consider a dewatered FPR wastewater treatment plant sludge. Analyses show an FPR copper concentration of 300 parts per million (ppm) on a dry weight basis. Beginning at the highest level of the hierarchy, you have already instituted source reduction practices, and ruled out human use alternatives. Animal use (livestock feed) requires that the copper level be less than 115 ppm. The maximum allowable copper concentration for land application is 1000 ppm. Based on this one characteristic, it would appear that livestock feed is not a management option for this FPR unless it is significantly diluted by mixing with other rations to reduce the copper concentration. Direct land application does appear to remain as a possibility. If the copper concentration were to increase above 1000 ppm, landfill disposal may need to be considered.

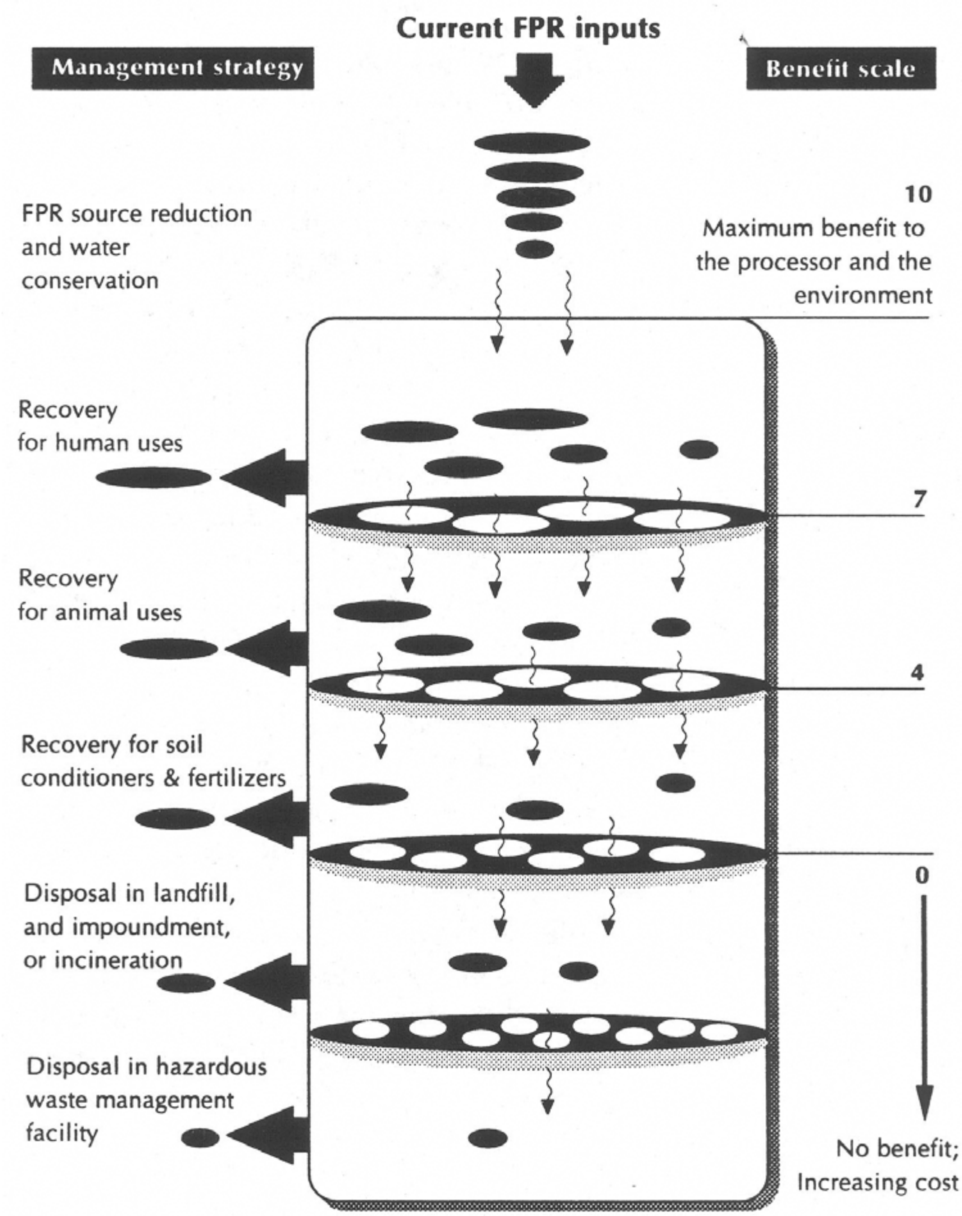
Each of the reuse and disposal chapters in Part II have been prepared to be consistent with applicable regulatory guidelines and recommended limits. As you consider alternative strategies for FPR use, refer to these chapters to see where your FPR fits. Identify those specific characteristics that limit the upward movement of your FPR on the hierarchy and examine ways of minimizing these limitations.

Part II: Implementing the Hierarchy

Having completed Part I of this manual, you are now ready to explore your FPR management alternatives as shown on the FPR Utilization Hierarchy (Figure II.1). By completing the worksheets, designing flowcharts, sampling your FPRs, and answering some important questions about FPR characteristics in Part I, you are equipped to look at your management program objectively.

The purpose of completing this part of the FPR Management Manual is threefold. The first purpose is to reduce FPR sources and conserve water within your plant--a necessary first step to any program. This level is highest on the hierarchy, yielding enormous benefits to your company and the environment. The second purpose is to fit each FPR into a hierarchy level and learn about that level to gain maximum benefit from its technologies and applications. Finally, this part explores strategies that move FPRs to higher levels on the hierarchy and describes a basic economic review to determine how feasible such a move would be. Below is an overview of each Part II chapter.

Figure II.1 FPR utilization and disposal hierarchy



- **Chapter 5: Source Reduction and Water Conservation**

The highest level on the hierarchy, these strategies are considered to be the best FPR management approach. They can be easily implemented and yield the greatest savings for your plant. Despite significant strides made by the food processing industry as a whole, many plants still fail to reduce FPRs at the source or to implement basic water conservation practices. This chapter discusses both concepts independently and points out how to aim for the ideal goal--little or no FPR generation.

- **Chapter 6: Residual Recycling/Recovery for Human Use**
- **Chapter 7: Residual Recycling/Recovery for Animal Use**
- **Chapter 8: Land Application: Recycling for Plant Growth**

Each of these chapters focuses on beneficial uses of FPRs and the technologies that can make FPRs ready for beneficial use. After source reduction and water conservation, these beneficial uses are the next best alternative. They yield somewhat high returns or minimize costs to your plant from a health, safety, and environmental standpoint. These three chapters are in order of decreasing value to your food processing facility and the environment.

- **Chapter 9: Landfill or Incineration Disposal**
- **Chapter 10: Hazardous Waste Disposal**

Chapters 9 and 10 discuss your only alternative after reduction and beneficial use--disposal. At this point on the hierarchy the FPR is a waste. *Chapter 9* covers landfilling, impoundment, and incineration disposal. *Chapter 10* discusses the worst-case scenario of a hazardous waste and how to make a hazardous waste determination.

- **Chapter 11: Moving on the Hierarchy**

This chapter briefly touches on strategies that improve FPR quality, move wastes up on the hierarchy, and reduce management costs. This chapter also presents the fundamentals for an economic analysis of alternatives. This analysis is by no means comprehensive, but it does provide an objective means of comparison.

A word about....Technology Transfer

It is worth noting at this point in the manual that use and treatment of FPRs has been extensively evaluated and researched over the past 25 years. Literature findings report on innovative technologies in virtually every area of food processing. The key to finding innovative strategies at each level of the hierarchy is to be familiar with what has been done in the past and then adopt a technology for your specific application. This is called technology transfer, and it is a vital element of an effective FPR management program. This part of the manual relies heavily on research and literature to provide examples of innovative technologies used at the hierarchy levels. The Additional Reading section at the end of each chapter in Part II directs you to key articles that provide further insight into the technologies discussed throughout the chapter. Also, Additional Resource F categorizes literature references by food groups. Additional Resource G provides an excellent paper on a literature review of technologies available for disposal and utilization of FPRs.

The goal of this manual is to provide you with as much relevant data and literature as possible. However, recognize that you may have to do a little exploring on your own to become up-to-speed on the latest technologies. Calling the author of a paper is one way to learn about new advancements in the technology. Or, where comprehensive literature reviews are not available, conduct your own search at a local college or university library. Periodicals and journals in your processing area are also excellent sources of relevant and timely information. Subscribe to those that focus on your interests. You can also build a file of relevant and innovative technologies as you find them in the literature.

Clearly, the concept of technology transfer can save you hours of "reinventing the wheel" and make your FPR program more innovative and technologically sound.

Chapter 5: Source Reduction and Water Conservation

Reducing FPR generation sources and rates yields numerous benefits. The most obvious benefit is improved plant efficiency. This connection between resources, technology, and plant efficiency is best explained in the Pennsylvania Department of Environmental Protection (PADEP) Source Reduction strategy Manual http://www.dep.state.pa.us/dep/deputate/airwaste/wm/MRW/SRS_Manual/SRS_Manual.htm where Michael Royston is quoted: "Industrial operations begin to affect the environment with the investment decision which is taken internally and subject to internal criteria of financial return and technological feasibility. However, in order to become operational, technology requires resources – water, air, land, raw materials, and energy – which are found in the physical environment. This interaction between technology and the physical environment results in depletion of the resources on one hand and a buildup of wastes – pollution – on the other. The strategy which the modern manager must learn if he is to cope with this double problem is that of non-waste technology, one which conserves resources, reduces pollution, and saves money at the same time."

The best solution to the FPR management problem is to avoid creating FPRs. For processors who use "pre-processed" ingredients, this goal may be feasible. For most processors, FPRs are an inevitable result of processing agricultural products for food or feed. But you should not blindly resign yourself to simply accepting this fate and continue business as usual. On the contrary, as Robert Shober from Campbell Soup Company explains, "With the implementation of stricter environmental regulations and rising costs required for treatment system expansions, alternatives to end-of-pipe treatment are required for successful competition in today's market." An effective source reduction program will conserve raw materials, reduce FPR management and processing costs, reduce environmental liability, increase productivity, enhance company image, and reduce the burden of regulatory compliance.

Much of the information contained in this chapter originates from the PADEP *Source Reduction Strategy Manual* and Robert Shober's paper entitled "Water Conservation/Wasteload Reduction in Food Processing Facilities." Both references are listed in the Additional Reading section at the end of this chapter.

5.1 Source Reduction

The comprehensive residual waste regulations in place since 1992 require large quantity Pennsylvania industrial generators to prepare and implement a Source Reduction Strategy (SRS). For the food processing industry, mandated SRS requirements apply only to FPRs that are wastes (Section 3.1), which are not used in a normal farming operation. SRS planning is a good practice regardless of your FPR position on the hierarchy. The following paragraphs provide a question-and-answer overview of SRS considerations.

Although the following regulatory requirements are important, do not lose sight of the goal – source reduction. Programs that strive for maximum source reduction will benefit your plant with improved efficiency and reduced environmental liabilities.

What is Source Reduction?

Source reduction is the minimization or elimination of FPRs at their point of origin, usually within the production process itself. Any strategy that reduces the amount or strength of FPRs generated during processing is considered to be source reduction. Typical source reduction strategies are:

- process modifications
- input substitutions

- improvements in input purity
- improved housekeeping and management practices
- improved machine efficiency
- use or reclamation of materials within a process
- improved packaging and conveyance
- water conservation

Source Reduction

Source reduction refers to lessening or elimination of wastes or their undesirable characteristics. Achieved through changes in the production process, source reduction includes: process modifications, feedstock substitutions, improved feedstock purity, shipping and packing modifications, housekeeping and management practices, and improved process efficiency. The term does not include dewatering, compaction, waste reclamation, or the use or reuse of waste.

Use or reclamation of an FPR after it leaves the process line is not source reduction. Accordingly, compaction, dewatering, or other treatments performed in preparation for disposal are not source reduction activities, nor is the transfer of an FPR from one emission media to another. For example, reducing solid residual material output by transferring a portion of it to the wastewater stream is not source reduction.

What is a Source Reduction Strategy?

Minimum components of an SRS include:

- A description of the source reductions achieved during the last five years. Results of your activities must be quantified. The five-year history allows you to claim past achievements and provides a context from which future planned efforts may be launched.
- A statement that a source reduction program has been established. This may include the corporate source reduction goals or a statement of commitment to the program from responsible management personnel.
- A description of specific initiatives to reduce FPRs, a timetable for execution, and a target reduction amount for FPRs generated. This description should be based on the results of your investigations and data compilation described in Part I of this manual. Reuse or disposal methods should also be noted in your plan.

If you propose no source reduction action, you must justify your decision with extensive documentation as required by PADEP. For example, conduct a detailed FPR characterization study and describe potential source reduction alternatives. Next, describe how each alternative was evaluated and why each was not selected. Your detailed discussion must address both the technical and economic barriers that eliminated each option. Ultimately, the level of effort and detail required to justify no source reduction action is substantially greater than preparing and implementing a source reduction strategy.

Who Must Prepare an SRS?

Mandated SRS requirements do not apply to FPRs used in normal farming operations (e.g., animal feed or soil amendments) or which are recycled for human uses. If your plant generates more than an average of 2,200 lbs of food processing wastes per generating location per month based on generation in the previous year, you are considered a large quantity generator and a SRS is required for each waste stream.

When Must an SRS be Prepared?

As of the printing date of this manual, food processing waste generators meeting the criteria of the previous paragraph (Who Must Prepare an SRS?) are required to have a current SRS in effect and available for inspection.

When Must an SRS be Submitted?

Your SRS must be available for inspection at any time and must be submitted to the PADEP upon request. The SRS must accompany any request or application to treat, process, or dispose of a food processing waste at a Pennsylvania permitted facility.

How Often Must an SRS be Updated?

Update your SRS every five years unless the PADEP approves of an alternative schedule. Also update the source reduction strategy whenever the type of FPR generated or the manufacturing process significantly changes. Updated plans should include the source reduction progress achieved during the previous five years and describe plans for the next five years.

Are SRS Progress Reports Required?

Biennial reports, required by PADEP for all large quantity food processing waste generators, must include progress reports on source reduction activities.

Elements of a Source Reduction Program

A source reduction program involves six basic elements.

1. <u>Top Management Commitment</u>

The success of any SRS is directly related to the support of top management. Management must communicate a positive message for source reduction. Support strategies may include:

- making source reduction a company policy
- publicizing successful initiatives
- setting specific volume or toxicity reduction goals
- demonstrating commitment through assessments and evaluations
- rewarding employees who identify cost-effective measures
- training employees in source reduction techniques
- designating a source reduction coordinator and involving all employees in a team approach

2. <u>FPR Characterization</u>

As described in Part I of this manual, thorough FPR characterization is essential for identifying reduction and reuse opportunities. Poor representative data severely handicaps effective planning and diminishes chances of success.

3. <u>Periodic Source Reduction Evaluation</u>

The *Seven-Step Program Review* described in Part I provides a basic format for conducting such an assessment.

4. <u>Cost Allocation</u>

Departments and managers should be made aware of and charged the true management costs for the FPRs their section generates. Then you can calculate the positive financial benefits that result from source reduction.

5. Technology Transfer

Many source reduction techniques have been developed which may be useful to your plant. Seek out and share technical information on source reduction from other sections or divisions in your company, from other firms, state and university programs, trade associations, or professional consultants.

6. Program Evaluation

Periodically review your SRS effectiveness. Use these evaluations to identify what works and what doesn't, and gauge the performance of the team members.

Measuring Source Reduction

Several common methods are used to quantify source reduction, including actual quantity change, adjusted quantity change, throughput ratio, and change in hazard or toxicity.

Actual Quantity Change

This is the change in weight or volume of FPR generated over a given period of time. In many cases, this measure may not adequately describe FPR generation because of changes in the production processes.

Adjusted Quantity Change

This measurement takes into account the changes in production activity. Basically, this approach involves the expression of FPR generation per unit production. To use this factor you must select a production activity that closely correlates to FPR generation. For example, your FPR generation rate can be related to the number of employees, raw materials used, the weight or number of product units, or even the dollar value of your product. The production activity you choose should be dependent or well correlated with the FPR generation mechanism.

The activity production index (API) required by EPA for reporting hazardous waste source reduction is a form of the adjusted quantity change measure. The API is used to distinguish year-to-year quantity changes due to source reduction activities. The index is computed by dividing the current year's unit production activity by the previous year's production activity. Figure 5.1 illustrates use of the API.

Figure 5.1 Use of the activity/production Index for computation of source reduction

Example: Potato Chip Food Processor

$$\textbf{API} = \frac{\textbf{1992 production}}{\textbf{1991 production}} = \frac{\textbf{8,000 tons potato chips}}{\textbf{10,000 tons potato chips}} = \textbf{0.8}$$

1.) For this example, say 600 dry tons of wastewater treatment plant sludge was generated in 1991 and 500 dry tons was generated in 1992. To calculate source reduction in 1992, multiply the previous years FPR sludge by the API.

600 dry tons x 0.8 = 480 dry tons

(480 dry tons represents the amount of expected sludge production without source reduction)

2.) To determine the source reduction, subtract 1992's actual sludge production from 480.

480 dry tons (expected) - 500 dry tons (actual) = -20 dry tons.

The negative result indicates that no source reduction occurred. In fact, the FPR quantity actually increased, relative to the amount of potato chips produced.

Throughput Ratio

The throughput ratio is the amount or mass of material released as an FPR divided by the total mass of input materials. The sum of the FPR amount plus the amount of material in the end product, plus any material consumed in the process, must equal the total throughput amount. Calculation of the throughput ratio helps to pinpoint process inefficiencies. A reduction in the throughput ratio signals increased efficiency and source reduction. Figure 5.2 shows how throughput ratio is computed.

Figure 5.2 Use of throughput ratio to monitor source reduction

Example: Potato Chip Food Processor

1991 Throughput Ratio Calculation

Inputs		Outputs	
Raw potatoes	20,000 tons	Potato chips	10,000 tons
Cooking oil	5,000 tons	Cooking evaporation losses	14,500 tons
Seasonings	100 tons	FPRs	600 tons
Total Inputs	**25,100 tons**	**Total Outputs**	**25,100 tons**

Solution:

$$1991 \text{ Throughput Ratio} = \frac{\text{FPR Amount}}{\text{Total Input}} = \frac{600}{25{,}100} = 0.0239$$

1992 Throughput Ratio Calculation

Inputs		Outputs	
Raw potatoes	16,000 tons	Potato chips	8,000 tons
Cooking oil	4,000 tons	Cooking evaporation losses	11,500 tons
Seasonings	80 tons	FPRs	500 tons
Total Inputs	20,080 tons	Total Outputs	20,080 tons

Solution:

$$1992 \text{ Throughput Ratio} = \frac{\text{FPR Amount}}{\text{Total Input}} = \frac{500}{20{,}080} = 0.0249$$

Compare 1991 and 1992 throughput ratios

1991: 0.0239 1992: 0.0249

The increase in throughput ratio in 1992 over 1991 indicates a decrease in efficiency. Source Reduction has not been accomplished in this example.

Change in Hazard or Toxicity

To employ this measure of source reduction, you must understand the FPR qualities or characteristics that restrict recycling. The factors that impose the greatest restrictions on recycling options are called limiting characteristics. A process change may reduce FPR limiting characteristics, and thus increase management alternatives. This qualifies as a bonafide source reduction activity. For example, changing from a caustic peeling process to an abrasive peeler results in the elimination of an alkaline FPR, which may only be land applied or disposed at a landfill. Changing to abrasive peeling results in non-caustic vegetable peels, which may find use as a livestock feed additive. In this case, the SRS has resulted in an FPR with greater value and expanded possibilities for beneficial use.

5.2 Water Conservation

Many food processors have no idea of the amount of water they need for efficient operation. Water supply and wastewater treatment costs account for considerable expense at most plants, with no payback. Substantial quantity reductions in FPR wastewater can be achieved by using effective, low-cost water conservation techniques. Water conservation measures have the potential, more than any other strategy, to dramatically improve your FPR management program. This fact has been continuously realized by food processors who have instituted conservation programs. Wastewater considerations aside, conservation of water can potentially lower production costs. For these reasons, special attention is focused on this crucial source reduction strategy. The following sections address this important topic.

Benefits of Water Conservation

Why should you conserve water? The primary response to this question is -- to save money. There are three major components involved in the cost of water. The first is cost associated with water supply. This includes your cost for purchase of municipal water or perhaps the installation and operation of your own well system or water storage facilities. The second factor incorporates costs associated with in-plant water use, including water treatment, heating, and pumping costs. The final factor is wastewater treatment. Wastewater treatment costs may include construction, operation, and maintenance items, or could be the cost for discharge to the municipal system. Regardless of the method, costs associated with regulatory compliance must be considered.

As described above, a strategy that reduces water consumption may result in snowball effect savings. For example, a 10% reduction in water supply leads to further in-plant savings and finally results in lowered wastewater treatment costs. One large food processing company found that such a reduction in water use could yield savings of approximately $950,000 annually.

Establishing a Water Conservation Program

Key source reduction program elements were described in the previous section. These general concepts can be applied specifically for initiatives aimed at water conservation. Establishing a water conservation program in your plant involves several steps, which are relatively easy to implement. However, as noted earlier, the most important factor is total commitment of plant management. The following paragraphs describe the key steps in establishing your water conservation program.

Step 1: Select a Water Conservation Supervisor

The person selected to fill this position should be made completely responsible for water management throughout the plant. The water conservation supervisor should report directly to the plant manager. To succeed you must make sure that this supervisor can devote a majority of time to the program. Overloading him or her with other unrelated duties will only diminish the effectiveness of the program.

Step 2: Establish a Water Conservation Task Force

The first duty of the water conservation supervisor is to create a task force. The water conservation task force should include knowledgeable individuals from all company departments, including production, engineering, and maintenance.

Step 3: Conduct a Plant-Wide Water Use Survey

In this first overview, the task force identifies heavy potable and non-potable water use or process problem areas and prioritizes them for detailed evaluation. This involves a review of the information you gathered during your FPR assessment (Part I) and a walk through the plant, paying special attention to obvious water use excesses. For example, look for leaking pipes, tanks, or valves, or water left running when the process is off line. By the end of this initial survey, the task force knows where to conduct detailed evaluations for the greatest immediate savings.

Step 4: Conduct a Detailed Process Water Use Survey

Based on the priorities established in Step 3, detailed process water use evaluations should be conducted. The task force should define the current water use and the minimum quantity of water needed for each process without diminishing product quality or reducing performance to an unacceptable level. Five recommendations apply:

- obtain hourly wastewater readings
- perform wastewater strength analyses (e.g., pH, BOD, suspended solids) by
- shift and department
- look for areas of neglected maintenance, which can account for up to one-half of
- excess water use
- determine consumptive water use in the product
- do not look for excuses – look for ways to make improvements

Step 5: Establish a Water Use Budget

Based on Step 4, establish reasonable water consumption estimates and develop a water budget. Seek an explanation when the budget is either exceeded or not met. When a budget is exceeded, reinforce accountability. For budget shortfalls, find out if someone has come up with a new way to conserve water. This technique may be applicable to other departments or plants.

Step 6: Develop Employee Training and Incentives

The best strategy to gain the support of people whose hands are on the valves and those responsible for controlling FPR generation is to offer environmental training and incentives. Water conservation and recycling are timely issues and people are often receptive to programs instituted for environmental protection.

The key to gaining cooperation is training. Establish an education program that makes everyone in the plant aware of the problems and costs of excessive water use. Use plant newsletters, water conservation posters, presentations at shift meetings, and one-on-one conversations to get the word out. Post charts, graphs, and suggestion boxes to facilitate communication and find new ideas. Finally, consider the introduction of an incentive program that offers prizes for various obtainable water and waste load reductions. Such initiatives can almost always change employee attitudes in favor of water conservation.

Process Modifications For Water Conservation

Reducing in-plant water use involves four basic steps:

- identify problem areas
- determine the cause of these problem areas
- review technical feasibility of alternative water use reduction strategies
- select the economically feasible alternative

Regardless of the approach you use to implement your water conservation program, correction of excessive water use problems will always involve some form of these four basic steps.

General Water Conservation Strategies

Ten general water conservation strategies are listed below. Applying these to your plant should result in considerable water savings. Some of the strategies listed are worthy of special emphasis, since they involve minimal cost, yet yield significant savings. For example, routine maintenance should include immediate repair of water leaks. Leak repair costs are specific and measurable. But remember, while the hidden costs of chronic water leaks are hard to pinpoint, these costs virtually always exceed the cost of repair.

Ten Strategies to Conserve Water

1. Repair leaks in pipes, tanks, pumps, etc.
2. Alter cleaning methods (eg. Dry vs. wet; or optimize chemical detergent mixes to maximize cleaning).
3. Reuse water and raw materials.
4. Separate wastewater streams (eg. Process, sanitary, and cooling).
5. Segregate process wastewater for pretreatment.
6. Modify processes to increase efficiency
7. Use nozzles on all hoses
8. Utilize high pressure, low-volume systems.
9. Replace older, inefficient equipment.
10. Install meters to monitor process flows.

Make every effort possible to change the age-old practice of hosing everything down the drain. Implement dry-cleanup procedures that involve sweeping, squeegee, and shoveling FPRs into suitable containers for recycling. Washing everything down the drain only leads to increased costs.

Washdown after dry cleanup should utilize high-pressure, low-volume hoses equipped with appropriate nozzles. Hoses should be supplied with shutoff valves at the discharge end and a coupling that allows quick interchange of various sizes and types of nozzles for varied cleanup jobs.

5.3 Additional Reading

DEP Source Reduction Strategy Manual, July 1, 1992 (last revised August 1997). On Internet at http://www.dep.state.pa.us/dep/deputate/airwaste/wm/MRW/SRS_Manual/SRS_Manual.htm

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Chapter 6: FPR Recovery for Human Uses

FPR recovery for human uses may be both direct and indirect. Direct uses include ingestion, such as food or nutritional supplements, or topical uses, such as cosmetic product additives. Indirect human uses can include FPR-derived products ranging from gaseous, liquid, or solid fuel materials, to biodegradable packaging, or even potpourri additives. Products used for the care and feeding of pets or other animals are not considered in this category of the hierarchy. These are addressed in the next lower level of the hierarchy, Recovery for Animal Uses, in Chapter 7. Likewise, FPR-derived fertilizer and soil supplement products, though they may be employed for houseplants and gardens, are not considered human uses either. These products are addressed under Recovery for Soil Amendments and Fertilizers in Chapter 8.

The human use category is the highest level on the FPR hierarchy immediately below source reduction and water conservation because human use products generally yield the highest return to the producer. Your investigation for potential FPR management alternatives should begin with human use options. Recognize, however, that human use alternatives are under stringent scrutiny due to health and safety concerns.

6.1 FPR Characteristics of Interest

Because many FPR-derived products are generated, it is difficult to develop a comprehensive list of FPR parameters within the scope of all human use possibilities. The knowledge of FPR characteristics and quantities gleaned from Part I of this manual should be the basis for your investigation. Common FPR characteristics of interest discussed alphabetically in the following paragraphs include:

- biological contamination
- edible fiber
- fats & oils
- heating value
- protein
- salt
- starch
- toxic substances

Biological Contamination

Handling and preservation of all food grade materials and FPRs must be conducted in a manner that inhibits the growth of disease-causing organisms.

Edible Fiber

Food fiber in FPRs may be captured/processed into various dietary fiber products. Apple, pear, and hulled grain fiber sources have been studied and show promise in this area.

Fats and Oils

Fats and oils may be extracted from some FPRs for various purposes, including human use. Slaughterhouse or meat processing FPRs are a source for fats and oils that are routinely recovered by rendering. One study examined oil extraction from two unique sources – mustard and grape seeds. Other FPRs may hold a similar potential.

Heating Value

This characteristic is most often measured in BTUs (British Thermal Units). This unit expresses the amount of heat released during combustion of a material. Heating value may be determined for the FPR as it is or in another solid processed form (charcoal), on biogas (methane) generated through digestion of the FPR, or on liquid fuel (alcohol) generated by fermentation.

Protein

FPRs that have a high protein content or that are capable of serving as a substrate for microorganisms may have potential to produce nutritional protein.

Salt

In some cases salt may be recycled. Reuse of excess salt used during treatment of animal hides is common practice. Salt content can be a barrier to some FPR uses. For example, the salt content of whey may limit its use. When salt is removed from whey, it may be possible to produce a whey-based protein supplement.

Starch

An FPR with a high starch content may have potential for starch recovery for food or even biodegradable packaging material. Some work has been done in this area on cull potatoes.

Toxic Substances

Contamination of FPRs intended for human food or animal feed must be avoided. Periodically the federal Department of Health and Human Services - FDA publishes a listing of "Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed." See Additional Resource H for this publication.

Action levels for poisonous and deleterious substances are established by the FDA to control levels of contaminants in human food and animal feed. Published levels and tolerances do not represent permissible levels of contamination where it is avoidable. Rather, they are based on the premise that certain trace amounts of these substances in food or feed are unavoidable.

According to FDA, "Action levels and tolerances represent the limits at or above which FDA will take legal action to remove products from the market. Where no action level or tolerance exists, FDA may take legal action against the product at the minimal detectable level of the contaminant." Blending of a food or feed containing a substance in excess of an action level with another food or feed is not permissible, regardless of the contaminant concentration.

The August 1992 FDA action level publication contains guidance on the substances listed below. Consult Additional Resource H for more detailed information concerning specific commodities.

1992 FDA Action Level Substances

- Aflatoxin
- Aldrin/Dieldrin
- Benzene Hexachloride
- Cadmium
- Chlordane
- Crotalaria Seeds
- Dicofol (Kelthane
- DDT, DDE, TDE
- Dimethylnitrosamine (Nitrosodimethylamine)
- Endrin
- Ehtylene Dibromide (EDB)
- Heptachlor
- Heptochlor Epoxide
- Lead
- Lindane
- Mercury
- Methyl Alcohol
- Mirex
- N-Nitrosamines
- Paralytic Shellfish
- Polychlorinated Biphenyls (PCBs)
- Toxaphene
- Toxin

6.2 Technologies for Human Use FPR Recovery

Technologies that capture and process FPRs for human uses will continue to develop as research focuses in this direction and existing technologies are more broadly used. Some of the more widely known, published technologies currently being applied or studied are briefly discussed in the following paragraphs.

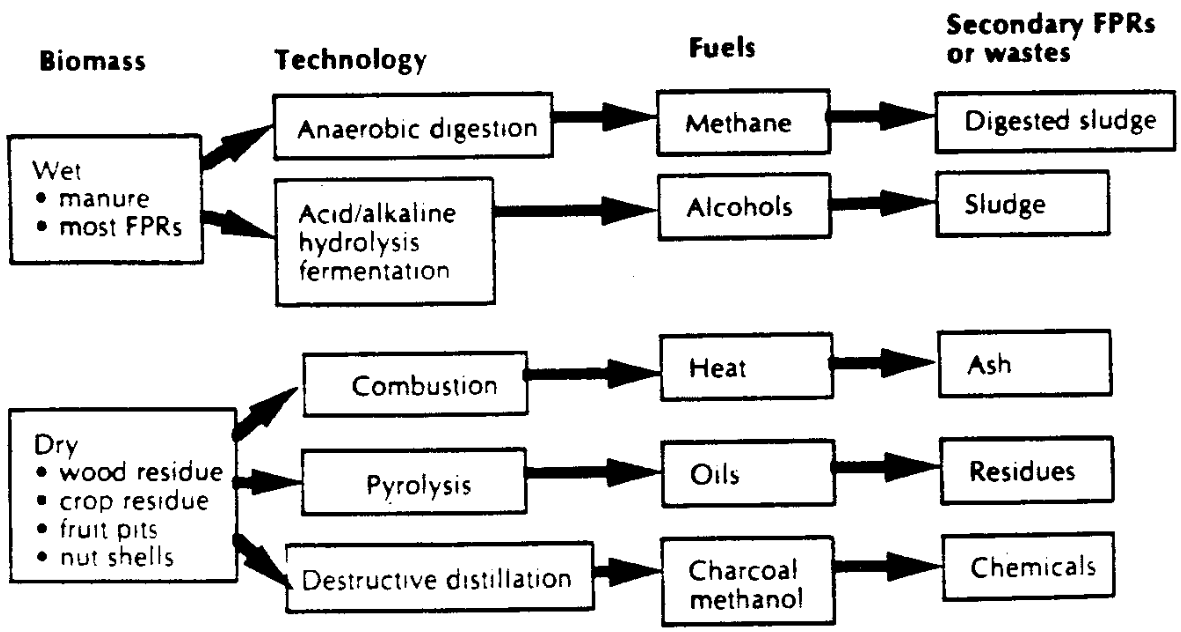
Energy Recovery

Depending on moisture content, FPRs may be used directly as a fuel for combustion or may undergo processing to produce secondary combustion products such as methane, alcohol, oils, or charcoal. The energy potential for FPRs may appear attractive at first glance, but you must consider all of the costs involved. Costs for collecting, transporting, storing, processing, and ultimately reusing or disposing of any secondary FPRs (FPRs generated during energy recovery) or wastes from the process must be economically justified.

The feasibility of FPR energy recovery strategies must consider the amount of recoverable energy versus the energy investment in processing, the compatibility of the energy form to its available uses, the availability of labor and equipment, the expertise necessary for processing, the cost of operating and maintaining the system, and the cost of using the resultant energy.

Figure 6.1 illustrates the possibilities for producing fuel from organic residues. The following section provides an overview of the technologies noted in the figure.

Figure 6.1 Possibilities of producing fuel form FPRs



Source: After Loehr, 1977

Anaerobic Digestion

Biogas generation from waste materials is centuries old and the general technology is well understood. This process uses anaerobic microorganisms to convert biodegradable organic materials into methane (CH_4), carbon dioxide (CO_2), water, and other gases. This gas mixture (CH_4+CO_2+other gases) is often called biogas. Biogas is heavier than natural gas and has about one-half the heating value.

Specially designed digestion facilities maintain an oxygen-free environment, required by methane-producing bacteria. Gases containing about 60% methane may be produced when high rates of digestion are sustained. When easily biodegradable materials are used, it is possible to generate as much as 8-9 cubic feet of gas per pound of volatile solids.

During generation, biogas becomes saturated with water. While the gas burns as produced, it is best to remove water vapor before fueling boilers, engines, furnaces, or water heaters with the biogas.

This prevents fouling of burners and control mechanisms. Carbon dioxide also may be removed, but improved performance of devices using the fuel may not justify the additional complications of removing CO_2. However, CO_2 must be removed from gas that is sold commercially. Hydrogen sulfide removal may be desirable if the gas is to be used in engines or if it is piped long distances.

Direct use of biogas without further processing is possible. To eliminate the drawbacks of using raw biogas as a boiler/burner fuel, one company developed a duel canister burner device. This system can handle high gas flow rates with minimum pressure drop and provides the ability to fire with natural gas or propane as a backup. The system allows for uninterrupted changeover to backup fuels by providing separate burners for simultaneous firing.

The largest application of biogas generation has been in the treatment of municipal sewage sludges. Biogas is used as a fuel to supplement digester heating needs. Use of anaerobic digesters for biogas generation from agricultural waste, primarily manure, has received attention in recent years.

A number of FPRs have potential for methane production. Several laboratory bench-scale and pilot plant studies have been performed. Generally, FPRs with low crude protein content (3.5-4.5%) have been used. FPRs used in these studies include residuals from processing apples, apricots, asparagus, corn, oranges, peaches, pears, pineapples, and sugar beets. Slaughterhouse FPRs are also thought to hold potential for biogas generation.

Acid/Alkaline Hydrolysis

In this chemical treatment process, complex organic materials (e.g., starch, cellulose, and hemicellulose) are broken apart through reaction with aqueous acids or alkalies resulting in the formation of sugars and other compounds. This process has been widely used with high carbohydrate materials such as corn or potatoes.

Fermentation

Fermentation is a chemical change induced by a living organism or enzyme. Bacteria, molds or yeast are usually involved. The reaction normally occurs under anaerobic conditions and results in the decomposition of sugars to ethanol (a form of alcohol) and CO_2. Ethanol can make a satisfactory fuel for engines.

Studies involving ethanol production from whey, potato FPRs, and apple FPRs have been conducted on a limited scale. Recently there has been considerable interest in bioengineered bacteria that have the ability to economically generate ethanol from biomass material. FPRs may be one of the more promising sources for this biomass. A license to commercialize this patented process has been granted and the developers expect to transfer the technology on an international scale.

Combustion

Two principal reasons for burning FPRs are to reduce the volume for easier handling and to derive benefit from the heat energy. FPRs used for combustion must be relatively low in moisture content (50% or less) and high in volatile solids. High moisture FPRs require considerable energy to dry them prior to burning. Fuel moisture content must be carefully controlled to allow consistent burning. The burner must be designed to adequately feed the FPR fuel, control air emissions, and handle resulting ash.

Several commercial FPR incinerators operate in the U.S. Typical fuels include fruit pits, spent tea leaves, and nut shells. Further information relating to regulatory issues for operating incineration facilities in Pennsylvania is provided in Chapter 9.

Pyrolysis

Pyrolysis is best described as high temperature decomposition of organic materials in an oxygen-starved vessel. The end products from pyrolysis are ash, oils, and gases including hydrogen, water, CO_2, methane, and ethylene. Temperatures as high as 1500° Fahrenheit are used and high pressures are common. Pyrolysis has been used on nutshell and fruit pit FPRs to produce charcoal briquettes.

Destructive Distillation

This process is similar to pyrolysis except that the gases generated during the reaction are captured and condensed to recover volatile products. This process does not appear to be in wide use for processing FPRs.

Protein Production/Recovery

Recovering proteins from FPRs can be done by two processes: 1) extraction or separation and 2) use of FPRs as a growth medium for microorganisms -- which are themselves a protein source. In extraction and separation processes, enzymatic hydrolysis, ultrafiltration (UF), or reverse osmosis (RO) may be used. Enzymatic hydrolysis has been studied on a variety of vegetable FPRs, including stems, leaves, and bean and pea residuals. UF and RO processes concentrate dissolved components from liquids and allow separation of smaller molecules from larger ones, such as protein. These processes have been used to recover edible protein and lactose from cottage cheese whey.

If FPRs are used as growth media, nutrients in the FPR material serve as a food source for certain species of algae, bacteria, molds, or yeast. Microbial protein or single cell protein (SCP) has been produced by cells growing on a variety of FPRs. SCP has emerged as an interesting and potentially important source of nutritional protein. Microorganisms are fast growing and can proliferate on a wide range of substrates. SCP is high in protein content and exhibits relatively good quality. A number of studies examining SCP production from fruit, vegetable, and acid whey FPRs have shown promising results.

Starch Recovery and Biodegradable Plastics

FPR starch such as that extracted from cull potatoes and in cornstarch FPRs has great potential as a feedstock source for biodegradable plastics manufacture. The process involves the hydrolysis of starch to glucose, fermentation to lactic acid, and addition of other compounds to form a linear thermoplastic polyester -- polylactic acid (PLA). PLA degrades in the environment without forming toxic byproducts and has properties similar to non-degradable plastics. The process is still in its developmental phases, but considerable interest in agricultural applications has developed since PLA degrades easily in the soil. Applications such as time-released coatings for fertilizers and pesticides, and agricultural mulch films are being considered.

Fats and Oils Recovery

Meat processors have historically been a recycler of FPRs. Recovery of edible fats through rendering is an excellent example of FPR utilization at the highest reuse level of the hierarchy. Edible rendering is usually conducted by wet or low temperature processes that do not evaporate input material moisture during cooking. Human use products derived from animal fats and oils include tallow, grease, and cosmetic additives.

Solvent extraction of oil from mustard and grape seeds, and olive press FPRs has also been performed. A full-scale facility treating olive and grape FPRs has been reported on Cypress.

Salt Recovery

Recycling of excess salt used in animal hide processing is a common practice. For example, some hide processing facilities use a three-step washdown method, including an evaporation system to recover salt. Recovered salt is returned to the hide treatment process.

Other Technologies

Addition of thermally modified cheese whey to spray dried buttermilk-whey blends has been found to increase product shelf life significantly. Ice cream made from the blend is reported to have excellent quality.

Fruit pits from cherries and peaches have been marketed successfully as potpourri additives. Other fruit FPRs may hold similar potential.

In meat processing, human use by-products originating from animal intestines and glands include sausage casings, surgical thread, and pharmaceutical products. Other valuable products such as enzymes, citric acid, natural food flavors, pigments, and dietary fiber have been produced from FPRs.

6.3 Regulatory Resources

Two groups protect food safety on the federal level. In the U.S. Department of Agriculture (USDA), the Food Safety and Inspection Service has jurisdiction. In the U.S. Health and Human Services Department, the FDA is given power. The federal regulations relating to food safety are highly complex, involving as many as a dozen agencies with partial or overlapping responsibilities, depending on the product. A discussion of the various responsibilities of these groups is well beyond the scope of this manual. However, it is significant to note that regulation of meat product foods, all drugs, and all cosmetics are generally performed at the federal level. If you desire guidance concerning a specific FPR, you should contact these agencies directly. In many cases contacting the appropriate state agency (see next paragraph) first may help to sort through just who you should talk to at the federal level.

On the state level, the PDA, Bureau of Foods and Chemistry regulates the processing, storage, and distribution of non-meat food products. The rules and regulations that generally apply to food processing are contained in 7 PA Code Part III, Chapter 45. Other PA regulations specific to the type of food processing also apply. Additional Resource I provides a listing of PDA regional offices to contact for assistance with specific questions.

6.4 Additional Reading

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Chapter 7: FPR Recovery For Animal Uses

Previous chapters concentrated on source reduction and water conservation, and recovery for human uses. When your FPRs pass through these hierarchy levels they drop down to the next best management strategy recovery for animal uses. In this manual, animal uses refers to FPR recycling for feed or animal care products. We do not discuss pet food use as this traditionally comes under rendering.

Many examples exist where the food processing and feed industries have mutually benefited from innovative recycling initiatives. In fact, some of the more common feed ingredients used today emerged from the ongoing search in each of these industries to find solutions to their seemingly unconnected problems. For the food processor, non-recyclable FPRs represent a disposal liability. On the other hand, livestock producers are always looking for ways to reduce their cost of production – particularly the feed component. When an FPR can be used as a feed substitute or supplement, and the economics of the arrangement can be justified, both parties gain and resources are conserved. For example, the by-product of soybean oil production, soybean meal, was once considered to be a disposal problem. Now this material is a high value feed ingredient. Corn gluten, bone, feather, and fish FPRs have also been turned into feed meal materials. Similarly, beet, cauliflower, citrus, pea, pineapple, potato, tomato, and other vegetable products, as well as cheese whey FPRs, have been found to contain valuable nutrients for livestock feeding programs.

FPRs, which are marketed successfully as feed materials have several common characteristics:

- adequate quantities
- relatively high nutritional value
- relatively consistent quality
- limited handling and storage problems
- economic competitiveness with other existing feed sources

These factors provide a general recipe for success and form the basis for evaluating whether your FPR can be developed for animal feed alternatives. If you have followed the guidelines in Part I of this manual, you have already begun to get a handle on these factors. Do not be dismayed if you cannot address each of the factors affirmatively at the outset. If the nutrient and toxic characteristics profile of your FPR are satisfactory, or can be modified through process changes to be acceptable, a small-scale animal feeding program may provide the means to explore solutions for larger-scale operations.

7.1 Requirements of a Productive FPR Feeding Program

The technical content of this section is largely excerpted from papers done by Wilson (1989) and Harpster, et al. (1993). These papers are referenced in the additional reading section at the end of this chapter.

Livestock feed requirements vary considerably. For example, ruminants (e.g., cattle and sheep) can utilize fibrous feed materials, while non-ruminants (e.g., swine) need more highly digestible feed. However, a certain amount of dietary fiber is important for all livestock. All feed programs must contain five fundamental components:

- water
- energy
- protein
- minerals
- vitamins

Regardless of the FPR source or animal species, certain basic requirements are necessary to establish a productive FPR feed program. The following paragraphs describe these requirements and their importance. Table 7.1 summarizes these factors in the form of a checklist for generally assessing your FPRs, suitability for animal feed recycling.

Table 7.1 Preliminary checklist for assessing FPR feed suitability

Question	Yes	No
1. Is the FPR free of glass, metallic, plastic, or other foreign debris that could possibly injure animals?	☐	☐
2. Is the FPR free of chemical or microbiological contaminants that may injure animal health or limit the use of the animal for its intended purpose (e.g., meat, milk or eggs)?	☐	☐
3. Is your FPR quantity and quality predictable on a day-to-day basis?	☐	☐
4. Is there sufficient FPR volume to warrant in-depth investigation of the animal feed option?	☐	☐
5. Does your FPR contain sufficient dietary energy and protein to justify investigation for animal feeding?	☐	☐
6. Are the FPR physical characteristics (e.g., bulk density and moisture content) and palatability such that animals could ingest sufficient quantities to meet nutritional needs for maintenance and production?	☐	☐
7. Are the FPR handling and storage options practical?	☐	☐

Foreign Debris

The FPR must be free of glass, metallic, plastic, or other foreign debris that could possibly injure the animals, digestive or respiratory tracts. Such injuries are commonly called hardware disease. You should know if your FPR has any of these elements in it. If present, these materials must be removed.

Chemical or Microbiological Contaminants

The FPR must be free of chemical or microbiological contaminants that may injure animal health or limit the use of the animal for its intended purpose (e.g. meat, milk, or eggs). Materials toxic to any class of livestock should not be considered for animal feed uses. Contaminants, which accumulate over time to unacceptable levels in animal tissue or show up in milk or eggs, must likewise be avoided. Before you have full feedability profile analyses performed on the FPR, assess the potential for toxic contaminants. For example, sanitary wastes from lavatories must not be present in the FPR. Table 7.2 provides a listing of mineral contaminants, relative toxicity, and suggested guidelines for feed content concentrations. If you suspect any of these parameters are in your FPR, have your material analyzed for them. Note that a few of the minerals contained in Table 7.2 are also contained in the feedability profile list described later in this chapter. Additional Resource H provides further guidance concerning FDA's 1992 Action Levels for Poisonous or Deleterious Substances in Human and Animal Feed. These action levels should also be considered before pursuing animal feed programs.

FPR Quantity and Quality

The FPR quantity and quality must be predictable on a day-to-day basis. Perhaps the first question is whether there is, or will be, a sufficient volume of fresh FPR material to warrant the expense and effort required to investigate feed program options. If seasonality is a consideration, investigate special provisions for storage (e.g., on-farm ensiling). Storage facilities may help balance supply and demand, and in some cases actually improve nutritional value. Remember, livestock producers are very cautious when it comes to managing feed rations. Animal diet changes should be controlled and gradual, spanning at least two weeks. Unpredicted diet changes imposed on the livestock producer from varying FPR availability or quality can seriously impact your FPR recycling program.

Dietary Energy and Protein

The FPR feed ration must contain sufficient dietary energy and protein beyond basic body maintenance to support the productive purpose of the animal. From the livestock producer's perspective, the value of your FPR as a feed is largely determined by its ability to replace conventional feed materials. Keep in mind that many producers are striving to identify the least-cost ration and your material must be able to compete favorably. Comparison of alternative ration components involves both cost and nutritional value factors.

Physical Characteristics

The FPR physical characteristics (e.g., bulk density and moisture content) and palatability must permit the animal to ingest sufficient quantities to meet its nutritional needs for maintenance and production. To obtain high performance from livestock they must consume large quantities of feed. If consumption is diminished because of the palatability of the FPR component and animal performance is reduced, the FPR has no real feed value to the producer.

Handling and Storage

The FPR handling and storage options must be practical. This is often the weakest link in the animal use option. If better storage methods can be researched and developed, other problems associated with seasonality and FPR quantity may be better addressed. Most FPRs are high in moisture content, hence handling, transportation, and storage present unique problems. Reducing moisture content of liquid or slurry FPRs increases storage and handling options by reducing containment facility expenses and decreasing hauling costs. However, select a dewatering or drying method that does not introduce foreign contaminants that may limit the FPRs use as a feed material. Also, account for the costs associated with removing water. Presently, on-farm ensiling of FPRs in combination with other forage materials appears to offer one potential option for long-term storage.

Table 7.2 Guidelines suggested for contaminants in individual mineral feed ingredients

Category	Maximum Tol. Level in Complete Feed (PPM)[a]	Typical Analysis Not Sug. Below Label (PPM)	Typical Analysis Suggested Between (PPM)	Prohibited Above (PPM)
1. HIGHLY TOXIC	1-9	5	5-500	500
Cadmium	0-5			
Mercury	2			
Selenium	2			
2. TOXIC	10-40	100	100-1000	1000
Cobalt	10			
Molybdenum	10			
Vanadium	10			
Barium	20			
Tungsten	20			
Copper	25[b]			
Lead	30			
3. MODERATELY TOXIC	41-100	500	500-2000	2000
Arsenic	50			
Nickel	50			
Iodine	50			
Antimony	70			
4. SLIGHTLY TOXIC	101-1000	2000	>2000	None
Boron	150			
Aluminum	200[c]			
Bromine	200			
Zinc	300			
Bismuth	400			
Manganese	400			
Chromium	1000			

Source: AAFCO, 1991

a) Dietary level that, for a limited period, will not impair animal performance and should not produce unsafe residues in human food derived from that animal. Values cited are those for the most sensitive animal species in "Mineral Tolerance of Domestic Animals," National Academy of Sciences/National Research Council, Washington, D.C. (1980).

b) Some animal species such as sheep may be particularly sensitive to high levels of copper.

c) NAS/NRC publication reference above; as soluble salts of high bioavailability. Higher levels of less-soluble forms found in natural substances can be tolerated. Species for this level is poultry; swine, horse, and rabbit are estimated to be similar by interspecific extrapolation; cattle & sheep 1000 ppm.

7.2 FPR Characteristics of Interest

As noted earlier in Chapter 4, tests and parameters used to determine FPR suitability as a feed ingredient is called the feedability profile. This profile allows the animal nutritionist to quickly identify potentially harmful characteristics and assess the nutrient value. For a listing of labs that perform the feedability profile, see Additional Resource D.

Information on animal nutrition and ration formulation is available in the literature. A detailed coverage of the topic is beyond the scope of this manual. Rather, this section is intended to introduce and generally define the terms used in the feedability profile. Where possible, the text and tables include numeric values indicating typical ranges or recommended maximum tolerable levels. In all cases, the values shown are excerpted from existing literature. Individuals desiring greater detail or explanation are encouraged to obtain the reference materials listed at the end of this chapter under Additional Reading.

If you pursue this level of the hierarchy, it is important that you seek expert advice from an animal nutritionist. This chapter only touches on some of the more important aspects of ration composition and should not be your sole source of information.

The basic feedability profile parameters are listed in Table 7.3. Typical recommended ranges for dairy cattle and swine are shown. The following section provides an abbreviated description of the feedability parameters within the categories below:

- energy and fat
- fiber
- minerals
- protein
- water

Energy and Fat

In recent years animal nutrition researchers in the United States have been moving away from the use of Total Digestible Nutrients (TDN) and Digestible Energy Concentration (DE) measures for expressing the useful energy value of feeds. This is particularly true for dairy cattle nutrition. However, swine nutrition information is still expressed in the older form. TDN and DE measures tend to underestimate the value of certain feed materials. Net Energy measures are considered to be more accurate.

Table 7.3 Basic Feedability Profile Analysis Parameters and Typical Recommended Ranges for Dairy Cattle and Swine

	Dairy	Swine	Units
Non -Minerals			
Dry Matter (DM)	-	-	%
Total Digestible Nutrients (TDN)[a]	55-75	-	% of DM
Digestible Energy Concentration (DE)[a]	2.69-3.22	3.40	Mcal/kg
Metabolizable Energy Concentration (ME)	2.00-2.89	3.25	Mcal/Kg
Net Energy of Maintenance (NeM)	1.15-1.70	-	Mcal/Kg
Net Energy of Gain (NEg)	0.82-1.08	-	Mcal/Kg
Net Energy of Lactation (NE1)	1.25-1.72	-	Mcal/Kg
Fat	3.5-5.0	-	%
Crude Protein (CP)	10-19	13-18	%
Neutral Detergent Fiber (NDF)	23-35	-	%
Acid Detergent Fiber (ADF)	19-27	-	%
Minerals	40	2.0-3.0	ppm
Manganese (Mn)	50	40-80	ppm
Iron (Fe)	10	3-5	ppm
Copper (Cu)	-	-	ppm
Boron (B)[b]	-	-	ppm
Aluminum (Al)[b]	40	50-80	ppm
Zinc (Zn)	0.10-0.18	0.10	%
Sodium (Na)	0.19-0.48	0.40-0.60	%
Phosphorus (P)	0.65-1.00	0.17-0.26	%
Potassium (K)	0.29-0.77	0.5-0.70	%
Calcium (Ca)	0.16-0.25	0.04	%
Magnesium (Mg)			

Sources: NRC, 1988a; NRC, 1988b.

Note: Actual dietary need is highly dependent on animal age, condition, activity level, and productive purpose. Values in this table are only for general comparative purposes to enable preliminary assessment of FPR feed characteristics. Dairy calf feeds are not considered in the listed range. Values listed for swine are for 10-110 kg growing-finishing stock.

a) These parameters are used when more definitive information is not available (eg. net energy measures or detergent fiber values).

b) See Table 7.2 for recommended maximum levels.

Feed testing laboratories cannot establish the true energy value of feedstuff through animal feeding trials. Rather, they predict the feed's energy value by using known relationships between the feed's fiber content and energy value. The following list of parameters retains the former measure and incorporates the Net Energy series as well.

Digestible Energy Concentration

Digestible Energy Concentration (DE) is food intake gross energy minus fecal energy. DE can be calculated from TDN on the basis that 1 kg of TDN equals 4.409 mcal of DE. The term is commonly expressed as Mcal/kg DM.

Metabolizable Energy Concentration

Metabolizable Energy Concentration (ME) is food intake gross energy minus energy lost in fecal, urinary, and gaseous products of digestion. ME is commonly expressed as Mcal/kg DM.

Net Energy of Maintenance

Net Energy of Maintenance (NEm) is the net energy feed value for maintenance of nonlactating animals. At this level there is no net gain or loss of energy in the body tissue. The term is commonly expressed in Mcal/kg DM.

Net Energy of Gain

Net Energy of Gain (NEg) is the net energy feed value above and beyond basic body maintenance levels that is used for tissue gain in nonlactating animals. NEg is commonly expressed as Mcal/kg DM.

Energy of Lactation

Energy of Lactation (NEl) is the net energy feed value for lactating animals. NEl is commonly expressed as Mcal/kg DM.

Fat

Fat is necessary to varying degrees in livestock feed depending on the species, age, and productive purpose. Dietary fat supplies certain essential fatty acids, carries fat-soluble vitamins, and supplies energy for maintenance and growth. Limited amounts of fat included in cow feed rations have been shown to maximize milk production in early lactation. Fat is commonly expressed as a percent of total dietary DM.

Fiber

A minimum amount of dietary fiber, of the proper quality and form, is essential to livestock health. Two different measures are used to describe feed fiber content.

Neutral Detergent Fiber

Neutral Detergent Fiber (NDF) is composed of feed fractions including hemicellulose, cellulose, lignin, and certain other fractions that are not solubilized by the NDF solution. NDF is commonly expressed as a percent of the DM.

Acid Detergent Fiber

Acid Detergent Fiber (ADF) is composed primarily of cellulose and lignin. ADF is commonly expressed as a percent of the DM.

Minerals

Minerals selected for inclusion in the feedability profile do not cover the full spectrum of essential elements needed by livestock. For example, the macrominerals chlorine and sulfur are not included. Nor are the essential trace minerals cobalt, iodine, molybdenum, and selenium. A number of other trace minerals generally considered to have little practical supplementation importance in livestock ration formulation are likewise not listed in the feedability profile. These trace minerals include arsenic, boron, bromine, cadmium, chromium, fluorine, lead, lithium, nickel, silicon, tin, and vanadium. (Table 7.2 provides suggested maximum levels for many of these elements.) While the minerals noted above are not routinely analyzed in the feedability profile, when the potential for excess levels exists, you should follow-up with laboratory analyses. As a case in point, two metals potentially in excess in certain FPRs are chromium (Cr) and molybdenum (Mo). These elements are used for corrosion control in cooling water and boiler water blow-down. They may also be present in air conditioner water. When such discharges become mixed with your FPR stream, testing for Cr and Mo may be appropriate.

Minerals included in the standard feedability profile are described in the following paragraphs.

Manganese

Manganese (Mn) is considered an essential trace mineral. Mn content of feedstuffs is highly variable. It is found in low concentrations in all animal tissues. The Mn requirement of cattle is not well defined.

Iron

Iron (Fe) is considered an essential trace mineral. Fe is an essential component of blood and enzyme systems. Deficiencies are most likely to occur in young stock. Most common feedstuffs contain moderate levels of Fe. Fe requirements of ruminants are not well understood.

Copper

Copper (Cu) is considered an essential trace mineral. Copper deficiency in grazing cattle is recognized as a major problem in certain parts of the world. Symptoms include reduced growth, weight loss, decreased milk production, etc. Excessive amounts of copper can lead to toxicosis as Cu concentrates in the liver. This is especially true of sheep, which are quite sensitive to dietary copper levels. In cattle, the minimum dietary requirement for Cu is closely linked to influences of other interfering substances such as molybdenum and sulfur. The typical recommended Cu content of complete dairy feed is 10 ppm.

Boron

Boron (B) is a trace element having slightly toxic potential to animals. The maximum suggested tolerable level in complete feed for the most sensitive animal species is 150 ppm.

Aluminum

Aluminum (Al) is one of the most abundant elements in the earth's crust, ranking third. However, Al is present only in trace amounts in animals and plants. A dietary need for Al has not been firmly established, but indirect evidence suggests that it is needed. Excessive consumption of Al can produce toxic effects by interfering with absorption of phosphorus and normal metabolic functions.

Zinc

Zinc (Zn) is considered a trace mineral. Zn is an essential component in numerous enzymes involved in protein synthesis and various metabolic functions. Research has shown negative effects from both deficiencies and excess quantities of dietary Zn.

Sodium

Sodium (Na) is considered a macromineral. Na is essential for regulation of body fluid balance, cellular glucose uptake, and nerve transmission. Cattle have the ability to conserve Na, so deficiency symptoms are generally delayed. After several months decreased milk production and rapid weight loss occur along with other symptoms. However, with restoration of adequate dietary Na, cows recover rapidly.

Phosphorus

Phosphorus (P) is considered an essential macromineral and is a fundamental component of bone and teeth. It is also found in the soft tissue, blood, and milk. This element is a very important component of feedstuffs. P deficiency leads to reduced mineral content in bones, appetite decline, reduced growth rate and feed utilization efficiency, and decreased milk production. Excessive dietary P may cause elevated plasma levels, bone resorption, and urinary problems.

Potassium

Potassium (K) is considered as an essential macromineral. K is the third most abundant element in animal tissue. This element plays a number of important roles, including regulation of osmotic pressure, water balance, nerve impulses, muscle contraction, and enzymatic reactions. Generally, most forages contain more than adequate amounts of K for dairy cattle. However, feed concentrates often do not contain sufficient K.

Calcium

Calcium (Ca) is an essential macromineral, and the most abundant mineral in the body. Most Ca is contained in the bones and teeth (98%). The remaining 2% is contained in the soft tissue and fluids. Ca is essential for proper formation of bones and teeth, nerve impulse transmission, cardiac regulation, blood clotting, and enzymatic regulation. Ca deficiency in young animals prevents normal bone growth while demineralization of calcium components in older animals can lead to weak brittle bones. Reduced milk yields are also evident in lactating cows. Excessive Ca can have a negative effect on other elements (e.g., phosphorus, magnesium, iron, iodine, and manganese). Feeds having Ca contents higher than 0.95-1.0% DM can lower cattle performance.

Magnesium

Magnesium (Mg) is considered a macromineral. Mg plays an important role in bone development, nerve impulse transmission, and enzyme regulation. In the extreme, an Mg-deficient diet can lead to convulsions and death in cattle. Mg toxicity in cattle is not reported as a practical problem.

Protein

Crude Protein (CP) is the total feed protein content. Intake CP includes both protein that is absorbed by the animal and the portion that is indigestible. CP is commonly expressed as a percent of the total dietary DM.

Water

Dry Matter (DM) is self-explanatory. It refers to the actual amount of material present minus water content. The term is commonly expressed in percent.

7.3 FPR Dietary Value and Ration Formulation

When considering the use of FPRs in the formulation of animal feed, keep in mind that feed components can often be combined to complement each other. For example, a high-energy, low-fiber, wet ingredient (like potato FPRs) may be mixed with a low-energy, high-fiber, dry ingredient (like corn fodder), to produce a more balanced feed material. In some cases the resulting ration may even be more palatable to livestock.

Table 7.4 provides a list of basic nutritional characteristics for various conventional and FPR-based feed materials. Review of this list may be useful for stimulating ideas as to how your FPR may be complemented with other materials to form a feed ration. (The NRC 1988a and 1988b publications listed in the Additional Reading section at the end of this chapter contains a much more comprehensive list.) Remember, values contained in the table may not necessarily describe your FPR. You must analyze each ingredient proposed for the ration to know if it is suitable, and how much of each constituent should be added. If the material is ensiled, it must be analyzed prior to feeding as the nutritional characteristics may have significantly changed through ensiling. Depending on post-ensiling analysis results, recombination with other feed materials or FPRs may be appropriate.

By this point, it should be obvious that undertaking a serious FPR feeding program can be a rather complex task. Controlling feed nutrient content, maintaining feed uniformity, and managing storage facilities are extremely important factors that can overwhelm the livestock producer and cause an FPR feeding program to fail if the food processor and the grower do not work together closely. The value of cooperation in such a program cannot be overstated.

One tool that may assist in formulating livestock feed rations using FPRs is currently under development at The Pennsylvania State University. The “P.S.” MacByproduct computer model will eventually incorporate ration formulation for beef cattle, sheep, and swine, as well as provide data concerning FPR availability and costs for alternative rations. This computer model should prove to be a powerful tool for livestock growers and the food processing industry.

7.4 Technologies for Animal Use FPR Recovery

Some of the technologies discussed previously in Chapter 6 for human use recycling also apply for animal use recovery. For example, protein production/recovery, fats and oils recovery, and fermentation are used to recycle a number of FPRs into products for animal feed additives.

Table 7.4 Comparative nutritive value of selected FPR feeds

Feedstuff	As Fed	Nutrient Analyses, Dry Matter Basis		
	Dry Matter (%)	Crude Protein (%)	Acid Detergent Fiber (%)	Total Digestible Nutrients (%)
Conventional:				
Soybean meal	90	55.1	6	87
Shelled corn	89	10.0	3	90
Alfalfa hay	90	17.0	35	58
Grass hay	89	9.1	36	58
Corn silage	33	8.1	28	70
Corn stalks	85	5.9	39	50
FPR:				
Apples	17	2.8	9	70
Apple pomace, plain	21	7.6	30	69
Apple pomace with press	27	4.9	53	30
Baker waste, dried	89	12.0	3	86
Beans, green, dried	89	16.9	32	63
Beans, navy, dried	89	24.0	8	83
Beans, lima, dried	90	23.1	6	83
Beet greens	10	20.8	21	63
Bread, dried	92	13.3	1	89
Brewers grains, wet	24	27.1	23	68
Cabbage	8	18.4	19	68
Candy	94	5.2	5	94
Candy, blend	94	13.0	12	91
Carrots	12	9.9	9	84
Carrot tops	16	13.0	23	67
Celery	6	20.0	16	65
Chocolate	94	12.9	4	112
Corn cannery waste	23	8.8	29	70
Distillers grains with solubles, wet	7	29.7	20	85
Feather meal	90	87.4	1	63
Gluten feed (corn)	90	24.4	12	82
Grape pomace, dried	91	13.0	54	33
Lettuce	5	23.0	16	65
Pasta	89	14.6	3	84
Peanut skins	94	17.4	16	68
Potato, culls	21	10.0	3	79
Potato waste, dried	90	7.8	6	82
Potato starch waste	90	10.8	4	79
Pumpkin	10	12.0	21	68
Soybean hulls	90	12.0	50	77
Spinach	7	31.5	12	65
Tomato pomace, dried	92	23.5	50	58
Whey, liquid	7	14.2	-	80

Source: Harpster, et. al., 1993

NOTE: Byproduct feeds are highly variable in dry matter and nutrients. The values presented here are approximate. Each ingredient must be analyzed before incorporation into animal diets.

Six Ways to Improve Your FPR Feed Value

Mechanical
Grind, chop, pelletixe, extrude, screen, roll

Heat
Dry heat, roast, micronize, pop, flash dry, dehydrate

Chemical
Treat with acid, alkali, or ammonia

Biological
Bacterial cultures, anaerobically digest, compost

Ensiling
Vertical (conventional, air-tight), horizontal (trench, bunker, pit, pile, large bag), round bale (bagged, wrapped)

Source: Harpster, et al., 1993

The basic technology categories used to improve the feed value of FPRs are summarized on the left.

Ensiling is a technology of particular interest since this process also provides a means of FPR storage, which is often a major FPR management problem. Additionally, ensiling gives an opportunity for blending FPRs with other feed materials to allow formulation of more complete feed mixtures. In this way the livestock producer can capitalize on the varying qualities of individual ingredients, more than one of which may be an FPR material.

Ensiling involves storage of feed material in an oxygen-free (anaerobic) environment to encourage fermentation. During fermentation, bacteria consume sugars and acids are created. The acids (primarily lactic acid) reduce the pH of the stored material and prevent growth of undesirable bacteria, which can diminish feed quality through spoilage. The fermentation process has also been reported to enhance nutrient quality in some cases.

Ensiling is performed in tower or bunker (trench) silos. Currently, the bunker silo is probably more applicable to FPR feed treatment. Proper operation of a bunker silo requires that the material be thoroughly compacted during filling. This usually involves placement of one-foot layers that are each compacted prior to placement of the next layer. Improper filling can result in excessive spoilage losses, which can exceed 20% in some cases.

Several examples of animal use FPR recycling programs are provided in Part III of this manual. Readers are encouraged to look through the Case Studies to gain an overview of current animal use recycling initiatives. Reviewing what others are doing may help you to identify how your FPR may be incorporated into a feeding program.

7.5 Starting Your FPR Feed Program

After you have carefully considered the factors involved in establishing an FPR feed program and performed the necessary laboratory analyses outlined in this chapter, you should contact your local Cooperative Extension office. Talk to the extension agent concerning the characteristics of your FPR and inquire as to the potential interest of local livestock producers. Cooperative Extension should be able to either provide advice concerning the feed potential of your FPR or direct you to others who can be of help.

Start with a small-scale pilot program to identify problem areas and solutions. Only after testing your pilot program should you consider launching a large-scale feeding program. Remember, if you sell, barter, or otherwise accept compensation from a grower who is using your FPR as a feed material, you will need to address a number of regulatory issues relating to commercial feed registration (as described below).

7.6 Regulatory Resources

On the federal level, animal feed safety responsibilities are shared between two agencies. The first is the Animal and Plant Health Inspection Service - Veterinary Services Agency, which is in the USDA.

This agency administers the federal Swine Health Protection regulations (Part 166). Part 166 requires that animal growers who feed garbage to swine follow certain sanitation procedures to kill potential disease organisms in the garbage and obtain a permit for operation. The federal regulations consider organic food processing residuals to be garbage and subject to regulation under Part 166. Contact your PDA regional office to learn the current status of Part 166 applicability.

The second federal agency that may have some involvement in FPR-derived feed products is the FDA. This agency is primarily involved with feeds that contain medications. However, if an FPR contains a substance exceeding the concentrations listed in Additional Resource H, FDA will become involved.

If you desire guidance concerning federal regulations, you should contact these agencies directly. However, in many cases contacting the appropriate state agency first may help to identify the individual who you should talk to at the federal level. The PDA-Bureau of Plant Industry regulates the distribution of commercial feed materials on the state level. Rules and regulations are established in accordance with the PA Commercial Feed Law of 1966. Animal feed regulations are contained in 7 PA Code Part III Chapter 71.

A comprehensive accounting of Chapter 71 of the PA Code is not possible in this manual. However, the following points provide a broad overview of these rules and regulations with regard to FPRs that are considered commercial feeds:

1. The Commercial Feed Law of 1966 applies to any manufacturer or distributor of commercial feeds who sells, barters, or otherwise accepts compensation for an FPR used as an animal feed. Accordingly, a food processing facility manufacturing a commercial feed (FPR) must be licensed by PDA.
2. In order to distribute your FPR feed it must be defined in the most recent Official Publication of the Association of American Feed Control Officials (AAFCO). The AAFCO currently has a number of FPR products defined. If a definition for a particular FPR material does not exist, the AAFCO must be petitioned to establish one. See Additional Reading at the end of this chapter for a full citation on the most current AAFCO publication.
3. The FPR product must not be "adulterated.” In other words, it must not be injurious to animal health or contain non-approved components.
4. The FPR product must be properly labeled in accordance with the feed law requirements.

   Additional Resource I of this manual provides a listing of PDA regional offices, which may be contacted if you need a copy of the applicable regulations, or have specific questions relating to animal feed issues. As noted earlier, the PDA regional office (Bureau of Plant Industry, or Bureau of Animal Industry for "garbage" feeding to swine) can also help to direct you to appropriate federal agencies when necessary.

7.7 Additional Reading

AAFCO. 1993. Official publication 1993, Association of American Feed Control Officials Inc. ISBN 1-878341-04-9. p. 179. Atlanta, GA.

Harpster, H.W., D.R. Buckmaster, and R.S. Adams. 1993. Recycling food industry wastes as livestock feed. In *Utilization of food processing residuals,* Ed. P.D. Robillard and K.S. Martin, NRAES-69, 4-14. Northeast Regional Agricultural Engineering Service. Ithaca, NY.

Merlo, C.A., and W.W. Rose. 1992. Alternative methods for disposal/utilization of organic by-products - from the literature. Presented at the 1992 Food Industry Environmental Conference, Georgia Institute of Technology, Atlanta, GA 30332.

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Wilson L.L. 1989. Food industry wastes as livestock feeds. In *Proc. food processing waste management and water conservation conference*, Ed. P.D. Robillard and H.A. Elliott, 131-135. Hershey, PA, 14-15 November.

Chapter 8: Recycling FPRs as Soil Conditioners or Fertilizers

After minimizing FPR generation (Chapter 5), and recycling FPRs for human uses (Chapter 6) and animal uses (Chapter 7), the last available beneficial use option is recycling for soil conditioning or plant fertilizer. Soil conditioners are substances that produce chemical or physical changes in the soil to promote and support plant growth. Fertilizers contain essential plant nutrients. When properly managed through a well-designed land application system (LAS), many FPRs can serve as both a soil conditioner and fertilizer. FPRs have been recycled through LAS programs for decades. Program effectiveness depends on the physical and chemical properties of the material and the site characteristics and crop.

This chapter identifies and evaluates critical components of an environmentally sound LAS – one that meets your needs, yet remains in compliance with applicable guidelines. The chapter is divided into five sections: Characteristics of Interest, Treatment Technologies, Components of a Land Application System, Regulatory Resources, and Additional Reading. Land application of wastewater involves detailed hydraulic loading considerations, and only limited discussion is provided. Individuals interested in learning more about FPR wastewater LAS requirements are encouraged to contact Bureau of Water Quality Management. The LAS detailed in this chapter is for solid, semi-solid, and slurry FPRs.

8.1 Characteristics of Interest

Clearly, FPR characteristics play an important role in the success of an LAS. The following FPR characteristics of interest are covered alphabetically in this section:

- biochemical oxygen demand (BOD)
- calcium carbonate equivalent (CCE)
- C:N ratio
- fats & oils
- foreign materials
- heavy metals & PCBs
- nutrients
- odors
- organic matter (OM)
- pathogens
- pH
- solids content
- soluble salts
- toxicity

Biochemical Oxygen Demand (BOD)

BOD measures oxygen use by a mixed population of microorganisms during aerobic oxidation of organic matter in a sample. The standard test is run over a period of five days, hence the term five-day BOD.

High BODs in FPRs are common. At excessive application rates high BOD FPRs can cause anaerobic soil conditions that slow decomposition of organics, clog the soil, and create odors. To manage for high BOD FPRs, you must maintain aerobic soil conditions by limiting the application rate and frequency.

Calcium Carbonate Equivalent (CCE)

This characteristic measures the FPR's ability to neutralize soil acidity compared to pure calcium carbonate. Calcium carbonate serves as the benchmark against which all liming materials are measured and labeled. For example, a material containing a 100% CCE is theoretically as effective as an equivalent amount of calcium carbonate. A material having a 50% CCE would need to be applied at twice the rate of pure calcium carbonate. The fineness of liming materials also impacts effectiveness since finer materials have increased solubility and make contact with a larger volume of soil.

Most FPRs have relatively low CCE values and do not require analysis for this parameter. When an FPR is generated by a caustic process or when lime is added for dewatering or stabilization, the CCE content should be evaluated. Over application of materials having a high CCE value can elevate soil pH and hinder crop growth and herbicide activity. In some cases, the CCE content of an FPR actually limits land application loading rates. For more information concerning agricultural liming materials consult the most recent *Penn State Agronomy Guide*.

C:N Ratio

The carbon to nitrogen ratio refers to the relative quantities of these two elements in an organic source or soil. It is used to predict inorganic-N availability for plant growth from OM in the short term. For FPRs, the C:N ratio is normally computed as the percent of dry weight content of organic carbon divided by the total N content of the material. The total nitrogen value used in the calculation comes directly from laboratory reports. Organic carbon content of FPRs is most often estimated by dividing the organic matter content by 1.72, as suggested by the Waikley-Black Method of Conversion (North Dakota Agricultural Experiment Station, 11998).

As a general rule, the C:N ratio of stable soil OM is around 10:1. When the C:N ratio is less than 20:1, a net release of inorganic N is expected that may be available for crop uptake (mineralization). C:N ratios above 30:1 usually cause immobilization, resulting in little inorganic nitrogen available for crop uptake. The period of N immobilization, sometimes called nitrogen or nitrate depression, varies depending on the rate of organic matter decay. For ratios between 20 and 30:1, there may be either mineralization or immobilization. Figure 8.1 illustrates the link between C:N ratio and plant available nitrogen. For comparison, Table 8.1 lists the C:N ratio of a number of FPRs.

The C:N ratio of your FPR is important to the overall fertility management program for crop production. Because N cycling in the soil environment is a complex, constantly changing balance, it is impossible to guarantee that sufficient soil N will be available to crops at the appropriate times when you rely solely on FPRs applied at assumed N mineralization rates. If yield reductions cannot be tolerated in your LAS, underapply the FPR with regard to nitrogen and supplement a portion of the crop N need with conventional chemical fertilizers. As you gain experience with a particular FPR and gain confidence that sufficient N mineralization is occurring, you can reduce or eliminate chemical fertilizer. For some crops, testing for N during the growing season may confirm the need for additional N. For example, additional chemical N can be side dressed on corn. Remember, when your program involves private farmers, a significant yield reduction or crop failure can terminate the program. It's better to manage the program cautiously until all involved are convinced that agronomic results can be confidently predicted.

Fats and Oils

This refers to fats and oils of plant and animal origin. Certain FPRs, particularly meat and poultry processing sludges, contain significant quantities of fats and oils. Overapplying such FPRs can decrease the permeability of some soils. Limiting the application rate of oil and grease to 1.5% of the soil weight, or about 30,000 lb/acre annually, is recommended. Caution is warranted when land applying liquid FPRs containing significant levels of fats and oils on existing vegetation. Such applications run the risk of smothering plants by clogging leaf pores.

Foreign materials

FPRs with glass, metal fragments, or plastic contaminants are unfit for land application. Segregate these materials from the FPR prior to land application.

Figure 8.1 Soil C:N ratio and nitrogen availability for plant growth

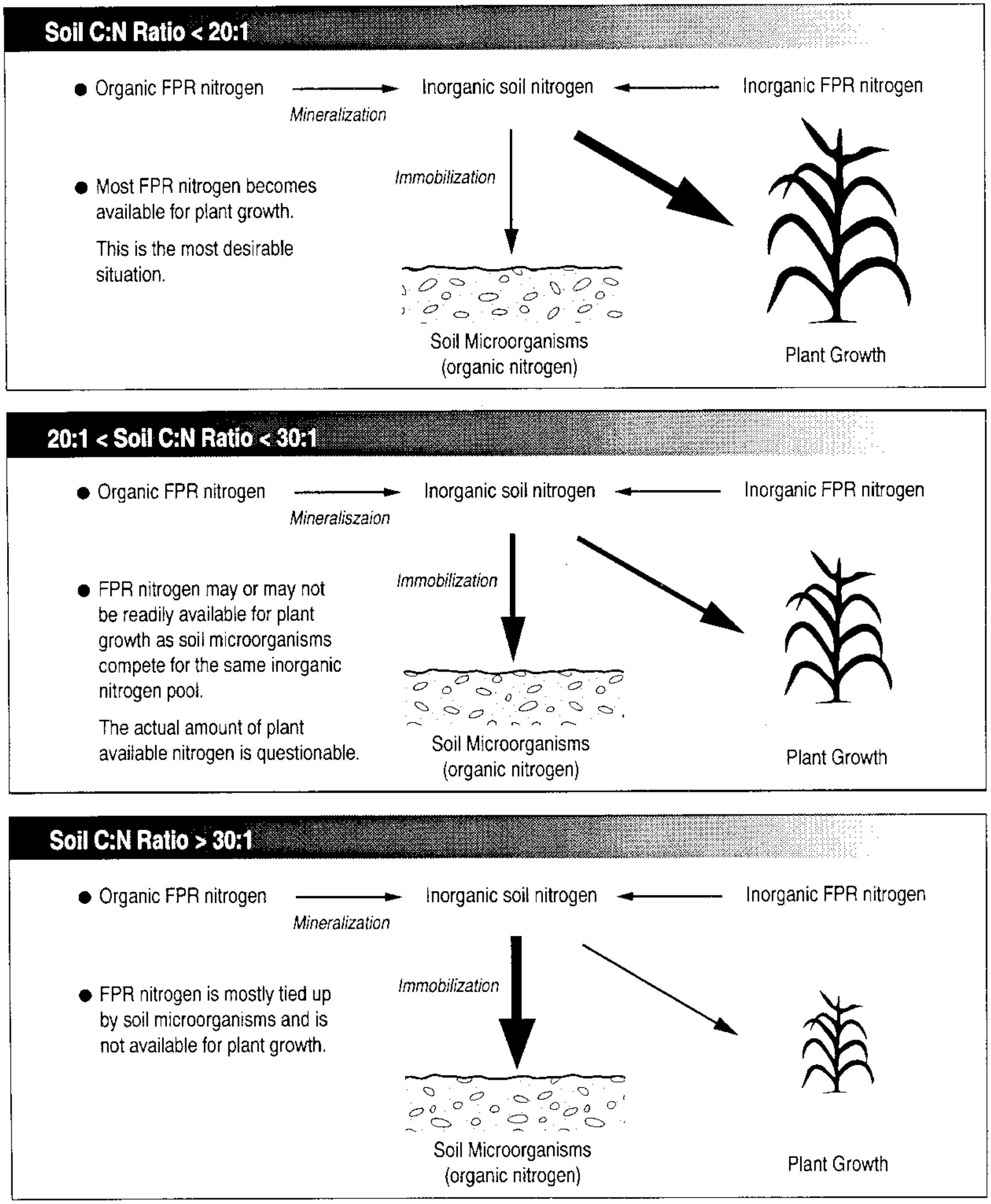


Table 8.1 Typical characteristic of selected FPRs

Material	Type of Value	N, dry weight, %	C:N Ratio, weight to weight	Moisture Content, wet weight, %	Bulk Density, lb per cubic yd
Crop Residues and Fruit/Vegetable-Processing Wastes					
Apple filter cake	Typical	1.2	13	60	1197
Apple pomace	Typical	1.1	48	88	1559
Apple-processing sludge	Typical	2.8	7	59	1411
Cocoa shells	Typical	2.3	22	8	798
Coffee grounds	Typical	—	20	—	—
Corn cobs	Range	0.4-0.8	56-123	9-18	—
	Average	0.6	98	15	557
Corn stalks	Typical	0.6-0.8	60-73 (a)	12	32
Cottonseed meal	Typical	7.7	7	—	—
Cranberry filter cake	Typical	2.8	31	50	1021
(with rice hulls)	Typical	1.2	42	71	1298
Cranberry plant (stems, leaves)	Typical	0.9	61	61	—
Cull potatoes	Typical	—	18	78	1540
Fruit wastes	Range	0.9-2.6	20-49	62-88	—
	Average	1.4	40	80	—
Olive husks	Typical	1.2-1.5	30-35	8-10	—
Potato-processing sludge	Typical	—	28	75	1570
Potato tops	Typical	1.5	25	—	—
Rice hulls	Range	0-0.4	113-1120	7-12	185-219
	Average	0.3	121	14	202

Table 8.1 (cont'd)

Material	Type of Value	N, dry weight, %	C:N Ratio, weight to weight	Moisture Content, wet weight, %	Bulk Density, lb per cubic yd
Soybean meal	Typical	7.2-7.6	4-6	—	—
Tomato-processing waste	Typical	4.5	11(a)	62	—
Vegetable produce	Typical	2.7	19	87	1585
Vegetable wastes	Typical	2.5-4	11-13	—	—
Fish and Meat Processing					
Blood wastes -slaughterhouse waste and dried blood	Typical	13-14	3-3.5	10-78	—
Crab and lobster wastes	Range	4.6-8.2	4.0-5.4	35-61	240
	Average	6.1	4.9	47	—
Fish-breading crumbs	Typical	2.0	28	10	—
Fish-processing sludge	Typical	6.8	5.2	94	—
Fish wastes	Range	6.5-14.2	2.6-5.0	50-81	—
(gurry, racks, etc.)	Average	10.6	3.6	76	—
Mixed slaughterhouse waste	Typical	7-10	2-4	—	—
Mussel wastes	Typical	3.6	2.2	63	—
Poultry carcasses	Typical	2.4 (b)	5	65	—
Paunch manure	Typical	1.8	20-30	80-85	1460
Shrimp wastes	Typical	9.5	3.4	78	—

Source: NRAES, 1992

a) Estimated from ash or volatile solids data.

b) Mostly organic nitrogen.

Heavy metals and PCBs

Heavy metal amounts in FPRs are determined using the acid digestion method discussed earlier in Chapter 4 under Sludge/Solids Analyses. Results are considered to represent the total concentration of each parameter in the FPR. Regulators recognize eleven chemical contaminants as significant to LAS. Table 8.2 lists these parameters and shows the maximum allowable total concentrations, annual loading, and cumulative loading guidelines observed by the PADEP. The PADEP observes the same regulated levels as the USEPA except for PCBs, which the DEP regulates at 4 ppm. Table 8.3 shows the ranges and typical concentrations for 45 elements in soil, thus illustrating that soil naturally contains baseline levels of these elements.

Parameters listed in Table 8.2 are regulated because plants can absorb excessive levels. Animals and humans consuming these plants can accumulate heavy metals and PCBs in body tissue. Cadmium content of land-applied materials must be carefully monitored for this reason. Copper, nickel, and zinc are regulated, not because they necessarily present a threat to animals or humans, but rather because at high concentrations these elements can inhibit plant growth. This inhibition is called phytotoxicity. FPRs should not ordinarily contain excessive concentrations of heavy metals or PCBs. However, two metals potentially in excess in certain FPRs are chromium and molybdenum. These are used for corrosion control in cooling water and boiler water blow-down. They may also be present in air conditioner water.

Table 8.2 Maximum pollutant concentrations and loading rates for agricultural utilization in Pennsylvania vs. EPA biosolids criteria

	PADEP Residual Materials Regulated Levels (1988)	
	Max. Conc. (ppm)*	**Maximum Loading Life (lb/ac)***
Arsenic (As)	41	41
Cadmium (Cd)	39	39
Chromium (Cr)	1000	300
Copper (Cu)	1500	1500
Lead (Pb)	300	300
Mercury (Hg)	17	17
Molybdenum (Mo)a	-	-
Nickel (Ni)	420	420
Selenium (Se)	100	100
Zinc (Zn)	2800	2800
PCBs	4	-

* Dry Weight Basis

Note: PADEP criteria shown in table apply to FPR agricultural utilization programs

a) EPA high quality levels for Molybdenum were suspended in March 1994 pending further research.

Table 8.3 Ranges and Typical Concentrations of Soil Elemental Content for Select Parameter

Element	Range in Soils (ppm)	Typical (ppm)
Aluminum (Al)	10,000 - 300,000	71,000
Arsenic (As)	1 - 50	5
Barium (Ba)	100 - 3000	430
Beryllium (Be)	0.1 - 40	6
Boron (B)	2 - 100	5
Bromium (Br)	1 - 10	5
Cadmium (Cd)	0.01-0.7	0.06
Calcium (Ca)	7000 - 500,000	13,700
Carbon (C)	1000 - 200,000	20,000
Cesium (Cs)	0.3 - 25	6
Chloride (Cl)	20 - 900	100
Chromium (Cr)	1 - 1000	100
Cobalt (Co)	1 - 40	8
Copper (Cu)	2 - 100	30
Fluorine (F)	10 - 4000	200
Gallium (Ga)	5 - 70	14
Germanium (Ge)	1 - 50	1
Iodine (I)	0.01 - 40	5
Iron (Fe)	7000 - 550,000	38,000
Lanthanum (La)	1 - 5000	30
Lead (Pb)	2 - 200	10
Lithium (Li)	5 - 200	20
Magnesium (Mg)	600 - 6000	5000
Manganese (Mn)	20 - 3000	600
Mercury (Hg)	0.01 - 0.3	0.03
Molybdenum (Mo)	0.2 - 5	2
Nickel (Ni)	5 - 5000	40
Nitrogen (N)	200 - 4000	1400
Oxygen (O)	---	490,000
Phosphorus (P)	200 - 5000	600
Potassium (K)	400 - 30,000	8300
Rubidium (Rb)	50 - 500	10
Scandium (Sc)	5 - 50	7
Selenium (Se)	0.1 - 2	0.3
Silicon (Si)	230,000 - 350,000	320,000
Silver (Ag)	0.01 - 5	0.05
Sodium (Na)	750 - 7500	6300
Strontium (Sr)	50 - 1000	200
Sulfur (S)	30 - 10,000	700
Tin (Sn)	2 - 200	10
Titanium (Ti)	1,000 - 10,000	4000
Vanadium (V)	20 - 50	100
Yttrium (Y)	25 - 250	50
Zinc (Zn)	10 - 300	50
Zirconium (Zr)	60 - 2000	300

Source: Data from several references tabulated in Lindsay, W.L., *Chemical Equilibria in Soils*, Wiley-Interscience, New York, 1979.

Nutrients

FPRs used for land application should contain some plant nutritive value. Essential plant nutrients are typically grouped into three categories based on the relative quantities needed for healthy growth. Primary nutrients, including nitrogen, phosphorus, and potassium, are needed in large quantities. Micronutrients are used in very small quantities. They include iron, manganese, boron, chlorine, zinc, copper, and molybdenum. The secondary nutrients--sulfur, magnesium, and calcium--are used at intermediate levels. The following paragraphs discuss the significance of primary nutrients in an LAS.

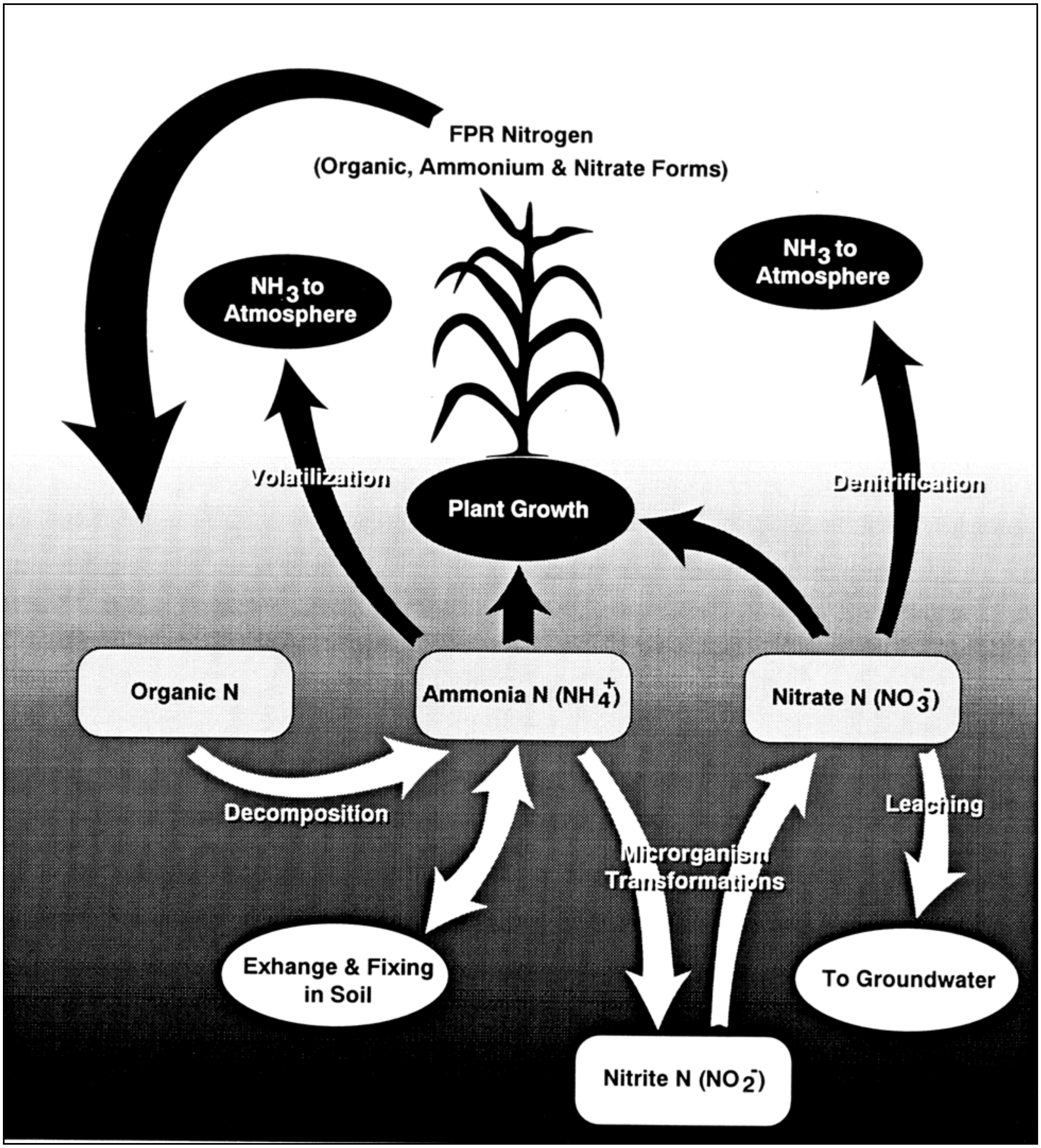
Nitrogen

Nitrogen (N) is a key component of the chlorophyll molecule; photosynthesis would not be possible without this element. Nitrogen is also a critical element in proteins and important in the regulation of metabolic processes. Sufficient N promotes vigorous growth and imparts a dark-green color in vegetation. A lack of N causes stunted plant growth and pale-green or yellowish leaf coloration, usually affecting older leaves first. Normally, yellowing begins at the tips of leaves and progresses down the leaf midrib. When N deficiency is particularly severe, yellowing vegetation continues to brown and die. While N deficiencies cause their own problems, so do N excesses. Excessive N application beyond the nutrient need of the crop being grown at the land application site can result in nitrate leaching. Groundwater supplies contaminated with nitrates are unfit for consumption. The maximum permissible level of nitrate-nitrogen in public drinking water supplies is 10 mg/l. It is not uncommon for groundwater nitrate levels in concentrated livestock agricultural areas to exceed this level.

FPR-N occurs in several basic forms; ammonium-N (NH_4^+), nitrate-N (NO_3^-), nitrite-N (NO_2^-), and organic-N. Ammonium-N and NO_3^- are used by plants. Kjeldahl-N is the sum of NH_4-N and organic-N components. Total N is the sum of all forms. FPR N forms depend on many factors, such as the type of material, its age, and how it has been stored. Nitrogen transformations continue after the FPR has been land applied. Figure 8.2 illustrates how nitrogen changes through the various forms as it cycles through the soil environment. Table 8.1 summarizes typical total N contents along with other characteristics found in various FPRs.

Nitrogen is usually the limiting factor in a LAS. For this reason, FPR LASs must observe a nutrient management plan (NMP) that considers the amount of nitrogen being supplied by all FPRs, manure, and chemical fertilizers that are being used in the context of the crop and expected yield. Factors involved in NMP preparation and N availability estimates are discussed under Components of a Land Application System later in this chapter.

Figure 8.2 FPR nitrogen transformations and potential fates in a land application system



Phosphorus

Phosphorus (P) is essential for metabolic processes and reproduction. Seeds and fruit often contain large quantities of P. Sufficient quantities of P improve crop quality, root growth, straw strength, and crop maturation. Phosphorus deficiency causes poor plant growth, delayed maturity, and small fruits. Insufficient P can often be recognized in small plants by a purple coloration of the veins.

Phosphorus fertility is usually expressed in terms of phosphate (P_2O_5). Laboratory reports often express results as elemental P. This value must be multiplied by 2.3 to determine the equivalent P_2O_5 value. The conversion factor is related to the different molecular weights of the two forms.

When FPRs are land applied on the basis of nitrogen loading, P loadings often exceed crop need. As a result, P slowly builds in the soil. Excessive buildup of any particular nutrient in the soil is generally not considered a sound agronomic practice because it can lead to inefficient use of other nutrients or toxicity in some cases. While high soil P levels are not toxic, in extreme cases excessive soil P has been linked to induced crop zinc deficiencies. Excessive P also causes enrichment of streams when it washes from agricultural fields in runoff.

Avoid repeated overapplication of P by monitoring FPR content and soil P buildup. When overapplication is unavoidable, space applications (perhaps every other year or every third year) to allow crop uptake between applications. Soil testing will indicate when rotation to another field is advisable.

Potassium

Potassium (K*)* plays a key role in many physiological processes such as protein synthesis and fluid balance. As with other primary nutrients, K deficiency is usually evident in older vegetation first. Yellowing and/or burning of leaf edges are a clue that K deficiency is occurring. Other symptoms include reduced plant growth and straw or stalk strength, reduced disease resistance, and reduced winter hardiness of perennial or winter annual crops.

Potassium fertility is usually expressed in terms of K_2O. Laboratory reports often express results as elemental K. Multiply the K value by 1.2 to determine the equivalent K_2O value. This conversion factor accounts for different molecular weights of the two forms.

Odor

Offensive odors originate from biodegrading FPRs. Historically, regulatory criteria in Pennsylvania have not differentiated between odor control and pathogen reduction. Stabilization processes discussed under Pathogens generally alleviate odor concerns for most land-applied materials, though this is not necessarily the case for all FPRs. Stabilization does help to reduce the potential that offensive odors will become a problem. One qualitative way to assess the potential for offensive odors from stored FPRs is to place a representative sample in a plastic wide-mouth jar for 1, 2, 4, 8, 24, and 48 hours and conduct a sniff test at those intervals. Information on FPR odor control is provided in Chapter 3 and at the end of Chapter 8. Additional Resource C provides a list of common odor characteristics you can use to characterize the odor.

Organic Matter (OM)

This important constituent of soil is a direct indicator of soil fertility and influences many other characteristics. The significance of soil organic matter should not be underestimated. Many agronomists feel that soil pH and organic matter together constitute the most important measures of soil fertility. FPRs are organic materials and therefore add to the soil OM reservoir. The most notable soil characteristics influenced by OM include:

- soil color - higher OM imparts darker color, brown to black
- moisture holding capacity - OM increases water retention
- aeration - OM improves aeration
- soil structure (e.g. granulation) - OM stabilizes and improves soil structure
- cation exchange capacity (CEC) - OM increases CEC
- nutrient retention in organic slow release forms - organic nutrients are less likely to leach
- bulk density and compaction characteristics - OM decreases bulk density and lessens the effects of compaction

Organic matter content is normally determined by the mass of sample lost on combustion at high temperatures (550°C). Results are expressed as a percent of sample dry weight.

Pathogens

Some FPRs contain pathogens, which have a negative health impact on humans or animals if they are not properly managed. One way to reduce pathogenic risk is to disinfect or stabilize FPRs before land application. For example, FPR wastewater must be disinfected, typically using chlorine, before irrigation. For solid and slurry FPRs, Pennsylvania has set no specific number or species of indicator microorganisms that may be present in a stabilized material. The definition of stabilization is based on the process used to treat the material. An FPR that has been treated by a Process that Significantly Reduces Pathogens (PSRP) is generally considered stabilized. When an FPR is aggressively treated through a Process that Further Reduces Pathogens (PFRP), better pathogen reduction is presumed. The following box describes PSRPs and PFRPs that are recognized in Pennsylvania.

If you want your FPR to qualify for relaxed land application siting criteria, you are required to use one of the PSRP or PFRP processes.

pH

This parameter is important for assessing handling, storage, and hazardous characteristics of the FPR. It is also a significant indicator parameter for composting. One method of stabilizing FPRs to reduce pathogens involves raising the FPR pH to 12.0 and maintaining that pH for at least two hours. Inducing a high pH for the purpose of stabilizing FPRs does not constitute formation of a corrosive hazardous waste. A high pH FPR may contain significant CCE.

Solids Content

This measures solid material in your FPR and is an indirect indicator of how much water is present. Solids content is commonly expressed as percent by weight. Knowing this property is essential for planning storage and handling facilities and calculating land application loading rates.

Soluble Salts

Soluble salts are materials that dissolve in water or are already in solution in the FPR. Major soil solution ions include calcium (Ca2+), magnesium (Mg2+), sodium (Na+), potassium (K+), chloride (Cl-), sulfate (SO42-), bicarbonate (HCO3-), and nitrate (NO3-). The sum of all ions in solution is called total dissolved solids (TDS). Four principal elements, Na+, K+, Ca2+, and Mg2+, usually dominate TDS.

The soluble salt content of a material may be determined by analyzing the concentration of the individual constituents and summing them--a tedious procedure. A satisfactory estimate of TDS for solid materials can usually be accomplished by measuring the electrical conductivity (EC) of an FPR water mixture. EC can be measured directly on liquid samples. TDS is found by multiplying the EC reading in millimhos/centimeter by 700 to give TDS in ppm or mg/l.

Soluble salts are of interest for three reasons. First, excessive salt concentrations can reduce germination and plant growth. As TDS increases, osmotic pressure effects make it increasingly difficult for plant roots to extract water. A soil exhibiting this phenomenon is called a saline soil. The second reason for monitoring soluble salts is that excessive levels of Na+ relative to divalent ions (Ca2+, Mg2+) can dramatically alter soil structure and reduce soil permeability. Soils having this characteristic are called sodic or alkali soils. Saline-sodic soils are characterized by both high TDS and excessive Na. The third reason for investigating soluble salts in FPRs is that specific ions can induce plant toxicities. Assessment of sodic- or toxic-inducing characteristics requires analysis of specific individual ions. The EC test will not yield the needed information in these cases.

Aside from the salinity and soil structure problems induced by high salt FPRs, certain ions can become toxic when plants are exposed to high concentrations. Sodium, boron, and chloride ions are in this category. Maas (1986) in his paper Salt Tolerance of Plants, presents a review of toxicity considerations regarding these elements. Chapman (1986), also provides coverage of this subject. Full citations for these references are given in the Additional Reading section.

The literature provides little guidance for land application of solid FPRs having high salt concentrations. However, a logical approach is to limit the application rate to a level that maintains the soil water solution concentrations below levels that may be harmful to crops or soil structure. To simulate field soil water solution conditions, mix the FPR with soil from the site at the proposed land application loading rate ratio. The soil/FPR ratio should be made on a dry weight basis. See Additional Resource E to learn how to prepare a soil/FPR sample to perform EC or SAR evaluations.

Table 8.4 shows how EC readings for the two-soil/FPR water solution methods in Additional Resource E are interpreted. Table 8.5 provides more specific guidance for interpreting saturated-extract EC readings. These tables provide guidance for selecting appropriate crops for high salt content LAS programs. Alternately, the tables can be used in combination with soil/FPR water measurements to determine safe loading rates for a particular crop.

Stabilization Processes Recognized in Pennsylvania
Processes That Significantly Reduce Pathogens (PSRP)
Sewage sludge must be properly stabilized or digested to reduce odor potential and pathogen content of the sludge. The acceptable stabilization and digesting processes are as follows:
• **Aerobic Digestion** This process is conducted by agitating sewage sludge with air or oxygen to maintain aerobic conditioning at residence times ranging from 60 days at 15°C to 40 days at 20°C. The level of volatile solids in the sewage influent must be reduced by at least 38% after processing.
• **Anaerobic Digestion** This process is conducted in the absence of air at residence times ranging from 60 days at 20°C to 15 days at 35°C. The level of volatile solids in the sewage influent must be reduced by at least 38% after digesting.
• **Lime Stabilization** Sufficient lime is added to produce a pH of 12 after 2 hours of contact.
• **Composting** Using the within-vessel composting method, the sludge is maintained at operating conditions of 55°C or greater for three days. Using the static aerated pile composting method the sludge is maintained at operating conditions of 55°C or greater for three days. Using the windrow composting method, the solid waste attains a temperature of 55°C or greater for at least 15 days during the composting period. Also, during the high temperature period there will be a minimum of five turnings of the windrow.
• **Heat Drying** Dewatered sludge cake is dried by direct or indirect contact with hot gases, and moisture content is reduced to 10% or lower. Sludge particles reach temperatures well in excess of 80°C, or the wet bulb temperature of the gas stream in contact with the sludge at the point where it leaves the dryer is in excess of 80°C.
• **Air Drying** Liquid sludge is allowed to drain and/or dry on under-drained sand beds, or paved or unpaved basins, in which the sludge is at a depth of nine inches. A minimum of three months is needed, two months of which temperatures average above 0°C on a daily basis.
• **Heat Treatment** Liquid sludge is heated to temperatures of 180°C for 30 minutes.
• **Other Methods** Other methods or operating conditions may be acceptable if pathogens and odors of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods, and the method is approved by the Department.
Processes That Further Reduce Pathogens (PFRP)
Any of the processes listed below, if added to the processed described above, further reduce pathogens. Because the processes listed below, on their own do not reduce the attraction of disease vectors, they are only add-on in nature.
• **Beta Ray Irradiation** Sludge is irradiated with beta rays from an accelerator at dosages of at least 1.l0 megarad at room temperature (20°C).
• **Gamma Ray Irradiation** Sludge is irradiated with gamma rays from certain isotopes, such as 60 Cobalt and 137 Cesium, at dosages of at least 1.0 megarad at room temperature (20°C)
• **Pasteurization** Sludge is maintained for at least 30 minutes at a minimum temperature of 70°C.
• **Other Methods Other** methods or operating conditions may be acceptable if pathogens are reduced to an extent equivalent to the reduction achieved by any of the above add-on methods.

Table 8.4 Interpretation of EC Readings (mmhos/cm) for Soils.

Units (mmhos/cm)		
Saturated Paste	**2:1 Water: Soil**	**Effects**
<1.0	<0.40	Salinity effects mostly negligible, excepting possibly beans and carrots.
1.1-2.0	0.40-0.80	Very slightly saline, but yields of very salt-sensitive crops such as flax, clovers (alsike red), carrots, onions, bell pepper, lettuce, and sweet potato may be reduced by 25 to 50%.
2.1-4.0	0.81-1.20	Moderately saline. Yield of salt-sensitive crops restricted. Seedlings may be injured. Satisfactory for well-drained greenhouse soils. Crop yields reduced by 25 to 50% may include broccoli and potato plus the other plants above.
4.1-8.0	1.21-1.60	Saline soils. Crops tolerant include cotton, alfalfa, cereals, grain, sorghum, sugar beets, Bermuda grass, tall wheat grass, and Harding grass. Salinity higher than desirable for greenhouse soils.
8.1-16.0	1.61-3.20	Strongly saline. Only salt-tolerant crops yield satisfactory. For greenhouse crops leach soil with enough water so that 2-4 quarts (2-4 L) pass through each square foot (0.1 m^2) of bench area, or one pint of water (0.5 L) per 6-inch (15 cm) pot; repeat after 1 hour. Repeat again if readings are still in the high range.
>16.0	>3.2	Very strongly saline. Only salt-tolerant grasses, herbaceous plants, certain shrubs, and trees will grow.

Source: Penn State University. Agricultural Analytical Services Laboratory, 1991.

Saline FPRs

For saline FPRs, you need to manage application rate, site selection (soil texture), crop selection, tillage, and timing. Generally, fine-textured soils have a higher saturation percentage, which reduces soil water EC more than coarse (sandy) soils. However, coarse-textured soils have lower clay content and are less subject to Na^+-induced soil structure problems. Also, coarse soils have higher infiltration and permeability. This permits more rapid percolation or flushing of the root zone. Coarse-textured soils, like sandy loam, are preferred soil textures to manage saline FPRs.

Crop selection is another important consideration for saline FPRs since plants vary in tolerance to saline conditions, as Table 8.5 indicates. Species that are moderately tolerant exhibit decreased growth and yield as salinity increases. Barley and Bermuda grass are exceptionally tolerant species. Beans, lettuce, and onions are among the least tolerant of saline conditions.

Finally, tilling helps to reduce the overall FPR salt content by mixing the FPR with a greater soil volume. Failure to adequately mix your FPR with the topsoil will invalidate your soil/FPR laboratory predictions and place your program at risk. Seeding directly into untilled application areas can hinder germination and early plant development. Limit high-salt FPRs to conservative loading rates and incorporate. Time your application well ahead of seedings. In the worst case, allow at least several rain events to occur before seeding. Monitor the soil soluble salt levels through regular soil analyses. As experience is gained with your material, adjust loading rates accordingly.

Sodic FPRs

Excessive sodium in the soil solution disperses soil colloids and swells clay particles, thus reducing hydraulic capacity of the soil. As a general rule, sodic or alkali soil structure problems related to excessive Na^{+} application are a secondary concern for application of solid or slurry FPRs in Pennsylvania. It is likely that salinity limitations would occur well before soil structure became seriously affected. Evaluate the soil/FPR water solution (as described in Additional Resource E) for the SAR when the FPR is known to contain significant amounts of Na^{+}.

Determination of the SAR of irrigation water is a standard practice in arid areas. Similarly, all FPR irrigation programs should consider the SAR of applied effluent. SAR is determined by the following equation:

$$\mathbf{SAR = Na^{+}/[(Ca^{2+}+Mg^{2+})/2]^{0.5}}$$

(ion concentrations in meq/l)

Knowing the SAR of irrigation or soil solution water alone is insufficient to determine whether Na^{+} will affect soil permeability. There is a relationship between the SAR and the EC such that relatively high SAR values can be tolerated when elevated EC levels exist. This relationship is illustrated in Table8.6, which shows the potential for soil permeability limitations from irrigation water having various combinations of SAR and EC.

Sodium hazard of irrigation water is aggravated by the presence of carbonate (CO_3^{2-}) and/or bicarbonate (HCO_3^{-}) ions, or by free calcium carbonates ($CaCO_3$) in the soil. Carbonate and bicarbonate ions tend to precipitate calcium and magnesium in the soil solution, thereby reducing their concentrations relative to sodium. This results in a net increase in the SAR.

Table 8.5 Salt tolerance of select agricultural crops

Crop	Salinity (a) at Initial Yield Decline, Threshold	Yield Decrease per Unit Increase in Salinity Beyond Threshold	Salt Tolerance Rating
Alfalfa	2.0	7.3	MS
Barley (forage) (b)	6.0	7.1	MT
Barley (grain) (b)	8.0	5.0	T
Bean	1.0	19	S
Bentgrass	—	—	MS
Bermudagrass (c)	6.9	6.4	T
Bromegrass	—	—	MT
Canarygrass, reed	—	—	MT
Clover, alsike, ladino, red, strawberry	1.5	12	MS
Clover, berseem	1.5	5.7	MS
Corn (forage)	1.8	7.4	MS
Corn (grain)	1.7	12	MS
Corn, sweet	1.7	12	MS
Fescue, tall	3.9	5.3	MT
Lettuce	1.3	13	MS
Millet, Foxtail	—	—	MS
Onion	1.2	16	S
Orchardgrass	1.5	6.2	MS
Potato	1.7	12	MS
Ryegrass, perennial	5.6	7.6	MT

Table 8.5 (cont'd)

Crop	Salinity (a) at Initial Yield Decline, Threshold	Yield Decrease per Unit Increase in Salinity Beyond Threshold	Salt Tolerance Rating
Sorghum	—	—	MT
Soybean	5.0	20	MT
Sudangrass	2.8	4.3	MT
Timothy	—	—	MS
Tomato	2.5	9.9	MS
Trefoil, Birdsfoot	5.0	10	MT
Vetch, common	3.0	11	MS
Wheat (b) (d)	6.0	7.1	MT

Source: Maas and Hoffman, 1977.

Note: Col. 1 given in millmhos per centimeter; Col. 2 given in percent per millimho per centimeter; Col. 3 abbreviations are as follows: S - Sensitive MS - Moderately Sensitive MT-Moderately Tolerant T- Tolerant

a) Salinity expressed as EC_e, in millimhos per centimeter at 25 C.

b.) Less tolerant during emergence and seedling stage. EC_e should not exceed 4 mmho cm or 5 mmho cm.

c.) Average of several varieties. Suwannee and Coastal are about 20% more tolerant, and Common and Greenfield are about 20% less tolerant than the average.

d.) Tolerance data may not apply to new semidwarf varieties.

Table 8.6 Potential for permeability limitations from irrigation

Sodium Absorption Ratio (SAR)	Hazard: None EC	Hazard: Slight/Moderate EC	Hazard: Severe EC
0-3	>0.7	0.7-0.2	<0.2
3-6	>1.2	1.2-0.3	<0.3
6-12	>1.9	1.9-0.5	<0.5
12-20	>2.9	2.9-1.3	<1.3
20-40	>5.0	5.0-2.9	<2.9

Source: Reed, et al., 1988

Note: All electrical conductivities are in mmhos/cm

As recommended earlier under saline FPR conditions, select an application site with coarse-textured soils. Addition of gypsum ($CaSO_4$) to irrigation water will increase the Ca^{2+} content and reduce the SAR. When adding constituents to affect the SAR it is important to monitor the EC of the resulting mixture. Increasing the EC may assist in counteracting Na^+-induced soil structure problems but end up increasing the salinity to unacceptable levels. Blending elevated SAR wastewater with low SAR wastewater prior to land application may be another alternative. Perhaps the best approach is to focus efforts on reducing sodium contamination of the FPR.

Toxicity

This characteristic is assessed using the TCLP, as described earlier in Chapter 4. The TCLP measures a contaminant's probability of leaching under slightly acidic conditions. Table 8.7 lists TCLP parameters and maximum allowable test concentrations. Materials that exceed maximum allowable concentrations are considered hazardous wastes. Normally, FPRs will not exceed these concentrations but if you suspect the presence of one or more of the parameters in Table 8.7, test for that parameter. For initial LAS planning, it is wise to have one TCLP test series conducted to document that your FPR is nonhazardous. Further TCLP testing would not be necessary unless the FPR changed significantly. Remember, if you elect not to test for toxicity you must be prepared to certify in writing that none of the constituents in Table 8.7 are present at or above the allowable levels.

8.2 Treatment Technologies

The soil conditioner/fertilizer level of the hierarchy has four categories of treatment technologies: (1) land application of wastewater, (2) land application of solids, semi-solids, or slurries by application vehicles, (3) composting of solid FPRs, and (4) dewatering technologies like heat drying and pelletizing.

Land Application of Solids, Semi-Solids, or Slurries

Beneficial end-use application of solid, semi-solid, or slurry FPRs can be conducted as agricultural utilization, or land reclamation. These approaches usually require land application vehicles for spreading. Each alternative is described briefly in the following paragraphs. Note that land reclamation requires a site-specific permit. Agricultural utilization of FPRs can be conducted without a permit <u>as long as you adhere to the guidance provided in this manual as summarized in the Regulatory Resources section</u>.

Table 8.7 TCLP Test Parameters and Maximum Allowable Levels

Compound	Regulatory Level in TCLP Extract (mg/L)[(a)]	Compound	Regulatory Level in TCLP Extract (mg/L)[(a)]
Arsenic	5.0	Hexachlorobenzene	0.13[c]
Barium	100.0	Hexachlorobutadiene	0.5
Benzene	0.5	Hexachloroethane	3.0
Cadmium	1.0	Lead	5.0
Carbon tetrachloride	0.5	Lindane	0.4
Chlordane	0.03	Mercury	0.2
Chlorobenzene	100.0	Methoxychlor	10.0
Chloroform	6.0	Methyl ethyl ketone	200.0
Chromium	5.0	Nitrobenzene	2.0
o-Cresol[b]	200.0	Pentachlorophenol	100.0
m-Cresol[b]	200.0	Pyridine	5.0[c]
p-Cresol[b]	200.0	Selenium	1.0
2,4-D	10.0	Silver	5.0
1,4-Dichlorobenzene	7.5	Tetrachloroethylene	0.7
1,2-Dichloroethane	0.5	Toxaphene	0.5
1,1-Dichloroethylene	0.7	Trichloroethylene	0.5
2,4-Dinitrotolulene	0.13[c]	2,4,5-Trichlorophenol	400.0
Endrin	0.02	2,4,6-Trichlorophenol	2.0
Heptachlor (and its epoxide)	0.008	2,4,5-TP (Silvex)	1.0
		Vinyl Chloride	0.2

(a) A waste having a TCLP extract with values exceeding any of these listed is considered a hazardous waste by virtue of toxicity. Where the waste contains less than 0.5% filterable solids, the waste itself, after filtering using the methodology outlined in Method 1311, is considered to the extract for the purpose of this section.

(b) If 0-, m-, and p-cresol concentrations cannot be differentiated, the total cresol concentration is used.

(c) Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.

Table 8.8 Comparison of Design Features for Principal Land Treatment Processes

Feature	Principal Processes		
	Slow Rate	Rapid Infiltration	Overland Flow
Application techniques	Sprinkler or surface[a]	Usually surface	Sprinkler or surface
Annual application rate, ft.	2 to 20	20 to 560	10 to 70
Field area required, acres[b]	56 to 560	2 to 56	16 to 110
Typical weekly application rate, in.	0.5 to 4	4 to 120	2.5 to 6[c] 6 to 16[d]
Minimum preapplication treatment provided in United States	Primary sedimentation[e]	Primary sedimentation	Screening and grit removal
Disposition of applied wastewater	Evapotranspiration and percolation	Mainly percolation	Surface runoff and evapotranspiration with some percolation
Need for vegetation	Required	Optional	Required

Source: USEPA, 1977.

a) Includes ridge-and-furrow and border strip.
b) Field area in acres not including buffer area, roads, or ditches for 1 Mgal/d (43.8 L/s) flow.
c) Range for application of screened wastewater.
d) Range for application of lagoon and secondary effluent.
e) Depends on the use of the effluent and the type of crop.

Agricultural utilization involves spreading FPRs at a rate that will improve soil properties for crop growth. The types of crops may range from agricultural field crops to turf grass, or even silvicultural crops. Benefits may include added nutrients, soil conditioning, or pH adjustment. You can apply these materials annually as long as the cumulative loading of key parameters is below the maximum cutoff values listed in Table 8.2 and nutrients are applied in accordance with a nutrient management plan. The key components of agricultural utilization systems are described in the next section of this chapter.

In land reclamation, FPRs may improve disturbed soils to better support vegetation. Generally only one heavy application is performed. Since this method allows heavy application of material, less acreage is needed annually. However, new acreage is required each year. A site-specific or general permit is required for land reclamation. Contact the PADEP, Bureau of Land Recycling and Waste Management for land reclamation requirements.

Composting

Composting is a biological process that metabolizes readily degradable organic matter into a soil-like material called compost. This process generates heat energy, water vapor, and carbon dioxide. High composting temperatures destroy pathogens and weeds, thus producing a stable, storable mixture that can be used as a soil conditioner. Dating back to the eighteenth century, composting offers a number of advantages over direct land application of FPRs. Composting has been used for treating apple, peach, pear, grape, apricot, tomato, chocolate, coffee, brewing, and other FPRs with great success. Sidebar 8.2 lists some of the advantages and drawbacks to composting FPRs.

Pros and Cons of FPR Composting

Pros:

Saleable product
Improves FPR handling and storage characteristics
Improves land application
Lowers risk of pollution and nuisance complaints
Pathogen destruction
Bedding substitute
May reduce soil-borne plant diseases
Possible revenue from processing of tipping fees
Fewer regulatory restrictions/constraints on finished product

Cons:

Land required for operations
Possibility of odors
Weather interferes with composting (unsheltered operations)
Marketing is necessary

Source: After NRAES, 1992

Most FPRs are compostable under suitable environmental conditions. Four factors must be satisfied for successful composting: First, the compost must contain a good mix of organic materials with sufficient carbon and nitrogen for microbial growth (C:N ratio). Second, an adequate supply of oxygen must be present to maintain aerobic microbial activity. This factor depends on porosity, structure, texture, and particle size. Most times bulking agents such as sawdust or wood chips are used to promote aerobic conditions. The third factor is sufficient moisture to support microbial activity without reducing pile aeration. Finally, composting must occur at temperatures that promote and support thermophillic ("heat-loving") microorganisms. Material pH also affects composting. Table 8.9 summarizes reasonable and preferred values for these factors that promote rapid composting.

Table 8.9 Recommended Conditions for Rapid Composting

Condition	Reasonable range(a)	Preferred range
Carbon to nitrogen (C:N) ratio	20:1 – 40:1	25:1-30:1
Moisture content	40-65%(b)	50-60%
Oxygen concentrations	Greater than 5%	Much greater than 5%
Particle size (diameter in inches)	1/8-1/2	Varies(b)
PH	5.5-9.0	6.5-8.0
Temperature (degrees F)	110-150	130-140

Source: NRAES, 1992.
(a) These recommendations are for rapid composting. Conditions outside these ranges may also be successfuls.
(b) Depends on the specific materials, pile size, and/or weather conditions.

Four methods of composting – passive, windrow, aerated piles, and in-vessel systems – are described below.

Passive composting

Passive composting involves piling piles of organic residues allowing nature to take its course. This system usually cannot maintain the desired conditions for rapid composting and therefore results in slow decomposition. Passive composting is not commonly used for FPRs.

Windrow composting

Windrow composting uses mixed raw materials in long narrow piles called windrows that are periodically turned or agitated. Though more efficient than the passive system, air exchange still relies on natural processes. Turning the pile replenishes pile porosity, disperses decomposition gases and water vapor, and rotates outer material to the inside of the pile where temperatures are higher. Mixing also promotes even composting of the entire volume and results in a better kill of pathogens and weed seeds. This system is not commonly used for FPRs.

Aerated pile

Aerated pile systems are broken down into two separate categories: passively aerated piles and aerated static piles. Passively aerated piles use open-ended pipes placed through the base of the pile. Due to the chimney effect, air flows into the pipes and up through the pile as heated gases in the compost rise. In the aerated static pile, piping is installed to supply air provided by mechanical blowers. The blowers help to control the composting process. This method allows formation of large piles, and no turning or agitation is required once the pile is formed. Well-constructed aerated static piles can complete the active composting phase in three to five weeks. Aerated static pile systems are probably the most common approach to FPR composting.

In-vessel

In-vessel systems confine the composting process in a container or vessel. Bins, agitated beds, silos, and even rotating drums are used. Most in-vessel systems are commercial systems that require a license for use or direct purchase--both substantial capital investments. The potential advantages of in-vessel systems include reduced labor costs, fewer weather problems, better operational control, faster and more consistent composting, reduced land requirements, and better odor control capabilities.

Heat Drying

Heat drying subjects the FPR to high temperatures and reduces moisture content to 10% or less. The benefits of heat drying make a land application system much easier to operate. One Pennsylvania meat processor has reported substantial savings by moving from direct land application of dewatered FPR sludges to land application of the same material after heat drying.

8.3 Components of a Land Application System

This section provides guidance for the siting and operation of an FPR land application system. By this point, you should have generally assessed the suitability of your FPR for land application. The next step is to determine whether or not suitable land application areas exist close to your plant. This part of the manual describes the basic components of an LAS so that you can select a site and operate the LAS. Ten components we described in this section:

- siting
- site preparation
- nitrogen availability
- field selection
- monitoring
- recordkeeping

- odor control
- storage
- transportation
- reviewing system performance

As you read this section, keep in mind that the design of an LAS involves the interaction and control of several physical, chemical, and biological processes. Site-specific variables such as climate, crop, soil, and waste characteristics limit LAS alternatives. However, in all cases, it is the engineering design process that accounts for this variability in choosing a practical and efficient LAS to meet FPR use and environmental quality objectives. If correctly designed and operated, an LAS site with limitations can be compensated for with changes in loading rates, cropping systems, pretreatment, surface and subsurface water control, and more intensive monitoring.

Siting

The ideal land application site would be an isolated farm growing a variety of animal feed crops in large ten-acre fields. The landscape would be flat to gently sloping with deep, well-drained, medium textured, loamy soils. No streams, wetlands, wells, or sinkholes would be near the fields and regional groundwater would be deeper than 4 feet. If farmer operators had any livestock or imported animal manures, they would be actively following a soil conservation plan and a nutrient management plan. Unfortunately, the ideal site does not exist for most processing plants. So what criteria can we use to assess the suitability of farmland for FPR land application? The following discussion answers this question.

Table 8.10 provides a summary of general site criteria for agricultural use of FPRs. These factors relate to soil and local water resources. Observing these characteristics assures that an adequate soil is present. Remember, land application technologies all rely on the soil to act as the treatment medium. Adequate soil depth, drainage, and texture are important elements that directly impact the soil's ability to physically, chemically, and biologically renovate applied FPRs.

Adequate soil depth provides room for biological activity, healthy root development, and plant nutrient uptake. Sufficient depth also assures that a good filtration medium is present to remove suspended matter in soil percolate water. Historically, 20 inches has been the minimum requirement. However, if pathogens, odors, or vectors are not problems with your FPR (e.g., stabilized) and it is applied with a technique other than direct subsurface injection, a 12-inch soil depth to bedrock is considered satisfactory. This reduced soil depth requirement is unique to FPRs because of their origin – human food and animal feed products.

Like soil depth, soil drainage requirements for land application of FPRs are relaxed if the FPR does not contain pathogens or has been stabilized. Soil drainage is the depth to the seasonal high water table (SHWT) and reflects the degree to which a soil maintains an aerobic environment. Aerobic conditions promote rapid degradation of organic materials, an important function of the soil treatment medium. The presence of drainage mottles in a soil profile is an indicator of SHWT depth. Historically in Pennsylvania, a 20-inch minimum depth to mottling has been required for land application. Since SHWT conditions occur infrequently (usually in the early spring), soils that are moderately deep (e.g., 20-40 inches) should provide adequate treatment during most of the year. Hence soils that exhibit drainage mottling as shallow as 12 inches from the surface may receive FPRs as long as the soil is at least 20 inches deep. Surface application is permitted on such sites when soil saturation is deeper than 12 inches from the surface. When soil saturation is deeper than 20 inches, injection application may also be employed. During extended wet periods when soil is saturated at depths shallower than 12 inches, FPRs should not be applied. Keep in mind that soil rutting and

Table 8.10 General site criteria for agricultural utilization of FPRs

Site Characteristic	Suitable	Unsuitable
Slope	≤15%[a]	>15%[a]
	15%-20% with well established cover crop or adequate crop residue	>20%
	20%-25% with subsurface injection	>25%
Soil depth to bedrock	≤20 inches to bedrock [≥12 inches][b]	<20 inches [<12 inches][b]
Soil drainage	≥20 inches to mottling [≥12 inches][b]	<20 inches [<12 _inches][b]
Soil pH	Consistent with recommended crop requirement[b]	<crop requirement[c]
Depth to regional groundwater	≥4 feet to regional groundwater	<4 feet

Source: Based on PA DEP agricultural utilization guidelines and regulations contained in Title 25, Chapter 291.

(a) If a soil conservation plan has been developed to include application on steeper slopes, the slope can be adjusted accordingly.

(b) Soil depths in brackets apply to FPRs which have been stabilized by recognized PSRP and PFRP methods.

(c) Unless FPRs are used to increase soil pH to recommended crop requirement levels within 6 months, following the first application. Recommended levels should follow the current *Penn State Agronomy Guide* recommendations.

equipment limitations make application on wet soils impractical. Land application on somewhat poorly drained sites requires special attention to timing in order to avoid problems in the field.

Historically, sewage sludge land application programs have observed a minimum soil pH of 6.5 to eliminate the possibility of heavy metal leaching through the soil, minimize crop uptake of heavy metals, and promote optimum plant growth conditions. Since FPRs typically do not contain significant quantities of heavy metals, this soil pH standard is relaxed for FPRs. Rather, FPR land application programs should strive to maintain a soil pH in the range that is recommended for optimum plant growth in the current *Penn State Agronomy Guide*.

Determining depth to regional groundwater technically requires a qualified hydrogeologist. However, for land application site suitability, the principal question is whether the regional groundwater table is greater than 48 inches below the surface. Usually you can make a reasonable estimate of regional groundwater depth by talking to nearby well owners or a well driller familiar with the area. `The U.S. Geological Survey (USGS) and Pennsylvania Geologic Survey (PAGS) are additional sources of groundwater information. Actual site measurements can also be used. On-site excavation of a backhoe pit greater than 48 inches and installation of a plastic stand pipe will allow measurement of standing water level. Let at least 24 hours pass after installation before taking measurements. Be advised that the standpipe measurement method could give you an invalid measure of the regional groundwater, since you may be measuring the seasonal high water table. Generally, in Pennsylvania, depth to regional groundwater is more than 48 inches, except in low-lying areas or along major stream channels or water bodies.

The principal resource used to screen soil suitability is the USDA soil survey. A soil survey has been prepared for every county in Pennsylvania. Contact the County Conservation District (CCD) or Soil Conservation Service (SCS) office to obtain a copy. Soil surveys are good tools for site planning purposes. Recognize that actual soil conditions in the field may differ significantly from those suggested in the soil survey. Another good resource is the personnel in your local CCD, SCS, and Cooperative Extension offices. These offices have an intimate knowledge of farm operations in the county. They may be able to quickly direct you to some promising contacts and resources.

A final factor affecting site selection is isolation distance. Table 8.11 shows the isolation distance standards for Pennsylvania. These buffer distances safeguard local water resources against potential contaminant migration off-site. Contaminants of concern are not limited to metals and toxic substances. They include biological contamination and nutrients also. Nitrate nitrogen (NO_3^-) is the parameter of most concern since it is quite mobile and often exceeds drinking water standards in agricultural areas that are heavily manured or over fertilized. Enrichment of surface waters with nutrients (phosphorus and nitrogen compounds) can lead to eutrophication and degradation of water quality.

Table 8.11 Required Isolation Distances for Agricultural Utilization of FPRs

Site Feature	Minimum Isolation Distance(ft)
Property line	50[a]
Occupied buildings	300[a]
Individual or public water supply well	300[a]
Upgradient of a surface water source	1000[a]
Intermittent or perennial streams	100
Exceptional value wetlands	100
Sinkhole or area draining to a sinkhole	100
Perimeter of an undrained depression	25
Bedrock outcrop	25

Source: Based on PADEP Residual Waste Regulations, Title 25, Chapter 291.

(a) The listed isolation distances may be reduced with written permission of the site feature owner (i.e., adjacent property owner)

Some isolation distances historically observed in land application programs for municipal wastes and non-FPR residual wastes can be reduced for FPR land application programs. Buffer distances to property lines, dwellings, and water supplies may be reduced with written permission from the owner. In all cases, remember that isolation distances are a safety precaution and sometimes only a means of avoiding nuisance complaints from neighbors. Maintaining correct isolation distances never compensates for deficiencies in the other components of an LAS.

Once you identify a suitable site, have the area examined by a qualified soil scientist. A SCS district conservationist may be able to visit the site and confirm that the soil survey either does or does not accurately represent the soils. A professional soil scientist can also be hired to confirm site suitability. Skipping this step could lead to future operational problems if the site turns out to be unsuitable.

Site Preparation

Site preparation includes accurately mapping the farms, establishing a conservation plan, soil sampling, and preparing a nutrient management plan.

Take the time to establish accurate mapping of your land application farms. Start by locating farm sites on a USGS 7.5 minute quadrangle. These maps are usually available at minimal cost from local sporting goods shops, bookstores, and the County Conservation District. USGS maps are excellent for identifying local physiographic features and road networks. Also, locate your sites on the SCS soils maps and highlight property boundaries.

Next, develop or acquire a larger-scale map of each site. Maps should be on a known scale with a north arrow and show the locations of streams, conservation plan structures, buildings, field roads, field lines, field ID numbers, and suitable land application fields. Farm site mapping may be as simple as the 660-scale aerial photography mapping used by SCS in the preparation of soil conservation plans, or you may conduct an actual topographic survey and generate high-quality topographic plans. In the latter case, farmers can use such maps for their agronomic planning and management. Going the extra mile to prepare an accurate and detailed site plan assists you in managing your land application program and fosters an effective working relationship with the farmer. The final maps must show clearly where your application sites are and illustrate clearly the location of principal features and application fields. The true test of your map is that newcomers would be able to locate the sites and find their way around.

All land application programs must be operated within the context of an implemented farm conservation plan. The conservation plan outlines the acceptable farming practices that minimize soil loss from the application site. Conservation practices may include structural facilities such as grass waterways, and/or nonstructural practices, like contour strip cropping. The conservation plan incorporates the farmer's objectives, the physiographic setting, and crop rotation. The crop rotation is the component that is probably the easiest factor to change. The rotation should be projected over at least the next three years.

Make sure that your planned FPR land application activities are consistent with the conservation plan. If no plan exists or your program significantly alters the current plan, you must update the conservation plan. The local SCS office will do the update for the farmer at no cost, but the revision will take time. You may need to hire an outside consultant. Even if you revise the old plan or start fresh with a new conservation plan, soil loss constraints may require you to modify your spreading program. Once the plan is finalized, it must be implemented before you can begin land application activities.

Another preapplication task involves soil sampling to determine soil fertility. At the onset of your program, test soil chemistry in order to establish a background database. This could be very important for FPRs that contain heavy metal concentrations substantially higher than background levels. The drawback to soil chemistry testing is cost; each analysis costs approximately $90. Laboratory test data and cropping information should be compiled into a single table for each farm and show at a minimum the field ID, available acreage, the previous crop, the planned crop, soil pH, soil phosphate (P_2O_5) status, and the soil potassium (K_2O) level. Table 8.12 is an example of such a table.

Table 8.12 FPR application field data for the 1993 growing season for the John Doe property

Field ID	Acceptable Land Application Acreage	1992 Crop	Planned 1993 Crop	pH	1993 Crop N Utilization lb/acre[a]	1993 Crop N which may potentially be supplied by FPRs lb/acre[b]	Soil Fertility[c]	
							P_2O_5 (lb/acre)	K_2O (lb/acre)
M3B	5.5	Sorghum	Barley	6.5	105	105	134	197
M3C	6.0	Alfalfa	Barley	6.5	85	0	84	84
M3D1	8.3	Barley	Alfalfa	6.8	300	300	102	262
M3D2	7.6	Barley	Barley	7.1	105	105	130	234
M3E	9.4	Corn Silage	Corn Silage	7.2	175	125	165	281
M3F	10.2	Alfalfa	Corn Silage	6.9	175	75	91	94
M3H	10.3	Corn Silage	Corn Silage	6.8	175	125	161	271
M3I	8.6	Alfalfa	Alfalfa	6.9	300	300	191	346
M3J	3.6	Alfalfa	Wheat	6.7	90	0	91	140
M3KA	8.0	Sunflower	Corn Grain	6.8	150	100	114	243
M4A	8.1	Barley	Corn Grain	7.2	150	100	74	112
M4B	11.6	Corn Grain	Corn Grain	6.7	150	100	98	178
M4E	3.5	Corn Silage	Barley	7.1	85	85	126	300
M5D	9.1	Alfalfa	Alfalfa	6.8	300	300	88	234
M5F	2.8	Barley	Wheat	6.2	90	90	180	477
M5G	5.8	Barley	Wheat	6.7	90	90	202	515
M5H	9.8	Alfalfa	Alfalfa	7.0	300	300	161	393
F1B	5.5	Corn Grain	Corn Grain	6.7	150	100	225	356
F2AN	9.8	Buckwheat	Corn Grain	6.9	150	100	37	56
F2AS	2.9	Sunflower	Corn Grain	7.0	150	100	32	66
F3B	6.1	Alfalfa	Alfalfa	6.6	300	300	74	112

a) N utilization reflects the amount of N which is removed by crop harvest. See Table 8.13 for typical nutrient removal rates by crop.
b) Listed values take into account planned conventional fertilizer use, carry-over N from previous crop (e.g., alfalfa), and organic fertilizer use history (e.g., manure or FPRs). Consult the latest *Penn State Agronomy Guide* for N carry-over values.
c) From most recent soil fertility analysis reports.

The nutrient management plan NMP is a dynamic crop fertility management tool specially designed for the unique circumstances found in each field on the farm. An NMP considers field fertility, the history of organic nutrients applied, the planned crop, and all nutrient sources used to supply crop needs for the entire farm, including manure, chemical fertilizers, and carry-over nitrogen from legume crops. Table 8.13 shows the expected nutrient requirements for various crops and should be used for NMP planning unless another crop nutrient removal rate can be supported. Alternatively, fertilizer recommendations in the most recent *Penn State Agronomy Guide* can be used. A NMP must be developed and implemented on any farm where land application occurs. Pennsylvania has enacted NMP legislation mandating NMP preparation for any farm meeting certain conditions. Specific regulations governing minimum NMP content are contained in Chapter 83 (Nutrient Management), which is accessible on the WEB at http://www.pacode.com/secure/data/025/chapter83/subchapDtoc.html. These regulations will apply to FPR LAS programs.

Additional Resource J contains "Field Application of Manure" from Pennsylvania's *Manure Management Manual.* This resource provides guidance concerning the nutrient value of manure, preparation of NMPs, and the calibration of manure-spreading equipment (see also Additional Resource K, FPR Field Application Vehicle Calibration). Further manure NMP guidance can be found in the most current *Penn State Agronomy Guide*. This guide is particularly useful because it provides the most up-to-date information on manure nitrogen availability.

One Pennsylvania beef processor has been land-applying FPRs for several years. The processor has identified eight practical factors that lead to a successful land application program:

- provide a quality FPR product
- learn and respect the farmer's needs
- respect your neighbors
- determine crop needs
- adhere to regulatory guidelines
- maintain excellent records
- establish routine FPR testing
- provide support services to the farmer when appropriate

For more details on this beef processor's program, see Part III, Chapter 14.

Table 8.13 Nitrogen, phosphate, and potash removal from soil by various crops

Crop	Units	Pounds Removed per Unit Production		
		N	P_2O_5	K_2O
Corn, grain	bu	1.0	0.4	0.3
Corn, stover	ton	21.0	8.0	37.0
Corn, silage (65% moist.)	ton	7.0	3.0	9.0
Soybeans, grain	bu	3.8[a]	1.0	1.5
Soybean, residue	ton	24.0[a]	7.0	16.0
Wheat, grain & straw	bu	1.5	0.7	1.4
Wheat, straw	ton	13.0	4.0	25.0
Wheat, grain	bu	1.3	0.5	0.3
Oats, grain & straw	bu	1.0	0.4	1.2
Oats, straw	ton	12.0	5.0	33.0
Oats, grain	bu	0.7	0.3	0.2
Barley, grain & straw	bu	1.4	0.6	1.3
Barley, straw	ton	14.0	5.0	31.0
Barley, grain	bu	1.0	0.4	0.3
Rye, grain & straw	bu	1.4	0.8	1.0
Rye, straw	ton	10.0	6.0	17.0
Rye, grain	bu	1.0	0.5	0.3
Orchard grass	ton	50.0	17.0	63.0
Brome grass	ton	33.0	13.0	51.0
Tall fescue	ton	39.0	19.0	53.0
Blue grass	ton	26.0	18.0	60.0
Clover-grass	ton	41.0	13.0	39.0
Timothy	ton	38.0	14.0	63.0
Sorghum-Sudangrass[b]	ton	7.0	3.0	9.0
Alfalfa	ton	50.0[a]	11.0	50.0
Reed Canarygrass[c]	ton	73.3	23.0	53.6
Small grain silage (55% moist)	ton	20.0	4.5	27.0

Source: Dr. Douglas Beegle (The Pennsylvania State University) – personal communication.

Note: Values given reflect average of six sources (unless otherwise noted) which estimate unit production removals. Source: Dr. Doug Beegle (PSU) - personal communication.

a) Legumes fix all of their required nitrogen except for a small amount applied in the starter fertilizer. However, they also have the capability to utilize nitrogen as indicated.
b) Nutrient removal similar to corn silage.
c) North Central Regional Extension, 1977. Utilizing Municipal Sewage Wastewaters and Sludges on Land for Agricultural Production. NCRE Publication No. 52. Michigan State University, East Lansing, MI.

Nitrogen (N) Availability

Since most FPRs do not contain excessive heavy metals or other deleterious substances, the nitrogen (N) content often determines the maximum amount of material that can be applied to a particular field for a given crop. Too little N can result in poor crop yield and possibly place your LAS program in jeopardy if you are working with private farmers. Too much N beyond crop needs can result in nitrate leaching and degradation of local groundwater--a liability you don't want. The key to determining the appropriate amount of material to apply is to know precisely just how much of the FPR nitrogen will be available for plant growth. Unfortunately, N availability from organic materials is difficult to predict.

FPR nitrogen occurs in several forms. The inorganic nitrate and ammonium forms are the ones used by crops, with nitrate being the most important. Usually, most N in FPRs is tied up in the organic form. Through decomposition, organic N is converted to inorganic forms and becomes available for plant growth (see Figure 8.2). Conversion of organic-N to inorganic-N is called mineralization. Nitrogen immobilization is the opposite of mineralization, where inorganic-N is consumed by living organisms and incorporated into living tissue. When the organism that consumed the N dies, the organic-N again mineralizes and is available for other organisms, including plants.

Nitrogen cycling within the soil is a complex process that is affected by many fluctuating environmental factors. For this reason, the standard agronomic soil fertility analysis does not include a test for nitrates. By the time a sample is taken in the field, packaged, shipped, and analyzed, the nitrate content may have changed drastically. Even assuming that sample preservation has been good enough to minimize nitrogen transformations, laboratory reports on nitrate received two weeks after sampling may have little resemblance to the actual field conditions when you receive the results. To improve N testing, recent efforts at Penn State have focused on ways of rapidly assessing soil nitrate levels. Contact your local Cooperative Extension agent and ask about the Quick-N test for corn sidedressing.

Available N predictions from field application of FPRs are a rough estimate. Reasonable approximations have been published that provide guidance for manure NMP purposes and for municipal sewage sludges and composts. No data on mineralization rates for FPRs are readily available. Perhaps the most reasonable approach is to assume that FPRs will behave much the same as animal manures. Hence, availability factors developed for land application of manure should be used unless better data are available. For composted FPRs, a 10% availability factor is appropriate. This compost-N availability factor has been used for municipal sewage sludge composts and should roughly approximate FPR compost-N availability. Consult the most current *Penn State Agronomy Guide* to obtain the current N-availability factors used for manures. Table 8.14 shows the manure N availability factors observed at the time of this printing.

Table 8.14 Percentage of total manure nitrogen remaining available to crops after storage and handling, as affected by application method and field history.

	N Availability Factor	
	Poultry Manure	**Other Manure**
Current year, time of application and incorporation		
Manure applied for corn or summer annuals the following year:		
Applied in the spring		
incorporation the same day	0.75	0.50
incorporation within 1 day	0.50	0.40
incorporation within 2-4 days	0.45	0.35
incorporation with 5-6 days	0.30	0.30
incorporation after 7 days	0.15	0.20
no incorporation	0.15	0.20
Applied previous fall or winter with no cover crop	0.15	0.20
Applied the previous fall or winter with cover crop harvested for silage[a]	0.15	0.20
Applied previous fall or winter with a cover crop as a green manure	0.50	0.40
Manure applied for small grains		
Applied previous fall or winter	0.50	0.40
Historical frequency of manure application on the field		
Rarely received manure in the past	0	0
Frequently received manure (4-8 out of 10 yrs)	0.07	0.15
Continuously received manure (>8 out of 10 yrs)	0.12	0.25

Source: The Pennsylvania State University, 1993.

[a] These low availability factors do not indicate a net loss of N. A large amount of N is removed in the cover crop silage. This N will be recycled in the manure when the silage is fed.

Field Selection

After identifying the site and running through the site preparation considerations noted above, you are ready to select a specific field for application. Follow the seven steps below to make your field selection.

Step 1: Assemble Background Farm Data

Compile FPR application field data tables for each farm in your LAS program. Table 8.12 provides an example field data spreadsheet. These data were originally compiled during site preparation for the initial year of operation. These tables need to be updated each year with current crop data and soil fertility information.

Step 2: Review FPR Sample Analyses

Review the most recent applicable FPR-chemical analysis to determine FPR suitability for land application. Compare FPR metal concentrations to those in Table 8.2. If your FPR parameters exceed those in Table 8.2, land application should not be conducted. Identify other FPR-limiting characteristics such as soluble salts, high BOD, or fats and oils. Refer to the Characteristics of Interest section of this chapter for guidance.

Step 3: Evaluate Nitrogen Availability

Compute FPR available nitrogen content using the following formula.

$$\boxed{\begin{array}{c}\textbf{Available}\\ \textbf{Nitrogen}\\ \textbf{Content}\end{array}} = \boxed{\begin{array}{c}\textbf{Total N Content}\\ \textbf{in \% dry}\\ \textbf{weight basis}\end{array}} \times \boxed{\begin{array}{c}\textbf{N availability}\\ \textbf{factor in \%/100}\end{array}} \times \boxed{\textbf{20}} = \boxed{\begin{array}{c}\underline{\textbf{available N}}\\ \textbf{dry ton of FPR}\end{array}}$$

Step 4: Review Individual Field Suitability

Review field data from Step 1. Eliminate the following fields from consideration for FPR application in the current year:

- Fields with soil pH less than the optimum range for the crop being grown. An exception to this is when pH has been, or will be, adjusted according to soil test recommendations prior to FPR application, or if application of the FPR itself will correct the soil pH to the appropriate range with six months of spreading.
- Fields with excessive soil P_2O_5 (>500 lb/acre) when other fields with lower P levels can provide adequate application acreage and can be practically scheduled.
- Second- and third-year pure alfalfa stands, unless specifically authorized by the farm operator.

Step 5: Review Crop Nutrient Requirements

Review Table 8.13 for crop nutrient requirements. Make sure crop-N is based on a realistic crop yield goal. FPR available-N applications should not exceed this value unless the soil test specifically recommends a higher N application for that crop, or the current *Penn State Agronomy Guide* fertilizer application guidelines recommend more N.

Step 6: Review FPR Land Application Data with Farmer

Discuss FPR application and review Table 8.12 with the farm operator(s). Use of specific fields for FPR application, method, and timing must be coordinated with other farm operation activities. Limitations on supplemental chemical fertilization beyond FPR-applied nutrients must be discussed. Review the need for liming of fields with pH less than the optimum range for the crop being grown.

Step 7: Examine Fields for Suitability

Walk the field(s) proposed for FPR application and note any obstructions that may limit FPR application operations (e.g., sinkholes, depressions, slopes, rock outcroppings). Application area limits that are not easily seen should be identified and marked in the field prior to application.

Method of Application

Once you have identified fields, application may be performed in several ways, depending on the solids content of the FPR and the crop. Surface application of liquid or slurry material is performed using tank trucks or liquid manure spreaders. Solid or semi-solid materials are usually applied using standard manure application equipment. If odor or soluble salts are limiting factors, incorporate the material promptly. Inject fluid FPRs using tank vehicles fitted with chisels and hose/nozzle delivery systems to place the liquid FPR in the chisel furrows. Remember, FPRs that may create noxious odors, attract vectors, or contain pathogens must be stabilized by one of the methods described earlier to qualify for relaxed soil requirements (i.e., depth). Direct subsurface injection requires a minimum 20-inch soil depth.

FPR land application of liquids must be performed in a manner that prevents ponding or standing accumulations of FPRs on the surface. Land-applied material on areas with inadequate litter or vegetation must be incorporated within twenty-four hours. Also, surface application on harvested forage crops (e.g., alfalfa, timothy, reed canary grass, etc.) must be performed within ten days following mowing. Application following the last cutting for the season may be delayed longer. Avoid spreading FPRs on land where food crops, that are eaten raw by humans, are being grown when potential pathogen transmission is a concern.

Winter application of FPRs should follow standard practices established for manure handling. Additional Resource J addresses winter application as follows: "Winter application (of manure) is the least desirable, from both a nutrient utilization and a pollution point of view, because frozen soil surface prevents rain and melting snow from carrying nutrients into the soil. The result is nutrient loss and pollution through runoff. If daily winter spreading is necessary, manure should be applied to fields with least runoff potential. It should be applied to distant or limited access fields in early winter and then to nearer fields later in the season." Field application of FPRs is not permitted on snow-covered ground. Remember, the potential for a pollution incident is greatest in the winter, and therefore so is your liability.

As the FPR generator you are responsible for making sure that your material is used on suitable areas and in accordance with the conservation and nutrient management plans. If you contract to have your FPR land-applied, you should require the hauler to document that all of the requirements for proper land application recycling are being met. In the end, as the generator, you bear the largest responsibility for proper handling of your FPRs.

Monitoring

A certain amount of FPR and soils monitoring is necessary. Part I of this manual stressed the importance of properly characterizing your FPR. Periodic resampling should be conducted to monitor critical characteristics. Based on knowledge of your FPR you should decide how frequently to check the FPR. However, the minimum frequency for reanalysis of FPRs is quarterly.

Field soil fertility should be established before your first FPR application. Continue with annual soil fertility testing for the duration of your land application program. If your FPR has elevated salts, the soluble salt level in the soil should also be annually monitored. For FPR containing elevated levels of heavy metals, soil chemistry should be assessed once every five years. It may be advisable to observe this frequency for monitoring soil chemistry for typical FPR land application sites in order to assure farmers that no imbalances are occurring in the soil.

Recordkeeping

Proper management of any FPR land application program requires that you maintain good records of FPRs and application fields. A record of the amount and all known characteristics of land-applied FPRs must be maintained. All soil analyses (fertility and chemistry) should also be accessible. Compile laboratory data into a spreadsheet that is updated as analytical results are received to monitor characteristics for any sudden changes. This works for both FPR and soil information. One meat processor uses a computer database to track NMP parameters and field scheduling with great success. Application records containing date, driver name, FPR volume, solids content, reference to applicable laboratory data, target application rate, application area, and weather conditions must be maintained. See Figure 8.3 for an example of a daily log. You should also maintain records of observed crop yields and any problems. Complaints should be investigated and notes concerning the nature of the complaint and how it was resolved should be maintained.

An annual report which compiles laboratory reports, daily operation logs, complaints, and any other management data collected throughout the year should be prepared. This document compiles annual information into one concise source. The annual report is your documentation that your land application program is conducted within the guidelines of this manual. This report, in addition to your current ongoing program files, contains all the information a regulator is likely to request if your facility is inspected. The annual report does not have to be submitted to PADEP, but it must be available for review upon request. A suggested outline for annual report preparation is shown.

The Annual Report Outline

Report Body

- Land application site general information (ID number, location, owners, operators, etc.)
- Summary operational narrative (describing period of use, general land application goals, and accomplishments for year including crop yields if available).
- Summary of FPR quantity applied (by field and totals).
- Site map (indicating application field and dry tons applied).
- Summary of FPR quality analyses (covering ranges and averages).
- Summary of soil chemistry and/or fertility analyses.
- Nutrient loading analysis summary (including estimated amounts of primary FPR nutrients supplied through the land application program by field and total)
- Summary narrative of any complaints or special difficulties and how they were resolved.

Appendices

A. Daily FPR land application reports
B. FPR analysis laboratory reports
C. Soil analysis laboratory reports

Odor Control

The best odor control measure you can implement is to thoroughly stabilize your FPR prior to land application. However, this is not possible in many cases. The following list provides general guidance concerning land application and odor control:

- keep FPRs well aerated
- select land application areas that are distant from neighboring residences
- avoid spreading when wind is blowing toward populated areas or when nearby neighbors are likely to be engaged in outdoor activities
- spread in the morning when air is warming and rising rather than in late afternoon
- spread on turbulent and breezy days to dissipate and dilute odors
- avoid spreading near heavily traveled roads and clean up any spills promptly
- incorporate odorous FPRs into soil immediately
- liming FPRs can reduce biological activity and odors; however, sometimes this only changes the odor and it remains objectionable.

Figure 8.3

Crop Year:__________
Application Cycle:__________

Farm:______________
Field:______________

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Cycle No.	Crop, Season & Applic. Method	Field ID and Date	FPR Analysis ID	FPR Total N %	Solids Content %	Field Applied FPR Gallons	Field Applied FPR Wet Tons	Field Applied FPR Dry Tons	Application Rate Target	Application Rate Actual	Acreage Measured	Weather Conditions & Comments Driver, Vehicle, Etc.	Initials
2A*	C-F-T	P1-9/30/91	9-201	5.68%	4.10%	30,000	127.5	5.23	8,000 gal/ac	8,197 gal/ac	3.66 ac	Sunny. 8:00AM-3:00PM.	L.W.
A													
B													
C													
D													
E													
F													
G													

* - Example

Crop Year: the year when the crop being fertilized by the FPR will be harvested.
Applic. Cycle: the number of reapplicaitons (on the same acreage) for the specified crop year. (see Cycle No. below)
Cycle No. indicates a specific portion of the field in a given cycle.
In the example, Cycle No. 2A shows that this is the second application for the crop year - in subarea A of the field.

Column B: A-Alfalfa, C-Corn, S-Soybeans, Other-specify: ______________
Su-Summer, F-Fall, Sp-Spring; T-top dressing FPR application, I-subsurface injection of sludge

Column C: Sludge application field and date identifier

Column D: Laboratory report no. for the most recent applicable FPR chemical analysis

Column E: Total FPR N content to be used for crop N loading

Column F: Solids content from lab analysis

Column I: Dry Tons = Solids (%/100) X Gallons X 0.00425

Column J: Intended (calibrated) vehicle application rate

Column K: Actual rate of application (based on recorded gallons applied to measured area)

Column L: Actual field acreage applied each day (measured in field)

Odors arouse public complaint against a farm operation. Thus, knowing how to handle public complaints can be important to your overall land management program. The Pennsylvania Farmers' Association (PFA) in cooperation with PADEP has established the Environmental Resources Local Affairs Program to solve farm problems related to public complaints received by PADEP. By using this program you can avoid potential penalties and solve the odor problems that may arise on your farms. Figure 8.4 shows how the program works. For more information, contact PFA's director of local affairs at 510 S. 31st Street, Camp Hill, PA 17001-8736, (717) 761-2740. For further discussion on FPR odors refer to Chapter 3.

Storage Considerations

FPRs must be stored in a manner that prevents pollution of local water resources and avoids creating nuisance conditions. Surface water running into storage areas must be eliminated and runoff must be controlled so that surface or ground water is not polluted. Construction of upland surface water diversion ditches will eliminate "run-on.” Runoff from stored FPRs can be eliminated by sheltering under roof or plastic membrane tarps. Alternatively, an impermeable curbed storage pad can be used which provides for leachate collection. Accumulated leachate must be disposed appropriately as wastewater.

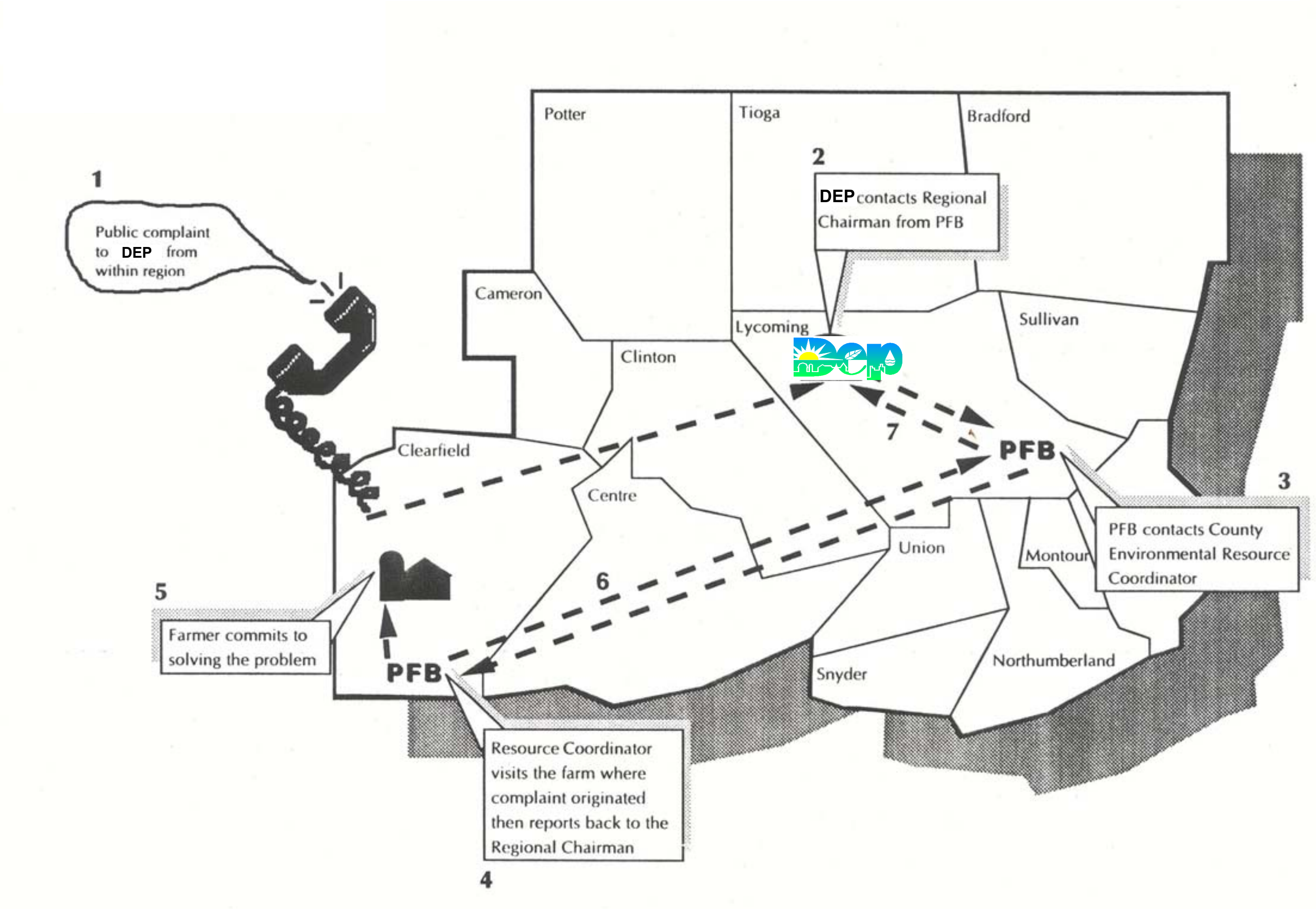
Nuisance control involves elimination or control of conditions conducive to the harborage, breeding, or attraction of vectors (e.g., flies, rodents, etc.) and offensive odors. Odor control techniques used for storage facilities are addressed in Chapter 3. Remember, odors are the most common source of complaints, so don't treat this issue lightly. For your FPR land application program to succeed you must direct sufficient thought and resources into storage facility considerations. As noted earlier in this manual, inadequate storage facilities can quickly unravel an otherwise well-conceived program. Regardless of the type of activity--whether it is land application, composting, storage, or some other activity. All FPRs should be stored in a manner that complies with Chapter 299 of the Residual Waste Regulations.

Transportation

When you transport FPRs, they must be completely enclosed or covered unless the nature of the material is such that it will not disperse from the vehicle. Putrescible FPRs must not be stored in a transportation vehicle for more than twenty-four hours. Stable, non-putrescible FPRs may be held in transportation vehicles for up to five days. Keep transportation equipment clean and maintain fire extinguishing equipment on the vehicle. Make sure that vectors, such as rats, don't have an easy means for access to the FPR.

Transportation of nonhazardous FPRs is regulated under Title 25, Chapter 299, "Storage and Transportation of Residual Waste.” PADEP administers these regulations. In general, these regulations include a requirement that the vehicles be completely enclosed or covered. The appropriate signs should be used and records should be kept in conformance with the regulations.

Figure 8.4 PFB/PADEP Environmental Affairs Program reporting process



Program Performance Review

Evaluate performance of FPR application activities with respect to the desired application rates, problems, etc. Discuss results of your evaluation with the farm operator. In some cases you may need to modify planned supplemental chemical fertilization or FPR application procedures to improve performance of your LAS.

8.4 Regulatory Resources

Regulatory resources are specific to land application and composting. The following section is broken down accordingly.

Land Application Operating Requirements

Aside from any local ordinances, all regulation of land application programs is done at the state level. Land application of FPR wastewater is regulated under Title 25, Chapter 91, Water Resources Regulations. Permits for treatment facilities and land application/irrigation facilities are required. Contact the PADEP, Bureau of Water Quality Management for more information concerning specific requirements.

Land application of nonhazardous FPRs other than wastewater is regulated under Title 25, Chapter 291, Land Application of Residual Waste of the Residual Waste Regulations. The PADEP, Bureau of Land Recycling and Waste Management (BLRWM) administers these regulations.

The use of food processing waste or food processing sludge in the course of normal farming operations does not require a permit from PADEP if certain operating requirements in the regulations are met and no pollution is caused by the activity. This permit exemption can be found in section 287.101(b)(2) of the *Residual Waste Regulations*. To be considered a "normal farming operation," the food processing waste must be used in a customary and generally accepted practice on a farm. The practice must be one that is used in the production or preparation for market of agricultural commodities.

An example of a normal farming operation involving land application is one where the FPR is used on a farm as a soil amendment. Such an activity may not pollute the air, water, or other natural resources. The land application must improve the condition of the soil, improve the growth of crops, or restore the land.

The following is a summary of operating requirements that must be met in the residual waste regulations in order to qualify for the permit exemption as a normal farming operation. These requirements can be met by following the best management practices for land application identified in this chapter.

Nuisance Prevention

Land application is to be conducted in a manner to prevent odors, vectors, ponding of liquids, public nuisances or adverse effects to the soil, food chain, or the environment.

Metal Loading Rates

The lifetime metal loading rates cannot exceed the limits identified in Table 8.2. The annual loading rate should be applied in accordance with the nutrient management plan for the site and cannot exceed the nitrogen requirements of the crop.

Isolation Distances

The land application cannot be conducted within the isolation distances identified in Table 8.11, except as otherwise noted in the table footnotes.

General Site Criteria

The land application area must comply with the general site criteria for agricultural utilization identified in Table 8.10.

Stabilization

Prior to land application the FPR must be stabilized or treated in accordance with the PSRPs and PFRPs described under the section on Pathogens, except as otherwise noted elsewhere in this chapter.

Health and Safety

FPRs that have the potential to cause problems if directly ingested by humans or animals should not be applied in areas where root vegetables which are eaten raw or will be grown within two years of the land application.

Conservation Plans

A farm conservation plan, prepared in accordance with Chapter 102, is required to be implemented on areas receiving FPRs.

Storage

Prior to land application, the FPR must be stored in accordance with Chapter 299 of the Residual Waste Regulations.

Water Supply Protection

If the land application operation adversely affects a water supply, a temporary water supply must be provided within 48 hours and a permanent water supply must be provided within 90 days.

FPR Characterization

A chemical and physical characterization of the FPR must be conducted prior to land application, as described in Chapter 4.

Field Marking

If the application area is not easily and visibly identifiable, the area must be marked prior to land application operations.

Daily Records

Daily records must be maintained that include the following:

- type, percent of solids, and weight or volume of FPR that is applied
- name, mailing address, county, and state of each generator
- transporters of the FPRs
- USGS map of all areas used for land application
- the application rate of FPRs

pH Requirements

The pH of the site must be maintained in the optimum range for the crop being grown during the application of the FPR.

Weather Condition

Land application when the field is frozen can occur when no storage capacity or other means of storage or disposal exists at the generation facility. During these conditions, the slopes at the land application area cannot exceed 3% and sufficient vegetation must exist to prevent runoff of FPRs. The application of FPRs must be in accordance with the site nutrient management plan and the farm conservation plan.

When an application of FPRs is not considered a normal farming operation, a permit, either general or site-specific, must be obtained from PADEP. An example of this activity is land reclamation use. PADEP may initiate a general permit to cover the land application, beneficial use, or processing of FPRs where such activities are not normal farming operations.

As the generator of land-applied FPRs, you may have additional obligations under the residual waste regulations. If you, as the generator, use your FPR in a normal farming operation, you will not be required to meet the specific regulatory obligations for generators. If, however, your use of FPRs is not a normal farming operation you will be required to prepare a biennial report, develop a source reduction strategy, and perform a chemical analysis of your FPR. If you follow this manual, these requirements will be accomplished, with the possible exception of the biennial report.

Keep in mind that even though PADEP permits may not be required for many FPR land application alternatives, you as the FPR generator still bear the major responsibility for proper handling and ultimate use. By following this manual you will greatly reduce the likelihood of facing a compliance problem. If a problem does arise, your response to pursuing a resolution may play a significant role in determining the posture assumed by PADEP in seeking a resolution. It is always best to assume a proactive approach in attacking environmental problems. If a problem arises, don't waste time pointing fingers, go after the problem and correct it. Questions relating to land application or composting of non-wastewater FPRs should be directed to the regional office of the PADEP.

Composting Operational Requirements

Composting of Food processing waste is regulated under Title 25, Chapter 295, Composting Facilities for Residual Waste. The PADEP administers these regulations.

The actual composting activity is considered "processing" under the Solid Waste Management Act. Therefore, the operation of a composting facility requires a permit. An exception to this permitting requirement is the use of FPRs in the course of normal farming operations. There are two options for permitting: an individual processing permit or a general permit. A general permit application may incorporate both the actual composting activity and the beneficial use of the compost. An individual permit application may only cover the composting activity, so a general permit for the beneficial use of the compost will also be required.

If FPR composting is carried out in the course of a normal farming operation, the activity does not require a permit. As stated earlier in this chapter, the FPR must be used in a customary and generally accepted practice on a farm. Also, the practice must involve the production or preparation for market of agricultural commodities. An example of a normal farming operation is one where the FPR is composted on a farm and the resulting compost is used on a farm as a soil amendment. It is not required that both activities, the composting activity and the beneficial use of the compost as a soil amendment, be conducted on the same farm.

To qualify for the permit exemption for the composting of FPRs in normal farming operations, you must meet the following operational requirements:

Water Pollution Control

A composting facility should be operated to prevent and control water pollution.

Nuisance Control

Composting is to be conducted in a manner to prevent odors, vectors, public nuisances, or adverse effects to the soil, food chain, or the environment.

Compost Additives

Other than agricultural waste and leaves, no other municipal or residual waste may be composted with the food processing residuals.

Isolation Distances

The facility cannot be within the isolation distances identified in Table 8.15.

Table 8.15 Compost facility isolation distances

Site Features	Minimum Isolation Distances
Floodplain	Not within 100-year floodplain
Exceptional value wetland	300 feet
Other wetland	100 feet[(a)]
Sinkhole	100 feet
Occupied dwelling	300 feet[(b)]
Perennial stream	100 feet from actual composting process
Property line	50 feet from actual composting process[(c)]
Private or public water source	1/4 mile upgradient and within 300 feet downgradient
Water table	4 feet

a) May be waived if storage or processing will not occur within that distance and either dams and waterways permit has been obtained under Title 25, Chapter 105 regulations or no adverse hydrologic or water quality impacts will result.
b) May be waived with consent of landowner.
c) May be waived if actual composting of waste is not occurring within that distance.

Erosion Control

A plan to manage surface water and control erosion during all phases of construction and operation at the facility must be implemented. The plan must be based on the requirements of Title 25, Chapter 102, Erosion and Sediment Pollution Control Regulations.

Land Application of Compost

The land application of the resulting compost in normal farming operations must comply with the land application requirements of this manual or Chapter 291 of the Residual Waste Regulations. The distribution or marketing of the material for operations other than normal farming operations must be done under a coproduct determination or general permit.

Water Quality Protection

If the composting operation adversely affects a water supply, a temporary water supply must be provided within 48 hours and a permanent water supply must be provided within 90 days.

Maintenance of Compost Operation

The composting must be conducted on a pad or a vessel that is capable of collecting all liquids or solids generated by the process. Any liquids generated should be reused on the compost pile or spread in accordance with the land application standards identified in this manual or Chapter 291 of the Residual Waste Regulations. Residues from the processing must be managed properly.

Daily Records

Daily records must be maintained that include the following:

- type, percent of solids, and weight or volume of FPR that is applied
- name, mailing address, county, and state of each generator
- transporters of the FPRs
- USGS map of all areas used for land application
- the application rate of FPRs

Storage

Any storage of food processing waste associated with the composting activity, including the compost itself, must meet the requirements of Chapter 299 of the Residual Waste Regulations.

FPR Characterization

A chemical and physical analysis of the FPR must be conducted prior to composting. Chapter 4 describes how to conduct a chemical and physical analysis of the compost.

If after composting, a determination can be made that the compost is a "coproduct" as described in Chapter 3, then no further regulation is required. A beneficial use permit would not be required.

The following box provides a brief question and answer summary addressing the location of composting facilities, normal farming operations, and compost distribution requirements. This overview will help you to see the distinctions made by the PADEP for regulatory oversight purposes.

Composting Facilities

Normal Farming Operations, and Compost Distribution Requirements

FPR Co. wants to compost its apple pommace from its cider processing operation and apply the compost to the land.

a. Where can the composting activity occur:

1) on-site at a farm which is contiguous to the food processing facility; or
2) on-site at the actual site of the production facility; or
3) off-site at a farm owned by FPR Co. or farmer McDonald; or
4) off-site at a location other than a farm.

b. What processing permits must be obtained or requirements must be met for the operation of a composting facility at each of the above locations?

Location 1

If the composting is performed at a farm which is contiguous to the processing facility, and the resultant compost is applied to the land at either that same farm or another farm, then no permit is required because the "normal farming operation" exemption applies. The exemption only applies, however, if a benefit to the soil is realized and no pollution is caused by the activity. As a normal farming operation, the operating requirements identified in this manual should be followed. If the resultant compost is generated for a non-normal farming operation, then the composting activity does not qualify for the permit exemption and a general permit or site specific permit must be obtained for the composting facility.

Location 2

If the composting is performed at the food processing facility, unrelated to a farm, then the FPR processing (composting) would be covered under a "permit by rule" for captive processing facilities. In other words, the facility is deemed to be "permitted" without PADEP review if it is operated in compliance with the requirements under section 287.102 for captive processing facilities.

Location 3

If FPR Co. takes its FPR off-site to a farm owned by FPR Co. or to a farm owned by Mr. McDonald for composting and the resultant compost is applied to a farm, then no permit is required because the "normal farming operation" exemption applies. The exemption only applies, however, if a benefit to the soil is realized and no pollution is caused by the activity. As a normal farming operation, the operating requirements identified in this manual should be followed. If the resultant compost is generated for non-normal farming operations, then the composting activity does not qualify for the permit exemption and a general permit or site specific permit must be obtained for the composting facility.

Location 4

If FPR Co. takes its FPR to a location which is not a farm for composting (processing), then either a site-specific permit or general permit must be obtained. A general permit for the beneficial use of the resultant compost must also be obtained, which may be combined with the processing permit.

c. When is a beneficial use general permit required for distribution of the compost material?

If the compost is derived from an on-farm composting operation and the compost is used in normal farming operations, no beneficial use permit is required for the land application if a benefit to the soil is realized and no pollution is caused by the activity. As a "normal farming operation," the operating requirements identified in this manual should be followed.

If an on-farm composting operation generates compost for non-normal farming operations, distribution, or sales, a beneficial use general permit must be obtained prior to any sale or distribution of the finished compost.

If an off-farm composting operation (waste processing facility) generates compost for use on or off a farm, a beneficial use general permit must be obtained prior to any sale or distribution of the finished compost. If the finished compost will be land applied, a site-specific individual permit may be obtained instead of a general permit.

Marketing Compost

In addition to deciding whether a general permit is required for the distribution and beneficial use of compost under the PADEP's Residual Waste Regulations, the PDA plays a role in marketing. Marketing of FPR-derived soil conditioners or fertilizers requires registration with the PDA in accordance with the Pennsylvania Fertilizer, Soil Conditioner, and Plant Growth Substance Law. Registration deals primarily with "truth in labeling" issues. The following is a partial list of compliance requirements:

- the FPR must contain recognized plant nutrient components
- the manufacturer producing the FPR fertilizer products must be licensed as a fertilizer manufacturer as required by the Pennsylvania Fertilizer, Soil Conditioner, and Plant Growth Substance Law
- the FPR must not be adulterated with a material harmful to humans, animals, or plants
- the FPR must be labeled properly as required by the fertilizer law

Contact the PDA, Bureau of Plant Industry to learn more about product registration.

8.5 Additional Reading

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Chapter 9: FPR Disposal in Landfills and Impoundments or Incineration

If you are using this chapter, you have exhausted your options at the upper hierarchy levels and found no other alternative but disposal. This would be the case for any FPR that cannot be managed within acceptable ranges of the Characteristics of Interest described in Chapter 8. Now you must look for a viable disposal alternative. This chapter briefly describes four disposal options under this hierarchy level. Regulatory Resources at the end of the chapter describes how to dispose of wastes at an existing facility and how to obtain permits for landfills, impoundments, and incineration. A brief discussion on operating your own disposal facility is also presented.

9.1 Municipal Waste Landfills

Municipal waste includes garbage and refuse from residential, commercial, and institutional establishments. Most of the operating municipal waste landfills in Pennsylvania can receive residual waste, including food processing wastes, as long as the landfill is approved to take the waste stream.

9.2 Residual Waste Landfills

Residual waste includes wastes from industrial, mining, and agricultural operations. Landfills that receive this type of waste are one of three types: monofills are designed to accept only one type of residual waste; captive facilities take residual wastes from only one generator; and commercial facilities take more than one type of residual waste from more than one generator. The landfill can be unlined, single lined, or double lined depending on the characteristics of the waste. Most of the permitted residual waste landfills in Pennsylvania are captive facilities. You may have to consider disposing of residual wastes at municipal waste landfills that have been approved to receive residual waste.

9.3 Disposal Impoundments

There are no permitted residual waste disposal impoundments that are approved to receive food processing residuals. All new residual waste impoundments are required to have either a single or double liner. The design depends on the physical and chemical characteristics of the disposed waste. As with all PADEP permitted facilities, each disposal impoundment must be approved to take a food processing waste.

9.4 Solid Waste Incinerators

This method of disposal uses controlled combustion within an enclosed container to thermally break down solid wastes. Since incineration is considered a process for reducing solid waste prior to disposal, operators of these facilities must dispose of or reuse the residue. Pennsylvania has a small number of permitted municipal waste incinerators that may be capable of receiving approval from PADEP for food processing waste. Residual waste incinerators are operated under 25 PA Code, Chapters 287 and 297. All existing residual waste incinerators are captive facilities.

9.5 Regulatory Resources Disposing at an Existing Facility

The following steps must be followed to dispose of wastes at an existing incinerator, landfill, or impoundment that is not a captive facility:

- Identify a facility that meets your transportation, storage, and economic needs.
- Meet with the facility operator, who will submit a physical and chemical description of the waste for PADEP approval.

- Operator completes Form U--Request to Process or Dispose of Residual Waste - using information that you supply.
- Certify that the process description and the analyses are accurate on Form U.
- Operator submits the completed form to PADEP and the facility.

In some cases, a facility will have an approved waste acceptance plan. Such facilities can accept the waste if they do not receive PADEP comments within fifteen working days after PADEP receives Form U if the facility has determined that the waste fits with the Form R (Waste Acceptance and Classification Plan). Otherwise, the facility must wait for PADEP comments and approval before accepting the waste.

Forms R and U are available on the Internet at http://www.dep.state.pa.us/dep/deputate/airwaste/wm/MRW/Forms/Master-Forms.htm

Establishing Your Own Facility

Owning your own facility has several benefits and disadvantages. The benefit of owning your own facility is that you can project disposal costs and maintain them throughout the life of the landfill. You also control the design and operation of the facility, thereby reducing the risk of future liabilities. However, facility design and operation is a significant undertaking. Siting and permitting require large capital investments and at least one to two years before the facility is operational. It also may take years to see a return on the investment. Ongoing operating requirements include groundwater monitoring and bonding. Such requirements often continue for years after you stop accepting wastes.

To begin the permitting process for establishing a facility, you start with the following steps:

- Familiarize yourself and/or your consultants with the regulations and the proposed site.
- Schedule a preapplication meeting with your regional DEP office. At this meeting, you will receive the appropriate forms and the permit review procedures.

9.6 Additional Reading

Pennsylvania Residual Waste Regulations, 25 PA Code, Chapters 287 and 299, available on the Internet at the Pennsylvania Code website http://www.pacode.com/secure/data/025/025toc.html

For a hard copy contact:

Pennsylvania Department of Environmental Protection
Bureau of Land Recycling and Waste Management
Division of Municipal and Residual Waste
P.O. Box 8472
Harrisburg, PA 17105-8472
(717) 787-7381

Chapter 10: FPR Disposal at a Hazardous Waste Facility

As the FPR hierarchy shows, hazardous waste disposal is the last alternative. Few of your FPRs generated on the process lines should fall into this category. Those that do must be kept separate from all other FPRs. This chapter briefly defines a hazardous waste, describes how to determine if you have one, and discusses how to properly manage hazardous wastes according to Pennsylvania regulations.

10.1 What Is a Hazardous Waste?

Hazardous wastes are wastes that, in sufficient quantities and concentrations, pose a threat to human health, or the environment when improperly stored, treated, transported, or disposed. In regulating hazardous wastes, Pennsylvania uses a federal list of over 600 specific wastes. In addition to the listed wastes, other wastes designated as hazardous include those that exhibit at least one of the following characteristics:

- ignitable - c combustible under certain conditions
- corrosive - highly acidic, basic, and/or capable of corroding metal
- reactive - unstable under normal conditions and capable of creating explosions and/or toxic fumes, gases, and vapors when mixed with water or when subjected to heat or pressure
- toxic - harmful or fatal when ingested or absorbed

Mixtures of hazardous wastes and nonhazardous wastes are also considered hazardous. Low-level radioactive wastes are <u>not</u> considered hazardous, unless mixed with hazardous wastes.

10.2 How to Make a Hazardous Waste Determination.

As with FPRs at the top levels on the hierarchy, it is important to know the waste characteristics so that you can make a hazardous waste determination. If a waste is listed under the federal Resource Conservation and Recovery Act (RCRA) or if it exhibits any one of the four characteristics listed above it is considered hazardous. Two of the RCRA lists (P and U lists) name specific chemical substances, and the other two lists (F and K lists) name wastes that are produced by a particular process or activity. If your waste is not included in these lists, you may still have to test the waste to determine if it is hazardous. The Pennsylvania hazardous waste regulations listed in the Additional Reading section at the end of this chapter define specific sampling methods and laboratory testing procedures.

10.3 Regulatory Resources

Hazardous waste cannot be stored for more than 90 days after the date accumulation begins unless a storage permit is obtained. For most small generators, this 90-day period begins when the amount of waste accumulated reaches 1000 kilograms. If you determine that your FPR is hazardous, follow the steps below to transport it properly.

- Obtain an EPA ID number. To receive a number, you must complete a notification of hazardous waste activity form that can be obtained by contacting EPA Region II at (215) 597-1230.
- Package and label waste according to U.S. Department of Transportation requirements for shipment.
- Secure a licensed hazardous waste transporter.
- Prior to shipment, complete a manifest form, which must travel with the waste. The manifest includes information on the waste, the generator, the transporter, and the ultimate destination.

- Maintain copies of manifests, quarterly reports that are filed with DEP, and the hazardous waste determination reports.

Also, if you generate hazardous waste, you are required to develop a source reduction strategy and keep it on-site. A permit from PADEP is also required prior to disposal. Source reduction strategies are discussed in Chapter 5 of this manual.

10.4 References and Additional Reading

Pennsylvania Hazardous Waste Regulations, 25 PA Code, Chapters 260a-270a are available on the Internet at the Pennsylvania Code website http://www.pacode.com/secure/data/025/025toc.html

The Pennsylvania Hazardous Waste Compliance Guide – Hazardous Waste Generator Requirements is available on the Internet at http://www.dep.state.pa.us/dep/deputate/airwaste/wm/HW/HW.htm

For a hard copy contact:

The Pennsylvania Department of Environmental Protection
Bureau of Land Recycling and Waste Management
Division of Municipal and Residual Waste
P.O. Box 8471
Harrisburg, PA 17105-8471
(717) 787-6239

Pennsylvania's Hazardous Waste Regulations incorporate many of the Federal, Title 40 Hazardous Waste Regulations by reference. The federal regulations are available for purchase from the Government Printing Office at (202) 512-1800 or via the Internet at http://www.access.gpo.gov/

Chapter 11: Moving on the Hierarchy

In Part I of this manual, you determined where your FPRs fit in the FPR hierarchy (Figure I2). Chapters 5 through 10 described the FPR characteristic limits and technologies used at each hierarchy level. Now, you can look at a few strategies that can move your FPRs up on the hierarchy. This chapter also discusses how to determine whether or not it is economically feasible to move. As the Food Processing Residual Hierarchy illustrates (Figure I2), moving from a lower management strategy, like landfilling, to a higher strategy, like recovery for animal uses, often increases the benefit to your company and the environment. However, only a thorough economic analysis can determine the magnitude of that benefit.

11.1 Flow Segregation

One practical, low-cost management strategy that can quickly increase FPR value is flow segregation. Flow segregation is simply separating FPRs into distinguishable residuals at the generation point before they enter the management strategy. For example, a vegetable processing company may run several process lines--onions, spinach, celery, lettuce, etc. However, the company runs one composite FPR collection system. Either wastewater flows to a common screening area, or an underfloor collection system collects FPRs from every processing line. This lack of segregation produces an FPR that is inconsistent on a week-to-week or even day-to-day basis.

Now, let's assume that the company is currently land-applying these vegetable screenings and would like to move up on the hierarchy to recovery for animal uses, i.e., animal feeding. As Wilson (1989) states, "a basic requirement for a successful livestock feeding program is a predictable amount and quality of each component in the animal's diet on a day-to-day basis." Vegetable FPRs that vary in makeup may not fit these criteria. However, if each FPR is segregated on the process line before it reaches the common collection system, the farmer will know the basic constituents of the FPR. He will be able to plan a consistent diet and thus be more interested in incorporating your FPR into his nutrient program.

Determine flow segregation possibilities by reviewing your plant flowcharts. Try to identify areas where you can segregate flows to produce a more useful FPR. Flow segregation may involve adding collection bins to the process line or installing new pipes to redirect flows. Of particular importance is use of flow segregation methods to divert problem flows. Sanitary wastes and shop wastestreams, for example, should not be combined or allowed to contaminate other streams.

11.2 Flow Combination

Combining FPRs might be necessary for more economical use and disposal. You may have negligible amounts of FPRs and thus flow segregation is not economical. In the vegetable example used in the previous section, combining consistent amounts of vegetable FPRs may produce a more nutritionally well-rounded feed for animals. Like segregation, flow combination may require changes in collection strategies or new piping to redirect flows to combined areas.

11.3 Input Changes

In some cases, you may need to change inputs in order to move an FPR up on the hierarchy. A good example of this is a chemical flocculant (e.g., metal salts) used at process water treatment facilities. The resulting sludge may have high levels of metals, which limit the sludge's ability to be recycled for animal uses. The sludge would have to be land applied or disposed of at an approved facility. This FPR could possibly move up on the hierarchy by changing the flocculant used in the treatment process.

Another example of changing inputs can be found in potato processing. Potato peels from caustic peelers are generally not suitable for livestock feed, whereas peels that come from steam peelers are feedable. Clearly, by removing a caustic from the process line, this company could advance on the FPR hierarchy.

To identify inputs that may need to be changed, you can review the analysis reports for FPRs. Often a limiting factor will show up. If your input/output worksheet (worksheet 7 from Chapter 1) is accurately completed, you can trace the output to the corresponding "problem" input. Sometimes, alternative technologies need to be investigated when inputs are changed, as in the case of converting from a caustic peeler to a steam peeler.

11.4 Waste Exchange

Waste exchange is a program that matches FPRs with a suitable market for reuse. Such a program provides waste characteristics, volume, and cost information for sellers and buyers of FPRs. Waste exchange can be a vehicle for you to move your waste up on the hierarchy with no capital investment. You can either sell the FPR directly to an appropriate buyer or sell it to someone who will treat the FPR and sell it to a third party.

To make a waste exchange program successful, you need to consider several factors. First, identify FPRs for exchange and classify the materials: recyclable, reusable, returnable, compostable, etc. Use the most valuable FPRs to attract exchangers who may take the less attractive FPRs, too. Second, create a chain of communication so that your recycling and use needs are well known throughout a potential market. Contact all recycling oriented outlets such as recyclers, scrap metal facilities, brokers, and others to identify local outlets. FPR handlers and exchangers often provide catalogues where you can successfully market your product. Don't be afraid to barter with companies. Sometimes usable FPRs can be traded for free freight. Third, find several markets for each product. In the exchange industry, markets open and close overnight so you don't want to be dependent on a single market for sale. Fourth, dedicate manpower and time to continually pursue waste exchange alternatives. This involves commitment at the corporate and individual level. Corporate commitment to an exchange program requires acceptance of the finances, manpower, and storage and equipment needs of the exchange program. Finally, use all available resources to find markets. Resources may include newspapers, phone directories, industry magazines, and business associations.

Within the northeastern region of the United States, several waste exchange programs exist. The Northeast Industrial Waste Exchange Program (NIWE) is one example. The Exchange matches FPR generators with potential markets. One success story of the Exchange is the match of an herb company generating 550 tons of exhausted herbs per year with a poultry grower who used the herbs as a feed supplement. The poultry grower was willing to pay for the exhausted herbs and the company is avoiding $38,640 in disposal costs. NIWE's list of services includes a quarterly *Listings Catalogue* that codes and classifies products for several buyers and sellers. The catalogue has a circulation of 18,800 and distributes primarily to Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, and Vermont. Another service is the computerized catalogue, which enables companies to access current information on resources available and resources wanted. The on-line listing is available twenty-four hours. The Northeast Industrial Waste Exchange is a nonprofit organization. Listing and finder fees can be obtained by contacting The Northeast Industrial Waste Exchange, Inc., 90 Presidential Plaza - Suite 11, Syracuse, NY 13202.

A second vehicle for waste exchange is the P.S. MacByproduct computer system developed through the Department of Animal Science at The Pennsylvania State University. This program helps farmers to develop feed rations using traditional feedstuffs and FPRs. One useful element of the program is the Feed Availability component. By using a Pennsylvania map and specifying a feed, the user can select a county and find the sources of feed available in that county. It is expected that food processors would want to advertise their FPRs through this useful tool if they are interested in marketing FPRs as an animal feed. For more information on P.S. MacByproduct contact: Harold Harpster, Department of Dairy and Animal Science, Penn State University, University Park, PA 16802.

On a smaller regional level, other exchange programs have also been established. For example, six counties in Pennsylvania pulled together and worked with local Conservation Districts and the Agricultural Stabilization and Conservation Service to develop the *Manure Marketing Directory*. Though directed toward farmers, this directory presents an innovative methodology for exchanging FPR information. The directory lists "manure exporters" and "manure importers" by county. Lists of custom manure haulers, manure analysis information, nutrient management plan preparers, and resource materials are also provided. Although this manual has limited application in FPR use and disposal, the concept for development is one that is easily transferable to the food processing industry.

For further information on waste exchange, also contact PA DEP's Division of Waste Minimization and Planning.

11.5 Economics of Moving on the Hierarchy

Clearly, FPR utilization is an economic "machine" fueled by a beneficial product, an adequate reuse market, and a suitable technology. Loehr (1977) notes several FPR beneficial use strategies that failed because of the lack of an adequate market. The overall move on the hierarchy must therefore be economically feasible. While a profit-making move is desirable, avoided disposal costs can also make a move up rewarding. As many processors know, waste-related investments rarely earn a profit. Instead, lowering management costs increases total profits. Heavy fines and surcharge fees for breaking environmental regulations or exceeding standards can be incentive enough to move. In any case, the economic analysis needs to consider all of these factors. Processors need to explore and use efficient and cost-effective technology that will move FPRs up on the hierarchy <u>and</u> find suitable markets for the FPR. These are the true tests of economic feasibility.

The most effective way of performing a cost analysis is to compare the cost of the existing management strategy with the cost of an alternative strategy. This text is not meant to be an exhaustive look at economics. Rather, it suggests one method that can be incorporated into the economic program already available at your plant. We stress here, though, that in order for upper management to approve your proposed program changes, you need to provide a persuasive and thorough economic comparison.

Before we look at economic analysis computations, let's examine what information you will need to perform an economic analysis. Note that all estimates should be calculated on an *annual basis*.

First, you must have realistic cost estimates. FPR management is laden with hidden costs. Within reason, account for all costs of the existing and proposed strategies, including:

- energy
- transportation
- tipping fees
- labor
- maintenance
- legal fees
- permit fees
- chemicals
- sampling and analysis
- penalties
- capital amortization
- salvage value
- consulting fees

It is absolutely imperative that you account for <u>all relevant costs and revenues</u> when doing your economic analysis.

If you completed Chapter 1 of this manual, worksheet 6 from the Seven-Step Program Review should provide most, if not all, of the cost information you need for the current management strategy. You should complete worksheet 6 for all alternative proposal strategies to estimate cost for these options as well. Note that installation costs that have already been paid off are not included when doing the cost evaluation. Also, costs that are the same for all alternatives may be ignored for comparison purposes.

Present Worth Economic Analysis.

Present worth economic analysis is a fundamental tool used by management to evaluate various business alternatives, whether they be production-oriented, FPR management, or simply investment-related. The concepts presented here can be found in almost any basic business management text. The present worth computation method shown below has been selected because of its ease of use when annual costs vary from year to year. Various equation forms can be used, but the same answer results. The methodology and examples here have been greatly simplified, but the results will be valid if you follow two basic rules: All relevant costs and revenues must be included, and the time period of the analysis must be the same for all alternatives being compared. The present worth equation is as follows:

$$\sum_{i=1}^{n} \frac{(C-R)_i}{(1+d)^i}$$

where:

- C = all relevant costs (dollars)
- R = all revenues received (dollars)
- i = the year within the time period over which the analysis is being considered (year)
- n = the total time period being considered (years)
- d = discount rate (expressed as a decimal; eg. 7% = 0.07)

Figure 11.1 illustrates the use of present worth analysis for decision making. To use the present worth analysis method complete the following steps:

- Determine all relevant costs for all alternatives under consideration (C).
- Determine all relevant revenues for all alternatives under consideration (R).
- Select an appropriate time period (n) - the period should usually reflect the life of one of the options (the time period must be the same for all options).
- Select an appropriate discount rate (d).
- Perform the present worth calculation for each alternative.
- Compare the present worth costs for each alternative. The least cost present worth option is the best choice based on economics.
- Complete your evaluation by considering non-economic factors. Such factors as reliability and ease of maintenance could in some cases justify selection of a more expensive alternative.

Again, we stress that these comparisons are by no means a complete view of the economics of moving on the hierarchy. But you should prepare these comparisons in order to have a clearer understanding of how your FPR management program contributes to profitability. When you can make an informed conclusion about the strategy, you will be able to present it convincingly to those who make implementation decisions.

Figure 11.1 Example Present Worth Analysis

Example from a Potato Chip Processor

Given: A certain potato chip processor currently disposes of FPR wastewater sludge by dewatering the sludge using a belt filter press and landfilling. The useful life of the filter press is expected to expire after 5 more years of use. The processor is considering two alternative options to landfilling over the next five years (n); land application, and cattle feeding. The filter press facilities are required for each option so costs involved in operation and maintenance of these facilities are constant for each option and can be ignored in the present worth cost analysis comparison. The discount rate (d) for the analysis has been selected at 7%, which will be constant for all alternatives.

Option A Continued Landfilling

For this option, total net cost increases by 20% per year. This rise in costs is reflected in the net cost shown for each year.

Year 1		Year 2		Year 3		Year 4		Year 5
$\frac{\$70,000}{(1+0.07)^1}$	+	$\frac{\$84,000}{(1+0.07)^2}$	+	$\frac{\$100,800}{(1+0.07)^3}$	+	$\frac{\$120,960}{(1+0.07)^4}$	+	$\frac{\$145,152}{(1+0.07)^5}$
$\frac{\$70,000}{1.07}$	+	$\frac{\$84,000}{1.14}$	+	$\frac{\$100,800}{1.23}$	+	$\frac{\$120,960}{1.31}$	+	$\frac{\$145,152}{1.40}$
$65,421	+	$73,369	+	$81,951	+	$92,336	+	$103,680
						Landfill Present Worth	=	$417,072

Option B - Land Application

This alternative involves purchase of land application equipment and establishment of a management system to secure a network of private land application farms. Annual operation and maintenance costs are expected to rise by 5% each year for the first 3 years. Costs in years 4 and 5 are expected to reduce as farmers begin to pay for the land application service. Annual net costs shown in the computations reflect these changes.

Year 1		Year 2		Year 3		Year 4		Year 5
$\frac{\$150,000}{(1+0.07)^1}$	+	$\frac{\$25,000}{(1+0.07)^2}$	+	$\frac{\$26,250}{(1+0.07)^3}$	+	$\frac{\$15,000}{(1+0.07)^4}$	+	$\frac{\$15,000}{(1+0.07)^5}$
$140,187	+	$21,930	+	$21,341	+	$11,450	+	$10,714
				Land Application Present Worth			=	$205,622

Option C Cattle Feeding

This option involves up-front costs for research, costs to secure 6 participating farms (dairy and beef), costs for installation of silage bunkers at each site, and costs associated with instituting a comprehensive quality control FPR management system. Net operation and maintenance costs are expected to increase by 5% for each of the first 2 years of operation. Through years 3, 4, and 5 the farmers are expected to pay for the FPR feed resulting in receipts exceeding costs. The following computation incorporates all of the varying net annual cost considerations.

Year 1		Year 2		Year 3		Year 4		Year 5
$\frac{\$175,000}{(1+0.07)^1}$	+	$\frac{\$20,000}{(1+0.07)^2}$	+	$\frac{(\$1000)}{(1+0.07)^3}$	+	$\frac{(\$1000)}{(1+0.07)^4}$	+	$\frac{(\$1000)}{(1+0.07)^5}$
$163,551	+	$17,469	+	($813)	+	($763)	+	($714)
				Cattle Feeding Present Worth			=	$178,804

Summary of Present Worth Computations

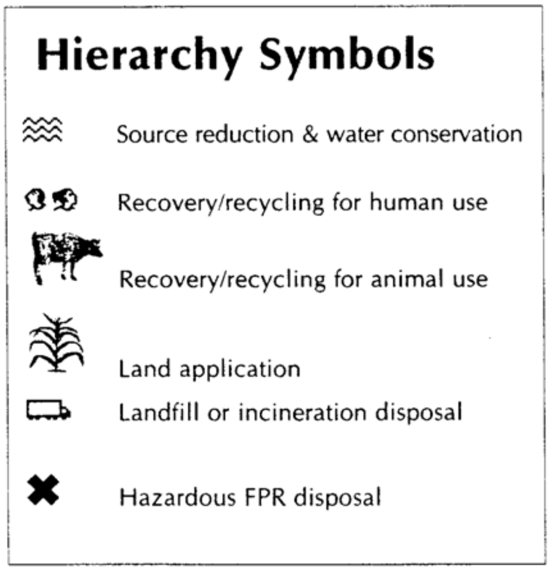
Landfill	Land Application	Cattle Feeding
$417,072	$205,622	$178,804

Conclusion:

The cattle feeding option clearly shows an economic advantage over other alternatives. Non-economic factors such as program reliability should now be considered before committing to any particular option.

PART III: CASE STUDIES

Now that you have completed your own plant overview, it might be helpful to look at some industry examples of success. This part of the manual compiles information from several companies. Some case studies are more detailed, emphasizing several of the hierarchy levels of management (see Figure I2), while others discuss one innovative aspect of FPR management. These case studies are examples and should not be used as a model for developing an FPR program. You must complete Part I of this manual to gain a thorough understanding of your FPRs and where they fit in the hierarchy. It is hoped, however, as you read though some of these innovative strategies you will be able to brainstorm ideas for your own company. As this manual evolves, we anticipate that more detailed and innovative case studies will be presented.



The chapters in Part III are named by food group: vegetables, fruits, meat, dairy, and grain. The introductory section of each chapter overviews common FPR management strategies and problems for that group. Several case studies are included in each chapter. Each case study is divided into sections by hierarchy levels noted in the text by the margin symbols in the box below.

The most effective way to use this section is to look up the food of interest and study the hierarchy elements that you are considering for your own plant.

Chapter 12: Vegetable Case Studies

12.1 Common FPR Management Strategies

Vegetable processing FPRs are primarily solids, though FPR water effluent is a major concern. Case studies for this food group reveal a few key management considerations indigenous to this industry. (Since fruit and vegetable FPR management is often similar, see also the common management strategies for fruits in Chapter 13).

Because vegetable processing strives to maintain a long shelf life and an acceptable product appearance, the industry as a whole has a high wastage factor – that is, a high percentage of the raw product is lost before processing begins. For example, one case study estimates a 60% wastage factor on a 300 tons/day cut corn operation. Another company processing 500,000 lb/week of raw product estimates a FPR factor of 30%. This produces an average of 150,000 lb of FPR per week. Fortunately, though high in quantity, these FPRs are often simply part of the raw product (e.g., carrot tops, bean shells, corn cobs) and thus have high utilization potential.

Another factor that greatly influences FPRs in this industry is flow segregation. In vegetable processing, a company may have several processing lines but a composite FPR collection system. For example, all FPR water flows to a common screening areas or underfloor collection system that collects FPRs from every processing line. This lack of segregation produces an FPR that is inconsistent on a week-to-week or even day-to-day basis.

Seasonality also affects vegetable FPR characteristics over time. Many companies grow their own product or purchase local produce. Thus, process lines operate sporadically depending on product availability. Though the FPR are high in nutrient value, a farmer who refeeds them is not assured of a consistently available by –product. Basic requirements for a successful livestock feeding program are a predictable amount and quality of each component in the animal's diet on a day-to-day basis. For seasonal vegetable FPRs these are difficult criteria to meet.

The case study evaluations show that despite seasonality and inconsistent FPR characteristics, vegetable processors have unique advantages in FPR management that can overcome these limitations. With a carefully staged program, vegetable FPRs provide excellent examples of FPR utilization.

12.2 Study 1: Corn, Mushroom, and Pea Processor

This case study evaluates a vegetable processing facility that produces cob corn, cut corn, peas, and mushrooms for dry packaging, wet packaging, and canning. This seasonal operation occurs under the conditions as shown below.

The process lines are in operation for two ten-hour shifts and then shut down for cleanup the remainder of the day.

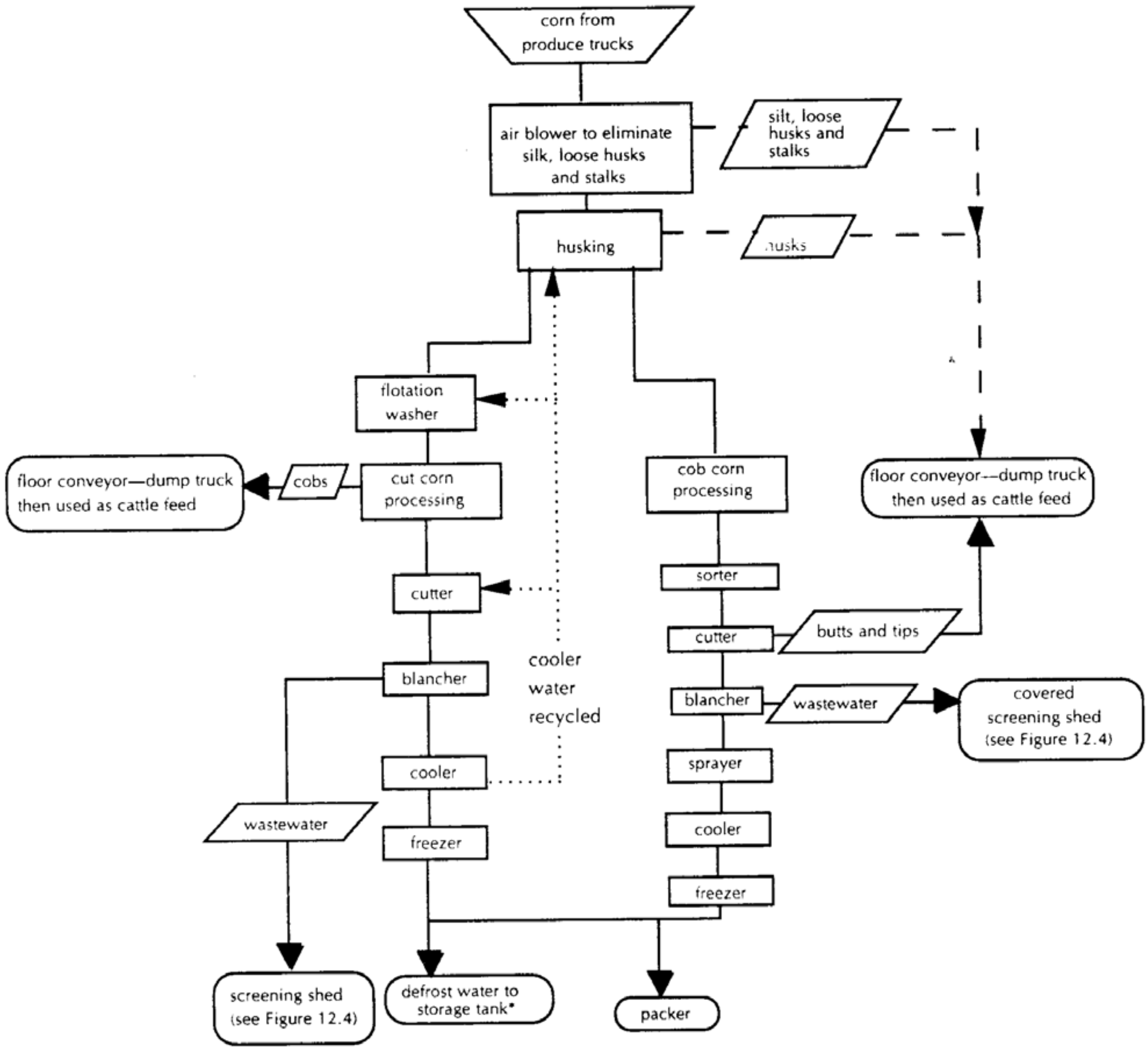
Figures 12.1 to 12.3 show the process lines for cob and cut corn, mushrooms, and peas, respectively. The majority of husks, cobs, pieces, and hulls from the lines are dry swept or loaded directly on a conveyor that moves the FPRs to a dump truck outside of the facility. No conveyor is used for mushroom pieces; these are dry swept either into a hopper or down the floor drains.

Production Schedule

	Production	Time	Wastage (%)
Cut/cob corn	300 tons/day	July-October	60
Peas	150,000 lb/day	May-June (6 weeks)	10
Mushrooms	25-35,000 lb/day	Year round	3-5

As indicated in Figure 12.4 (the FPR water treatment flow chart), the covered screening area has two separate shaker screens. This allows segregation of high BOD and SS FPR water and low BAD/SS FPR water. As expected, cut corn and peas comprise the first screenings and mushroom pieces, and corn butts and tips comprise the second. Currently, these solid FPRs are combined and sold to a farmer at a cost of $1.25 per ton. A final solid FPR is the sludge generated in the aerated lagoon at the FPR water treatment facility. To date, the pant has had to pump sludge from the lagoon only once, in 1987. The sludge is land-applied.

Figure 12.1 Flowchart of cob/cut corn processing and related FPRs



* NOTE: This water is used four times before it is sent to wastewater treatment: first to defrost the cut corn freezer, second to cool blanched cob corn, third to move cobs onto the sprayer, and fourth to move cobs into the blancher.

Figure 12.2 Flowchart of mushroom processing and related FPRs

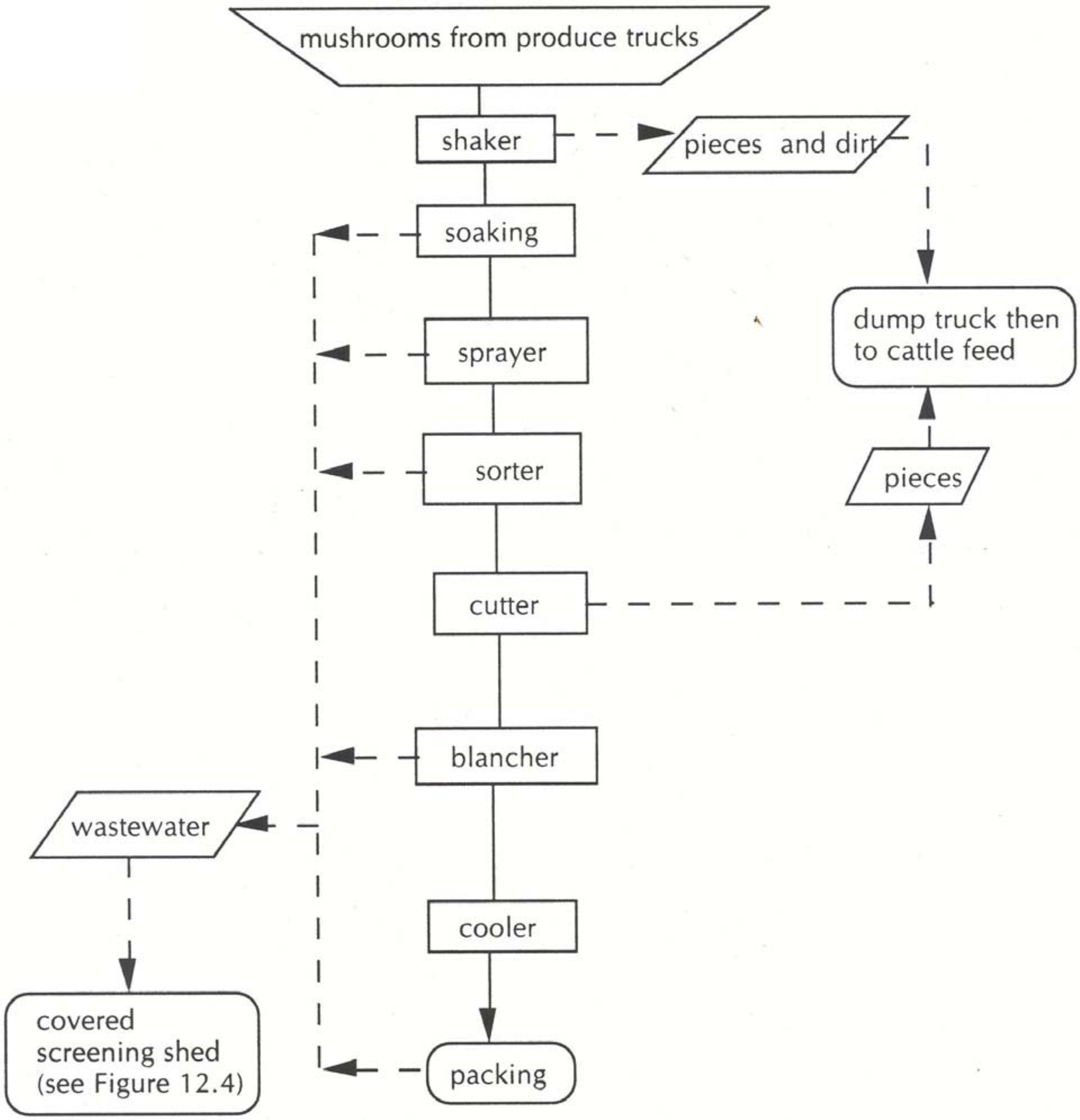


Figure 12.3 Flowchart of pea processing and related FPRs

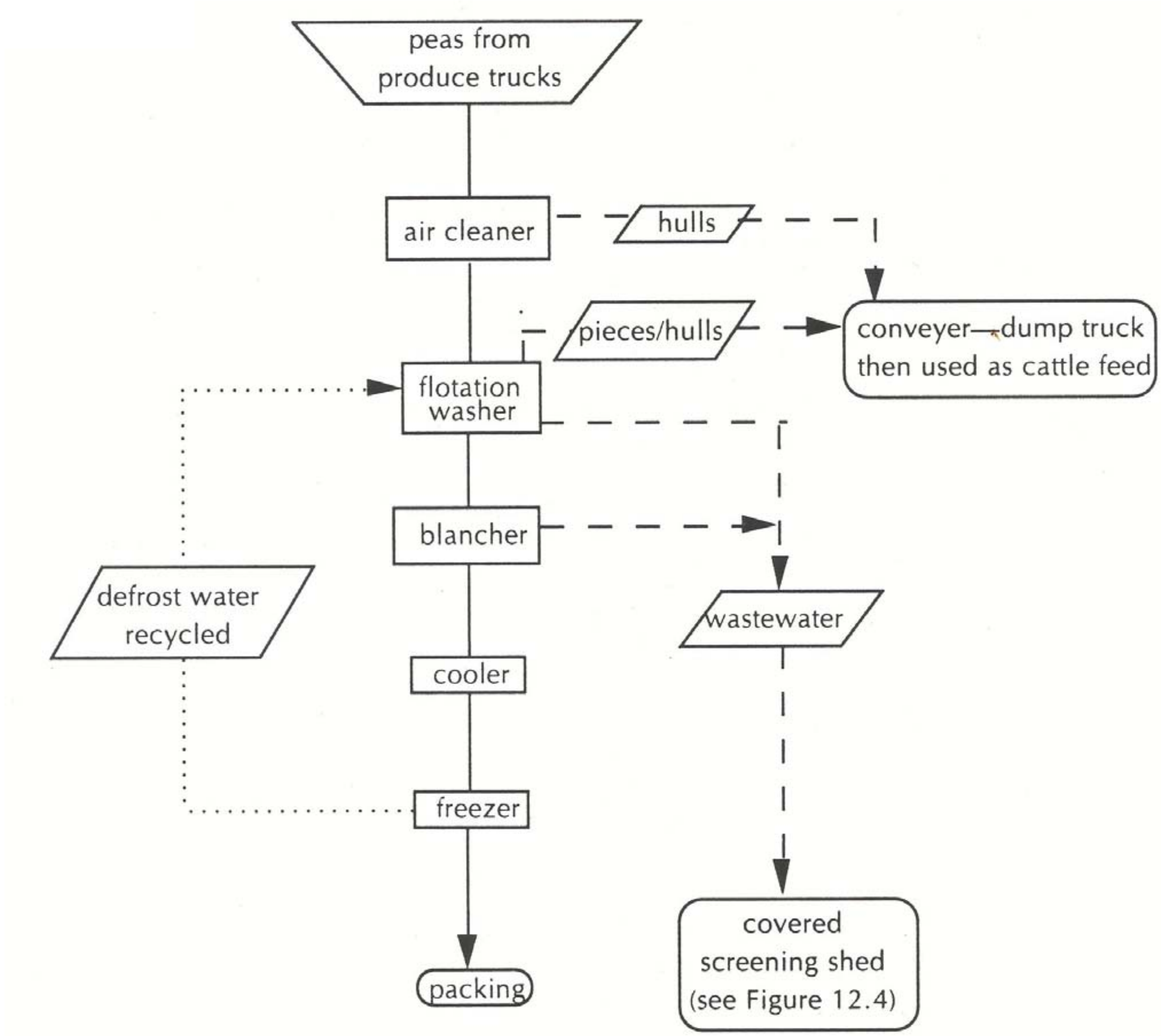
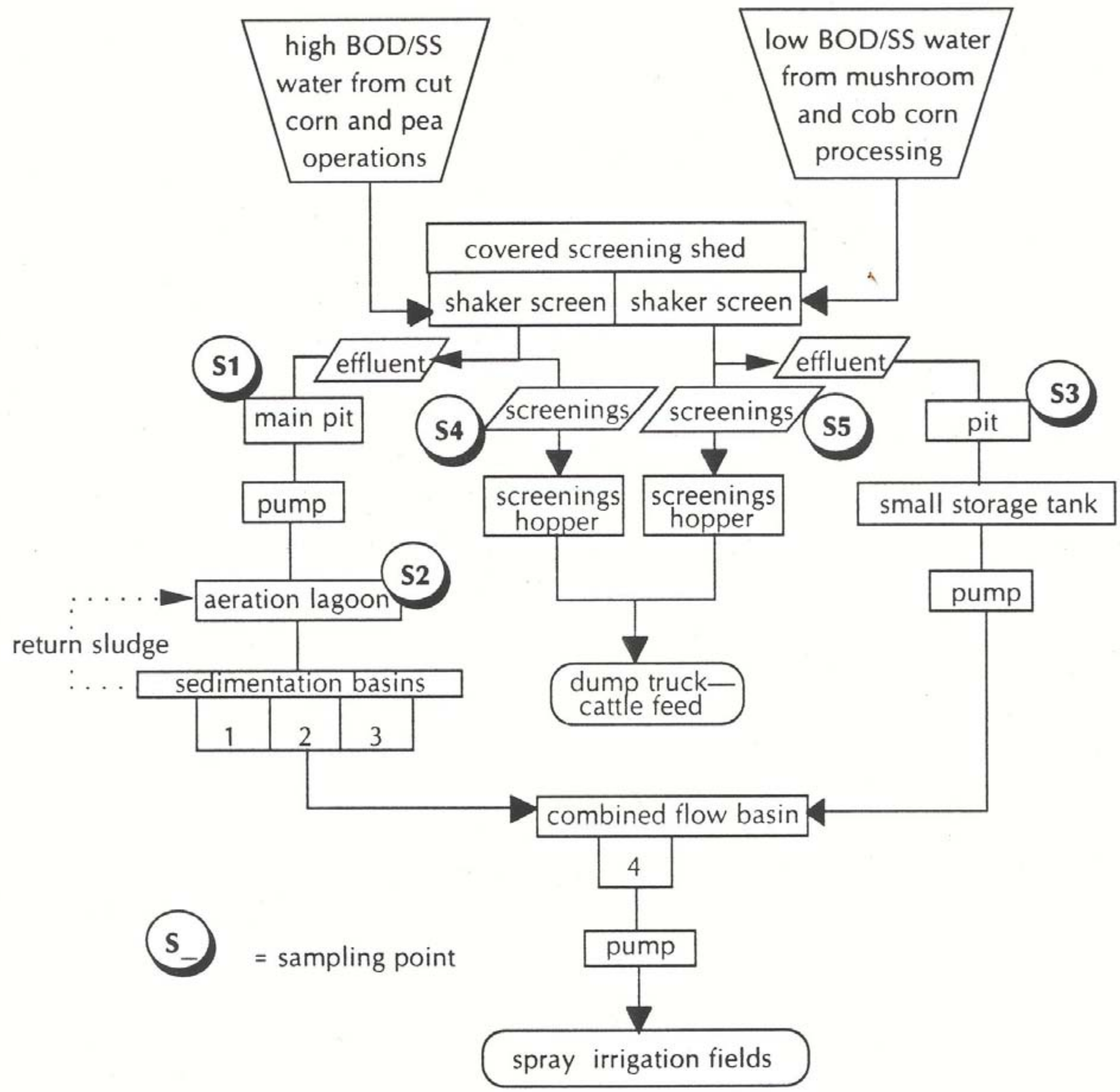


Figure 12.4 Flowchart of wastewater treatment at a vegetable



From 1983 (when a lagoon was first installed) to 1987, this company's FPR water treatment system was not sufficiently reducing BOD or SS. In consultation with an engineering firm, the plant began to make minor in-plant modifications to reduce flows and decrease loadings. Eventually, the plant upgraded the lagoon-spray irrigation system. This section describes the upgraded FPR water treatment system, which consists of two effluent screens, an aerated lagoon, three sedimentation basins, a combined sedimentation basin, and spray irrigation fields for effluent disposal. Figure 12.4 shows a flowchart of the FPR water treatment system.

The plant segregates two primary FPR water flows from the process lines. Cut corn and pea FPR water is high in BOD and SS. This flow is screened and then aerobically treated prior to spray irrigation. Low BOS/SS FPR water comes from the cob corn and mushroom process lines. This flow is screened and temporarily stored prior to spray irrigation. Tables 12.1 and 12.2 show the characteristics of the high BAD/SS and low BAD/SS FPR water. The aerobic lagoon is equipped with one 60-HP aerator, two 10-HP aerators, one 20-HP aerator, and one 30-HP aerator. Effluent from the lagoon flows through three sedimentation basins that further settle out solids and return the mixed liquor suspended solids to the lagoon.

Table 12.1
Flow characteristics from cut corn and pea processing FPR water

Sample Times	BOD (mg/l)	TSS * (mg/l)
Prior to lagoon treatment 9/90		
10:30 am– 12:30 pm	8500	2600
2:30 pm – 5:30 pm	6500	2400
6:30 pm – 9:30 pm	6300	2100
10:30 pm – 1:30 am	6700	2000
2:30 am – 5:30 am	6000	1600
6:30 am – 9:30 am	8500	2300
24-hour composite	6600	2200
Following lagoon treatment 8/91		
Grab sample	489	5270
* Total suspended solids		

After high BOD water goes through the lagoon and the first three sedimentation basins, it combines with the low BOD/SS water (pumped from the temporary storage tank) in the fourth basin. This produces as combined flow for spray irrigation on 17.5 acres of permitted land sown in Reed Canary grass.

The spray irrigation permit does not allow application on frozen ground. In the winter months after corn and pea processing, FPR water from the mushroom processing line (the only line in operation) is stored in the lagoon. In the spring, this water is spray irrigated, thus emptying the lagoon for the upcoming corn/pea processing.

To reduce flows and BOD/TSS in the flow, this company incorporated some simple physical and chemical modifications and practices into the FPR management system. Following these changes the lagoon was upgraded and a sedimentation basin was added.

The company employees other source reduction and water conservation strategies as well. This company uses dry cleanup and solid FPR collection wherever possible in the process lines. This reduces not only water use but also solids overloading to the lagoon. One of the most exemplary water reuse strategies in operation at this plant is the recycling of approximately 24,000 gpd of defrosting water originating in the cut corn freezer, as shown in Figure 12.1. The water is used four times before it is discharged to the treatment system. First, the water is used to defrost the cut corn freezer. It flows over the coils at a rate of 325 gpm for about twelve minutes six times per day. After each pass it is collected in a 4,000-gallon tank located inside the plant. When cob corn processing is in operation, the water is used three more times at strategic places in the line. Water is pumped from the tank and sprayed over blanched cob corn. Next, it flows to a tank below the blancher and is used to move ears out from under the blancher. Finally, this water flows to the front of the blancher to force the next batch of ears under the blanching hood. The water is then discharged to the FPR water treatment system.

Other water reuse methods are shown in Figures 12.1 and 12.3. Cooler water from the cut corn process is recycled back to both cutting, husking, and flotation washwater. This flow is about 30,000 gpd. Figure 12.3 shows how defrost water from pea processing is directed back to the flotation sprayer at the beginning of the pea line. Mushroom and corn husking FPR water bypasses the lagoon, converges with water from the lagoon-sedimentation basins, and is directly spray irrigated. This reduces loading on the lagoon of these low BOD and SS flows, thus increasing the lagoon retention time and removal efficiency. This plant replaced the 2-mesh primary screen with a 30-mesh screen.

In so doing, suspended solids removal increased from 10% to 40%. A second screening is also done to further reduce solids.

Despite efforts to reduce BOD and SS through the modifications described above, the company estimates that 60% of the BOD/SS loading comes from the ambient pressure steam blancher during sweet corn processing. It is possible that a hydrostatic steam blancher may reduce BOD/SS in the FPR water. More data on this blancher type needs to be collected – specifically the BOD and SS values/gallon effluent for the ambient pressure steam blancher but no values exist for comparison with the hydrostatic blancher.

Table 12.2
Flow characteristics form cob corn and mushroom processing FPR water prior to spray irrigation

	BOD (mg/l)	TSS * (mg/l)
Sampled on 9/90		
9:30 am– 12:30 pm	1500	190
1:30 pm – 4:30 pm	2000	200
5:30 pm – 8:30 pm	2100	420
9:30 pm – 12:30 am	1700	260
1:30 am – 4:30 am	1900	310
5:30 am – 8:30 am	2000	300
24-hour composite	2100	300
Sampled on 8/91		
Grab sample	473	46
* Total suspended solids		

A second alternative for reducing solids is to add a flocculant. A consulting firm explored this possibility and sampled FPR water flows after adding various flocculants. Three flocculants were tried – alum, ferric sulfate, and Ageflock CF-50D (a polymerized basic aluminum chloride) – with Ageflock being selected for further tests. Using 30-50 mg/l of Agefloc and a cationic polymer to settle out the solids produced the best results. Table 12.3 shows the flocculant effects.

Table 12.3 Vegetable wastewater characteristics before and after flocculant addition

	Soluble BOD (mg/l)	BOD (mg/l)	TSS (mg/l)
Raw wastewater	4800	7200	3800
After flocculant additions	3600	4000	220
Note: Agefloc was the flocculant used in this analysis.			

It may be possible to recover starch from sweet corn FPR water and market the slurry to starch companies. This would move the FPR product up on the hierarchy. The company is working with a consulting engineer to explore this possibility.

The combination of all solid FPRs from the four process lines produces a solid FPR that is not homogenous. The possibility exists to move these FPRs up on the hierarchy by segregating them for animal feeds with known nutrient characteristics. The FPRs from both screens in the screenhouse were sampled for feedability. Results are shown in Table 12.4. In analyzing the feedability profiles, the high protein, low dry matter values of the corn/pea screenings suggest a high pea content. Low fiber, high digestibility factors indicate a high quality screening versus the light, “chaffy” nature of some screenings. This material should be valuable when feed directly or it could be ensiled with a fiber source. If fed directly, a laxative effect would be expected, and long roughage should be offered. There are no toxic mineral problems, although supplemental calcium, magnesium, and potassium are needed.

Table 12.4 Feedability profiles for corn/pea screenings and corn/mushroom

	CORN/PEA SCREENINGS	CORN/MUSHROOM SCREENINGS
Manganese (ppm)	21	19
Iron (ppm)	734	2230
Copper (ppm)	13	34
Boron (ppm)	7	2
Aluminum (ppm)	126	225
Zinc (ppm)	98	158
Sodium (ppm)	1077	2500
Phosphorus (% of wt)	0.37	0.34
Potassium (% of wt)	0.56	0.23
Calcium (% of wt)	0.30	0.40
Magnesium (% of wt)	0.14	0.07
Oven Dry Matter (% of wt)	18.31	9.56
In vitro Dry Matter[a] (% of wt)	90.08	66.75
Crude Protein (% of wt)	27.78	28.98
Acid Detergent Fiber (% of wt)	15.86	19.53
Neutral Deter. Fiber (% of wt)	33.35	42.21

Note: Samples were taken at sample points S4 and S5 on Figure 12.4

[a] In vitro dry matter is a measure of digestibility for an animal. The analysis uses actual rumen fluid to simulate how well the animal will digest the FPR. The higher the percent of dry matter, the greater the digestibility.

The mushroom/corn screenings show obvious characteristics of low dry matter, relatively high protein, and moderate digestibility. Mushroom pieces likely make up a high portion of the mixture. High iron levels, as in a number of other FPRs, are probably related to soil contamination. Potassium and magnesium levels are low. Because of the low dry matter, transport and storage problems are expected. This FPR can be ensiled with a fiber source.

12.3 Study 2: Fresh Packing Vegetable Processing

This processing plant is a family-owned and –operated company that processes, packs, and ships fresh produce. Their product line includes salads, spinach, shredded cabbage, carrots, turnips, parsnips, broccoli, cauliflower, radishes, brussel sprouts, and kale. Processes include cleaning, trimming, washing, drying, and packaging the produce. The company processes approximately 500,000 pounds of raw products per week. The average FPR factor is 30% of the original product. Raw FPR products generated on an average amount to approximately 150,000 pounds per week. Processing occurs in two separate facilities – one for food service and prepackaged items and the other for retailed spinach, shredded cabbage, and a mixed salad product.

This company has no FPR water treatment system. Washwater from equipment cleaning is screened and discharged to a municipal treatment plant. The water is disinfected from the chlorine-based detergents used in cleanup.

The facility generates vegetable trimmings and FPRs from cutting and grading in two separate buildings. Figures 12.5 through 12.9 show the process lines in the first building. Figures 12.10

through 12.11 show the process lines in the second building. All trimmings within the two buildings drop to an underfloor collection system that transports FPRs to a 30- to 40-square-foot dumpster located outside each building. One dumpster contains lettuce, carrots, and salad trimmings; the other contains spinach, cabbage, escarole, and endive. The company generates 15 to 20 dumpsters of FPRs per week. In the past, a farmer emptied the dumpsters free of charge. The FPRs were used as supplemental animal feed.

Major constituents of this company's FPRs may include:

- lettuce leaves, cores
- cauliflower stems, leaves
- cabbage leaves, cores
- pepper cores
- carrot tops
- broccoli stems, leaves
- celery leaves and butts
- defective turnips
- yellow and decayed spinach leaves
- parsnip, brussels sprouts, radishes, onion peels and cores
- escarole, endive leaves and butts

Figure 12.5 Process lines for lettuce, celery, peppers, and onions

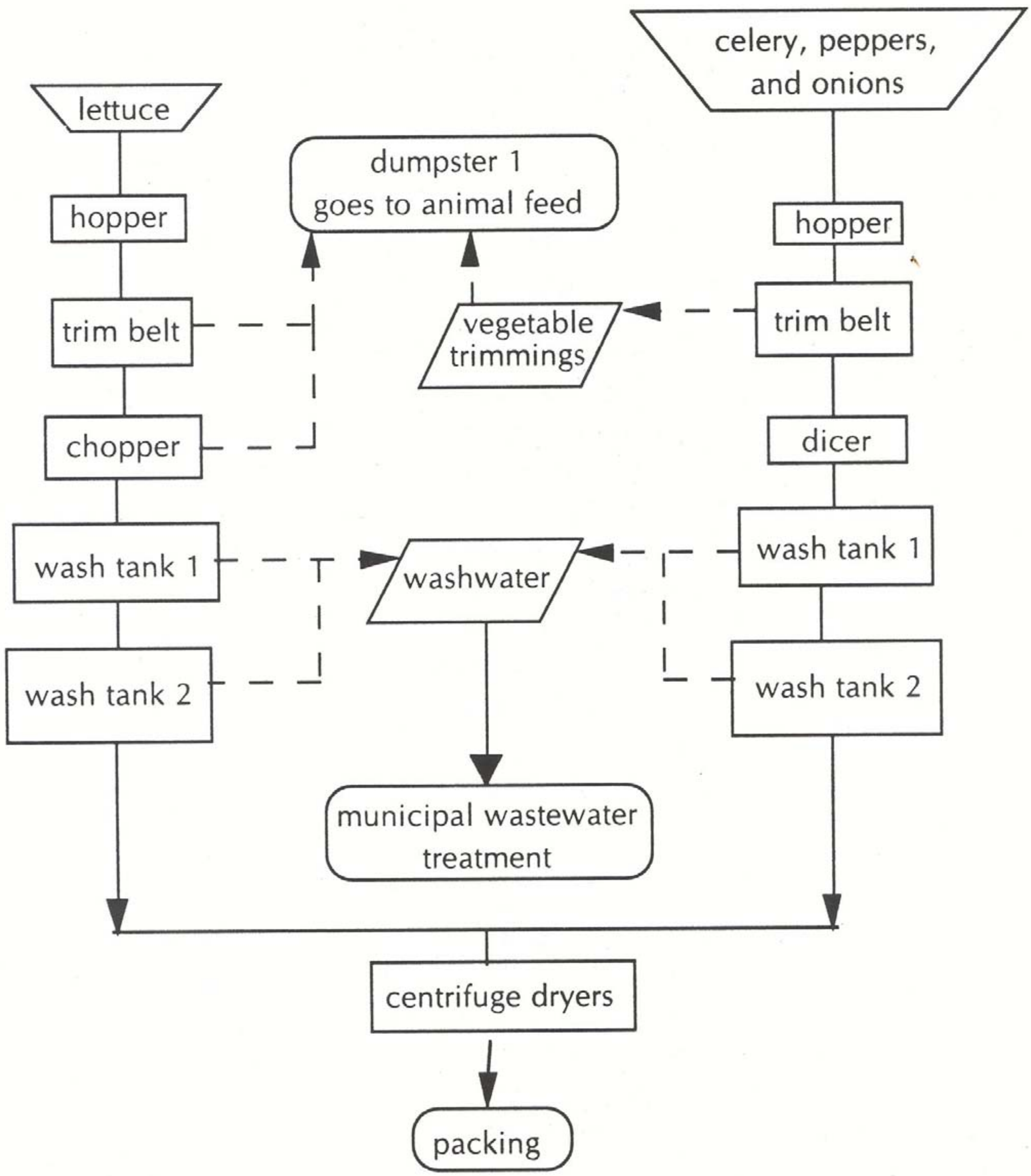


Figure 12.6 Carrot process line

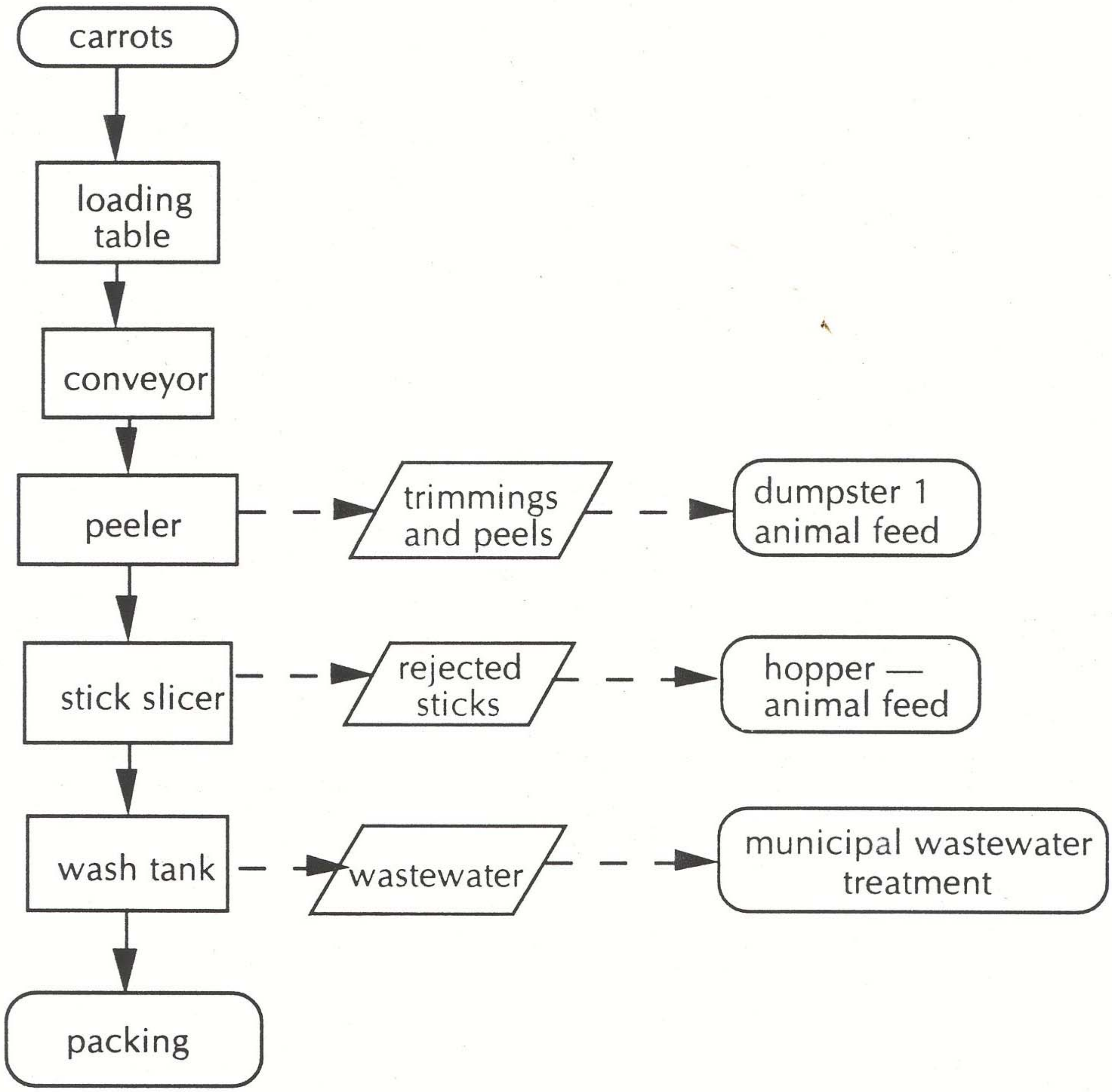


Figure 12.7 Celery process line

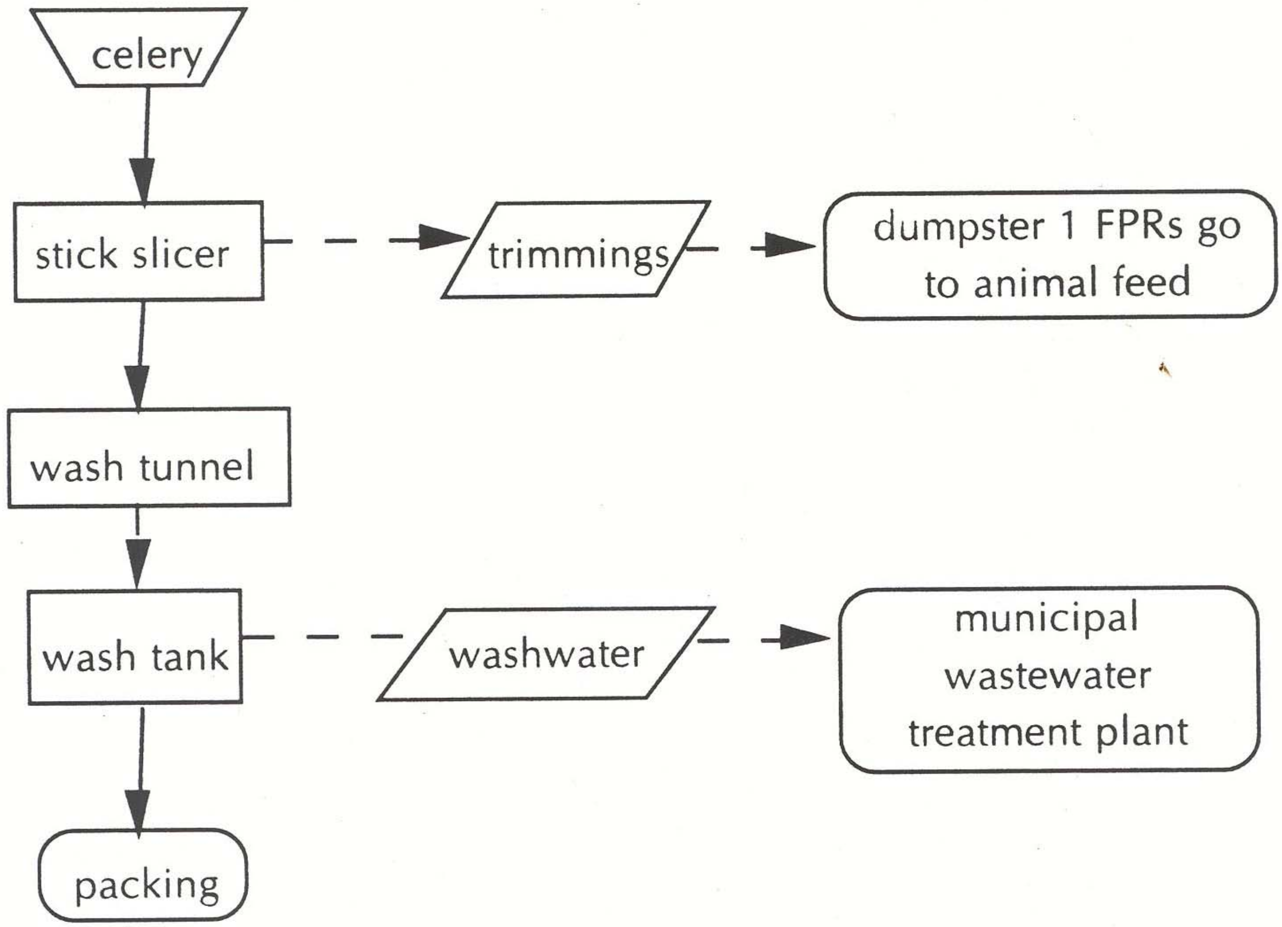


Figure 12.8 Broccoli and cauliflower process line

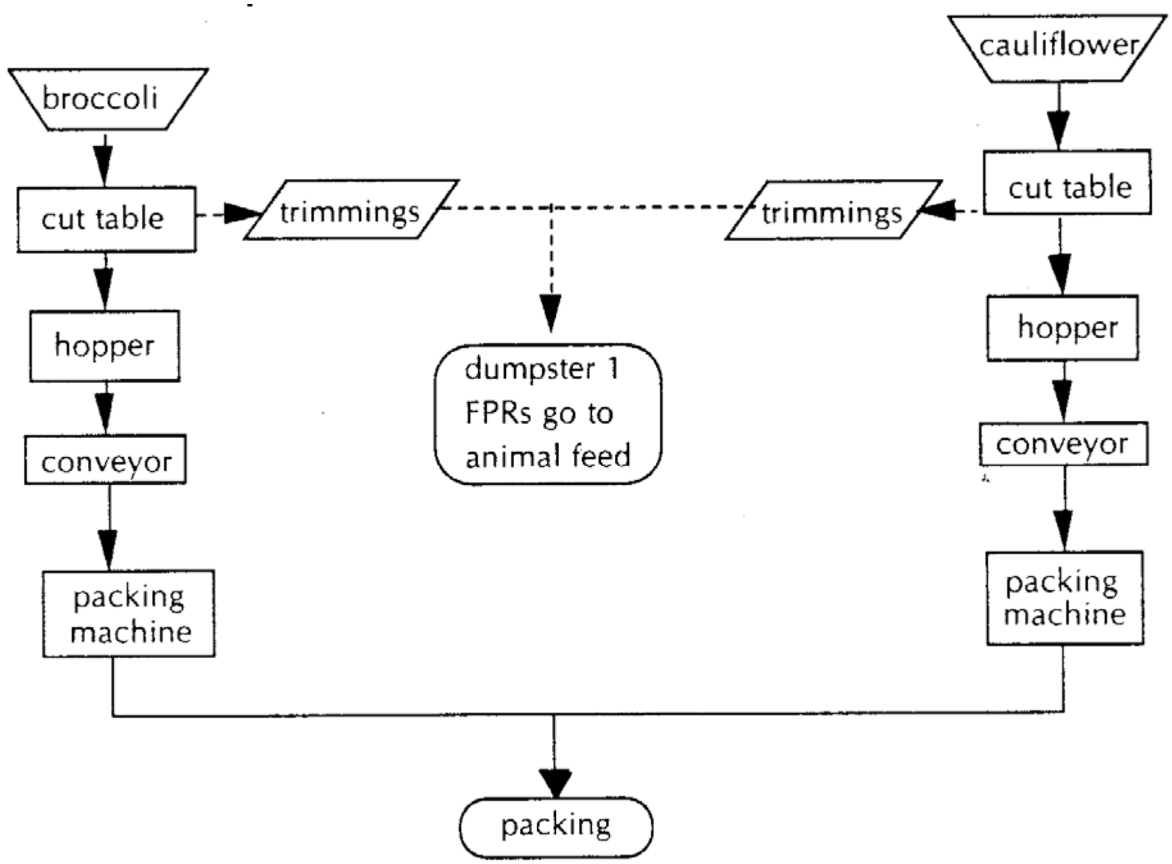


Figure 12.9 Miscellaneous vegetable fresh process line

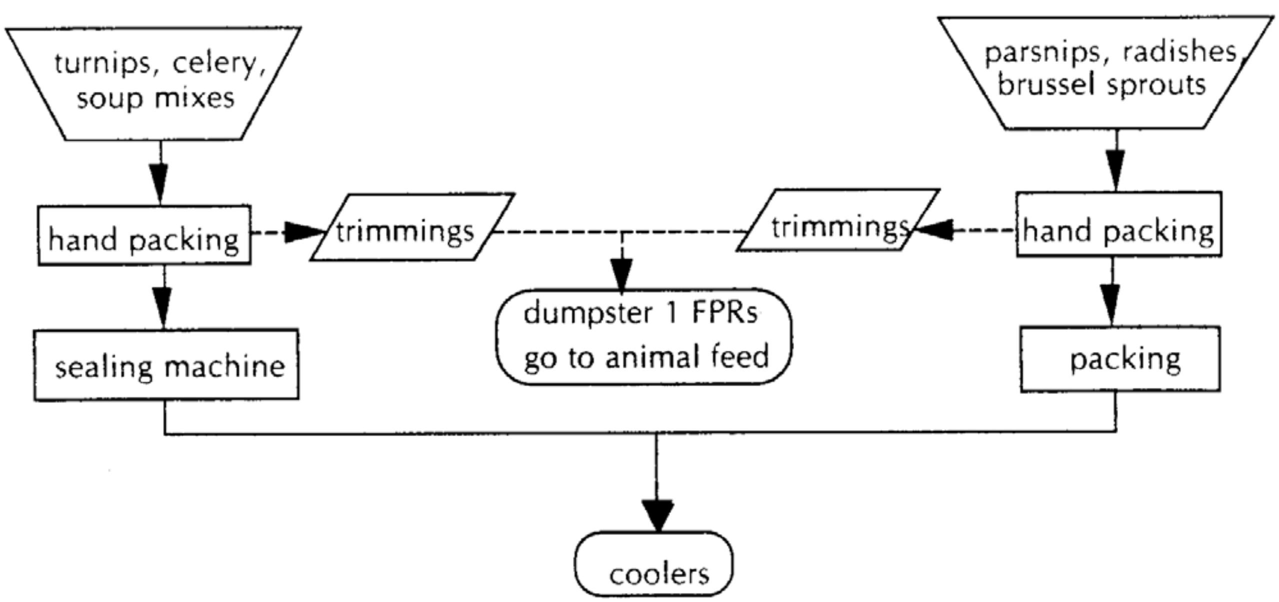


Figure 12.10 Spinach process line

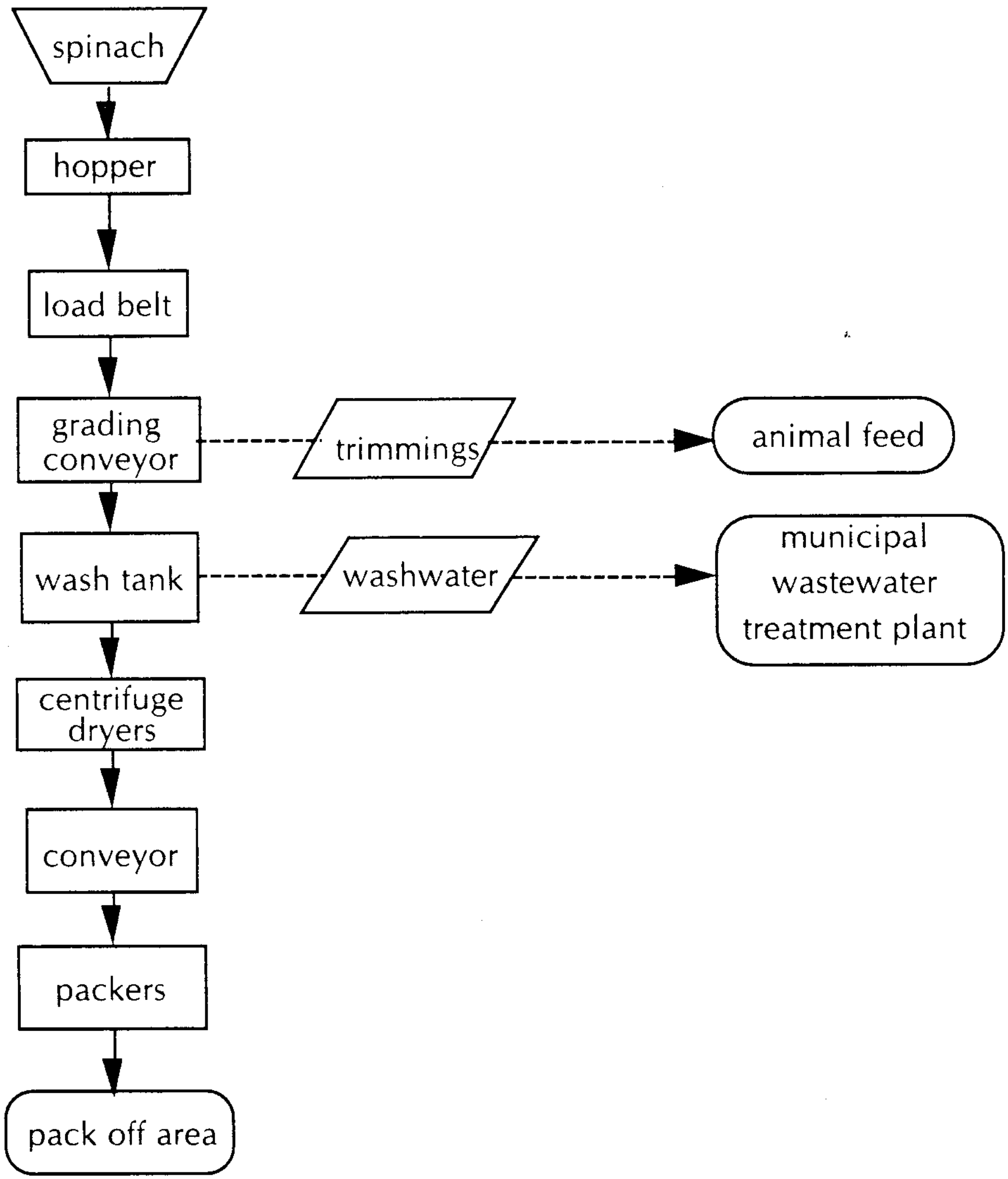
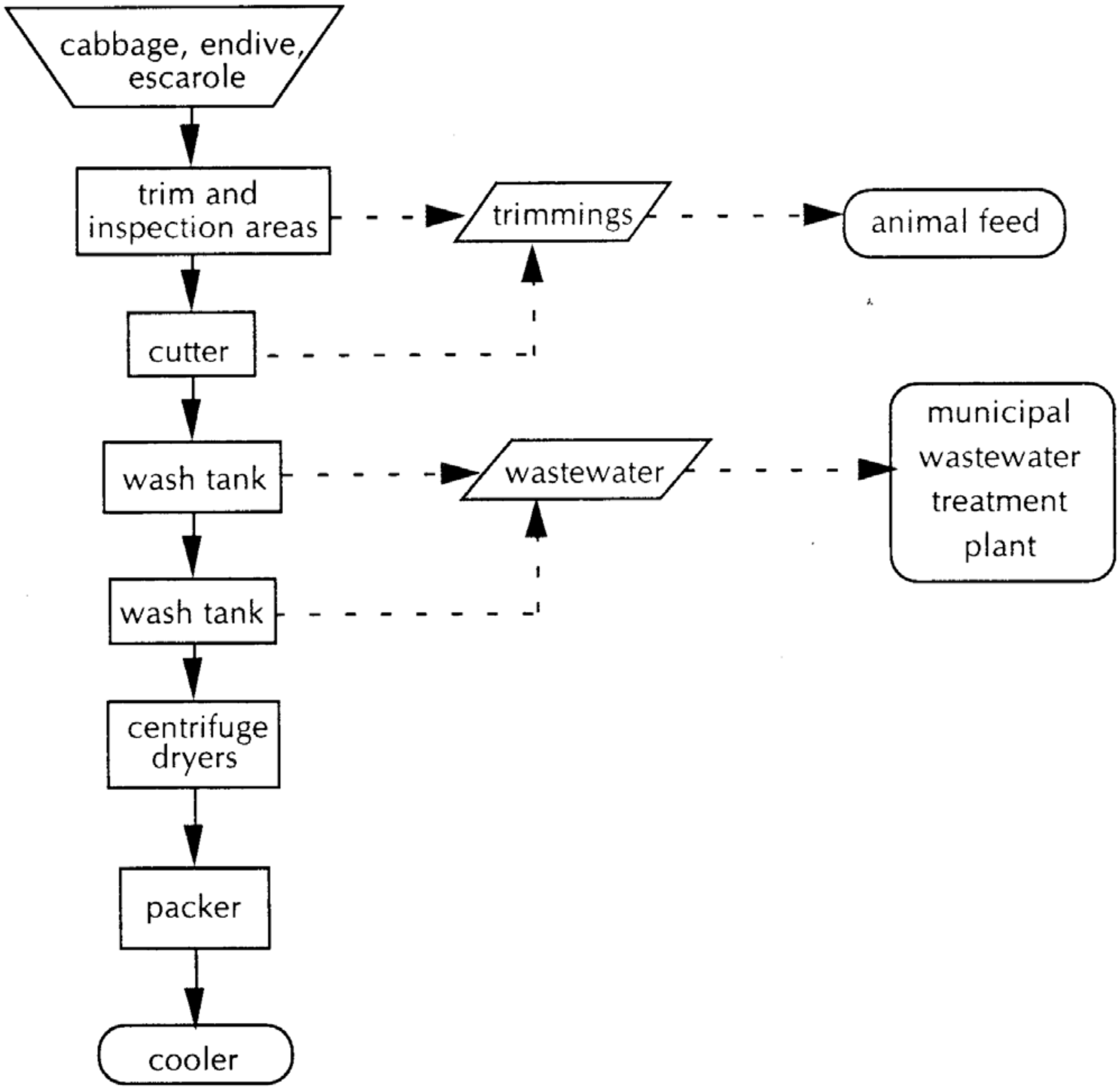


Figure 12.11 Cabbage, endive, and escarole process line



A second indirect FPR product comes from the company's onion operation. A farmer peels the onions and sends them to the plant for packaging. Onion peels and FPRs are currently being composted and then land-applied. The peeler estimates a 30% FPR factor from each bag on onions. The peeler currently peels 600 bags (15 to 20 pounds each) of onions, producing about 10,000 pounds of FPR per week. The company disposes of FPR water screenings and spoiled product in a municipal FPR dumpster.

Each processing building has an underfloor collection system that collects vegetable trimmings. During cleanup, loose trimmings are dry swept into the system. This reduces water use and keeps the moisture content of the FPR dumpsters to a minimum. The company's new facility will have an FPR removal system that dry vacuums trimmings to a central collection area.

The company recycles approximately 5,000 gallons of water through the chlorinated hydrocooler. This is the first-wash process for spinach. This water is discharged daily to the municipality. Chlorinated compounds are used in this cleaning process.

To reduce water use and thus discharge, the cleanup shift practices a preliminary dry cleanup and then uses water for equipment washdown. Employees are encouraged to sweep up before hosing down floors and machinery to limit using water as an "FPR mover."

In the past, the farmer did not charge for hauling solids FPRs. The farmer now wants to charge $150 per dumpster. This could cost anywhere from $2,250 to $3,000 per week. The company had the product tested to find its value as a feed additive. Results of the tests are given in Table 12.5. If the company can show farmers that the FPR has potential as a feed additive, this may reduce or eliminate hauling costs.

Table 12.5 Feedability profiles for vegetable FPRs

	Salad FPR Dumpster #1	**Vegetable FPR Dumpster #2**
Manganese (ppm)	30	44
Iron (ppm)	200	864
Copper (ppm)	13	9
Boron (ppm)	18	33
Aluminum (ppm)	121	144
Zinc (ppm)	40	24
Sodium (ppm)	2500	2500
Phosphorus (% of wt)	0.45	0.47
Potassium (% of wt)	2.14	3.16
Calcium (% of wt)	0.45	0.67
Magnesium (% of wt)	0.19	0.25
Oven Dry Matter (% of wt)	7.84	9.96
In vitro Dry Matter (% of wt)[a]	87.65	86.07
Crude Protein (% of wt)	15.28	18.78
Acid Detergent Fiber (% of wt)	14.82	18.32
Neutral Detergent Fiber (% of wt)	13.03	19.20

Note: Samples were taken from dumpster 1 (carrots, lettuce, salad trimmings) and dumpster 2 (spinach, cabbage, escarole, endive) at a vegetable processing facility. All sample results are on a dry weight basis. Values over 2500 are indicated as 2500.

a) In vitro dry matter is a measure of digestibility for an animal. The analysis uses actual rumen fluid to simulate how well the animal will digest the FPR. The higher the percent of dry matter, the greater the digestibility.

From a feedability standpoint, the FPRs in Table 12.5 should be considered as very wet forage; the dry matter is even lower than typically found in fresh grasses and legumes. The digestibility is exceptionally high. However, the relatively low fib content indicates that this FPR would have little roughage or "scratch factor" value in a ruminant ration; a very long hay supplement would be advisable. Regular delivery and prompt feeding within two to three days in hot weather would be required to avoid decay and spoilage. The extremely high water content would probably limit use to fairly close proximity to the food processing plant. This FPR also has potential to be ensiled with a dry roughage. Mineral content is acceptable, although the relatively high potassium level should be noted when balancing the total ration. Possible pesticide residues are a concern with any fruit and vegetable FPR and should be monitored.

The company is also exploring options for dewatering the dumpster FPRs, including pelletizing, heat drying, and grinding. Trimming samples have been run through a heat dryer to remove 50% to 75% of the moisture. Results from the feedability analysis of this heat-dried FPR (shown in Table 12.6) will allow the company to make decisions on how the product can be used. Options may include feed additive, mulch additive, or land application.

Table 12.6
Feedability profiles for heat-dried FPRs

	Spinach Mixture 1x Dried [a]	Vegetable matter 2x dried [a]
Moisture (% By Wt)	65.2	28.7
Phosphorus (% By Wt)	0.14	0.30
Ph	5.77	7.32
Nitrate-Nitrogen (ppm)	460	260
Nitrite-Nitrogen (ppm)	0.4	2.5
Calcium (ppm)	4190	11200
Copper (ppm)	<10	20
Iron (ppm)	3970	20200
Magnesium (pm)	860	1370
Manganese (ppm)	40	150
Potassium (pm)	8290	6700
Zinc (ppm)	40	150
Protein Modified Dumas (% by wt)[b]	9.4	17.2
Acid Detergent Fiber (% by wt)	7.3	15.9
Neutral Detergent Fiber (% by wt)	12.6	27.8

Note: Samples Analyzed At Lancaster Laboratories.

(a) Mixtures Were Run Through A Heat Dryer To Reduce Moisture.
(b) The Percent Protein Was Calculated From % Nitrogen Using A Factor Of 6.25.

Table 12.7
Feedability profile for onion peel FPRs

PARAMETER	DRY BASIS (%)	AS RECEIVED (%)
Moisture	---	---
Dry matter	8.5	8.5
Protein	8.7	8.7
Digestible protein	4.6	4.6
Acid detergent fiber	21.6	21.6
TDN —estimated	72.6	72.6
Net Energy of Lactation (Mcal/Kg)	0.35	0.35
Calcium	0.87	0.87
Phosphorus	0.18	0.18
Potassium	1.16	1.16
Magnesium	0.13	0.13
Note: Results from Agri Analysis, Inc., Bird-in-Hand, Pennsylvania.		

FPR Segregation

Although the company operates year-round, FPR characteristics fluctuate. For example, if a spoiled load of produce must be dumped, FPR characteristics of the entire dumpster change. Depending on feedability potential, FPRs may need to be segregated in the plant to produce a more consistent quality.

Carrot FPR Disposal

The plant uses a carrot shredder to produce shredded carrots for salads and bagged carrots. The shredder rejects carrot pieces too small to fit and drops them into a bin. The product is still edible but the company can’t find a use for the pieces. They are currently used for feed. By finding a market (i.e., soup company, restaurant, etc.), this FPR could be moved up the hierarchy and turned into an income-generating activity.

Onion Peel Disposal

Onion peel disposal poses another problem. The primitive “composting” system the farmer currently uses is odorous, unsanitary, and vector attracting. The peels are simply being piled up and turned periodically. The peels are simply being piled up and turned periodically. The peels have been tested for feedability. Results are shown in Table 12.7. Although these peels have protein and estimated energy levels roughly equivalent to a medium quality grass hay, they contain alkaloids that may cause anemia and toxicity in cattle, horses, and, to a lesser extent, sheep. A feed containing small portions (5-10% of diet) for nonlactating, nonpregnant ruminants may be possible. However, since no known treatment exists for “onion poisoning,” feeding at a higher level would increase risk. Other options for use need to be pursued.

FPR water screenings and possibly spoiled or damaged product may have land application potential. By composting and land applying these FPRs the company could reduce municipal FPRs and move them up on the hierarchy.

Chapter 13: Fruit Case Studies

13.1 Common FPR Management Strategies

Fruit FPRs are similar in many respects to vegetable FPRs. Management methods depend heavily on the fact that such FPRs attract insects and rodents and cause offensive odors. Thus, they create environmental and health concerns if allowed to stand too long. Fruit FPRs are also seasonal by nature. Variability or lack of segregation is not a major concern, since many fruit processors concentrate on one product.

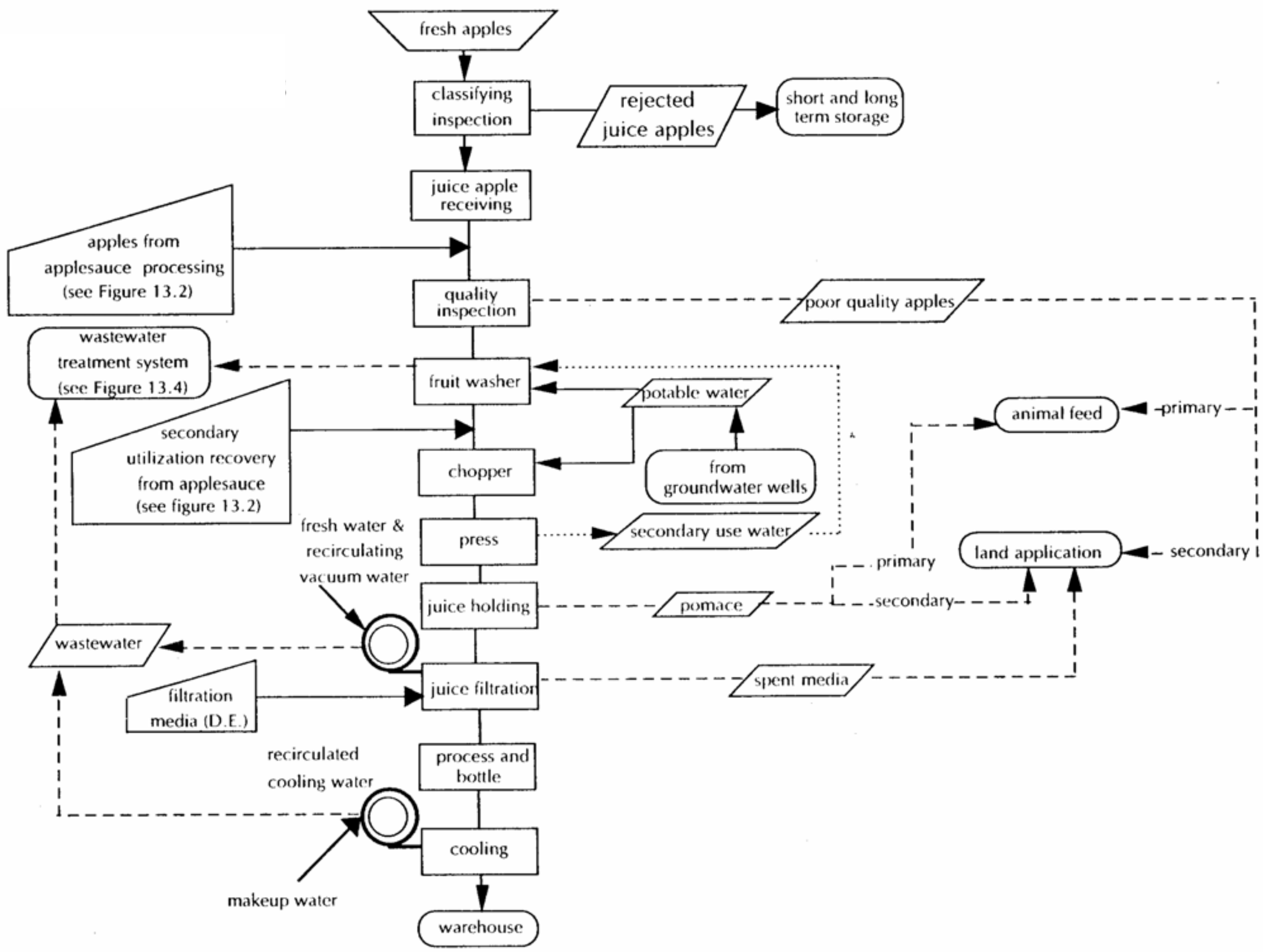
Like most FPRs, fruit residuals have general characteristics that define their unique processing. Effluents from fruit processing are composed mainly of carbohydrates such as starches, sugars, pectin, and vitamins. About 70% of the total organic matter is dissolved and thus can't be removed by physical methods. Treatment of these effluents often includes biological or chemical processes. The pH of most fruit FPRs is neutral unless caustic peelers are used, in which case intermittent pHs of 12 to 13 can be detected.

A final note on fruit (and vegetable) processing FPRs is that they are sensitive to changes in processing technique. For example, dry caustic peeling produces less FPR with a lower BOD than wet peeling. Or, in the case of vegetables, steam blanching corn produces a starchier effluent than a hydrostatic blancher. This sensitivity to plant technology should always be taken into account during both plant modification and FPR management planning.

13.2 Study 1: Fruit Processing

The processor in this case study has the following products: apple juice, applesauce, apple butter, vinegar, and pie filling (apple, cherry, and peach). The company has seven processing plants. A corporate FPR management program covers all FPRs generated. The environmental management system described below focuses primarily on one processing plant. References made to the corporate FPR management program or individual plants are noted in the text. Figures 13.1 through 13.3 show process flow charts for three production lines: apple juice, apple sauce, and apple slice.

Figure 13.1 Flowchart of apple juice processing



Major solid food FPR streams consist of pomace, leaves, and FPR apples. Pressed pomace may be generated at a level exceeding 300 tons/year at one plant. Disposal options for this FPR are always being explored, with primary pomace going to animal feed and secondary pomace to land application. Land application is practiced with commercial farm equipment, i.e., manure spreaders. Other alternative uses are being evaluated by the company. Beneficially used cherry pits and peach pits amount to approximately 60,000 lb/year. The company has been able to market both pit types as a potpourri additive. Other disposal alternatives include mulch, compost, fuels, and land application. Leaves are land-applied and FPR apples are either used as animal feed or land-applied depending upon their condition.

As noted in Figure 13.1, diatomaceous earth is used as a filtration medium for apple juice processing. The spent medium is mixed with the leaves and FPR apples prior to land application.

Solids generated in the wastewater treatment system include screenings from the rolling screen and hydrasieve tangential screen in the wastewater treatment facility, and sludge removed periodically from the temporary storage ponds. Screenings vary in weight and volume from 4,000 to 10,000 lb/month during the processing season. Both solids are land-applied in accordance with agricultural utilization guidelines.

Wastewater flowing from the production lines at one plant averages 2,643,000 gallons/month. Figure 13.4 shows a flow diagram for wastewater treatment and disposal. Water for restroom facilities, the cafeteria, and drinking is drawn from public water supplies and disposed of through the municipal system. At sampling point C1 in Figure 13.4, raw wastewater is analyzed for biological oxygen demand (BOD) and total suspended solids (TSS)—both parameters are of concern for fruit processing. Influent ranges for these parameters are estimated at 3000 to 8000 mg/l BOD and 180 to 1300 mg/l TSS. Following hydrasieve screening and hydrated lime pH adjustment at the screenhouse, during spring, summer, and fall, water is pumped to a multi-stage overland flow pretreatment system. During the winter, flows bypass the overland treatment and go directly to the storage ponds.

The overland flow pretreatment system consists of six 180 x 30 ft sloped plots. An average of 50,000 gal/day flows to the plots. FPR water is tested for BOD and TSS before and after overland flow treatment, and percent reduction is computated. Table 13.1 shows percent reductions for three months. Following pretreatment, water is directed to storage pond B for bacterial reduction and aeration. Both storage ponds are equipped with 7.5 hp aerators. In the winter months water bypasses the overland pretreatment plots and flows directly to the storage ponds. The only chemical addition made at the pretreatment plot is urea, which is broadcast periodically over the six plots.

Table 13.1 BOD and TSS reductions from overland flow pretreatment plots

	Top slope (mg/l)		Bottom Slope (mg/l)		Reduction (%)	
Month	**BOD**	**TSS**	**BOD**	**TSS**	**BOD**	**TSS**
September	3555	800	1629	30	54	96
October	6227	722	2776	18	55	98
November	5970	1521	1521	14	75	99

Note: Sampling point S2 on figure 13.4.

Following pretreatment and aeration, FPR water goes to pump station 2 for pH adjustment. From this point it is directed to one of two spray irrigation fields—west field and east field. Both fields were designed with underdrain systems where percolating water may be collected and redirected back to the storage ponds. The underdrains serve multiple purposes. Marginal application sites were approved by the PADEP with underdrain installation. East field has a curtain drainage system running parallel with the field on the top slope to divert shallow groundwater springs from the woods located above it. As Figure 13.4 indicates, several sampling wells are located in each field to monitor the final soil treatment process. Table 13.2 shows average monthly values for these parameters over one year. Samples are pulled weekly from the sprayheads.

Figure 13.2 Flowchart of apple sauce processing

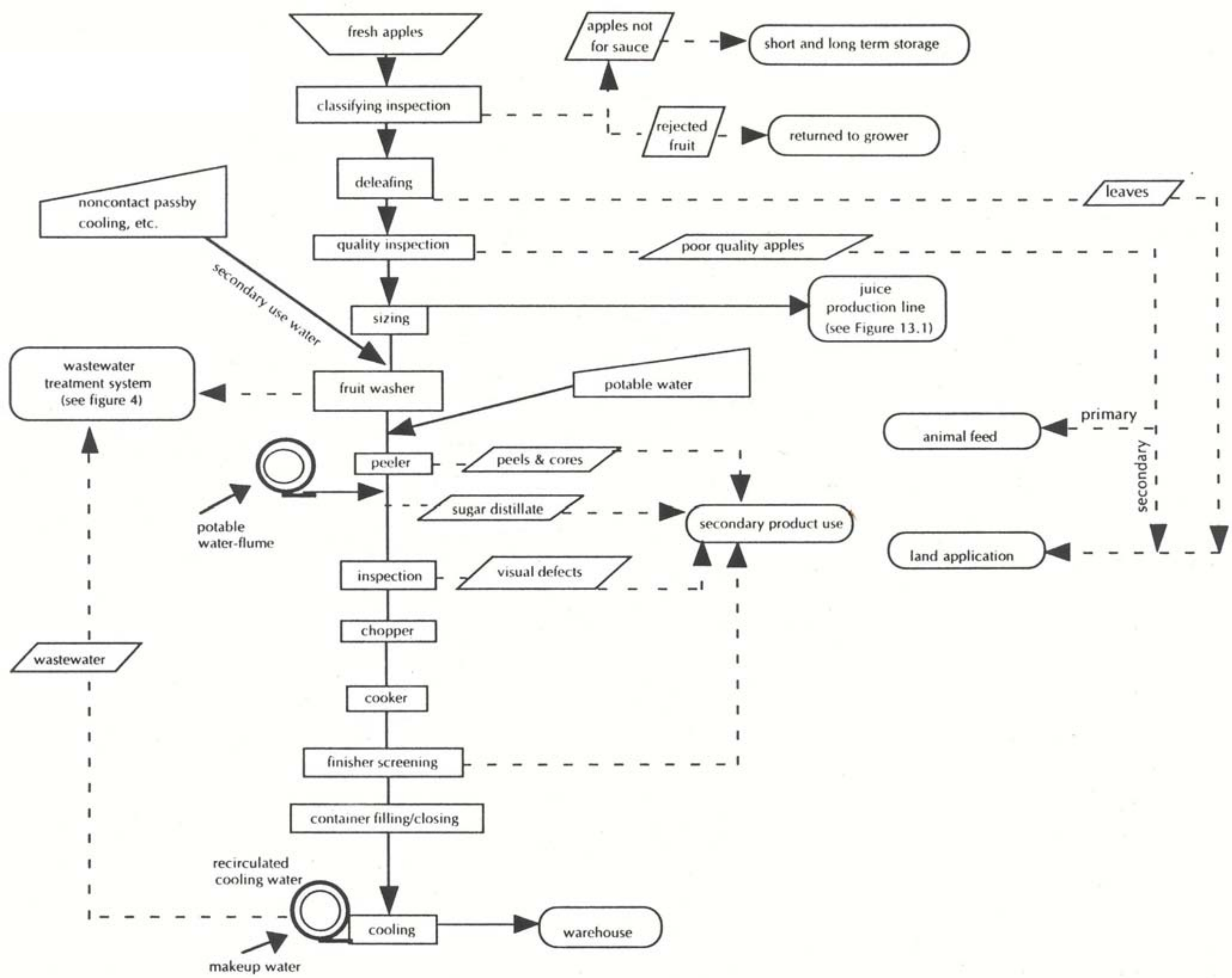


Figure 13.3 Flowchart of apple slice processing

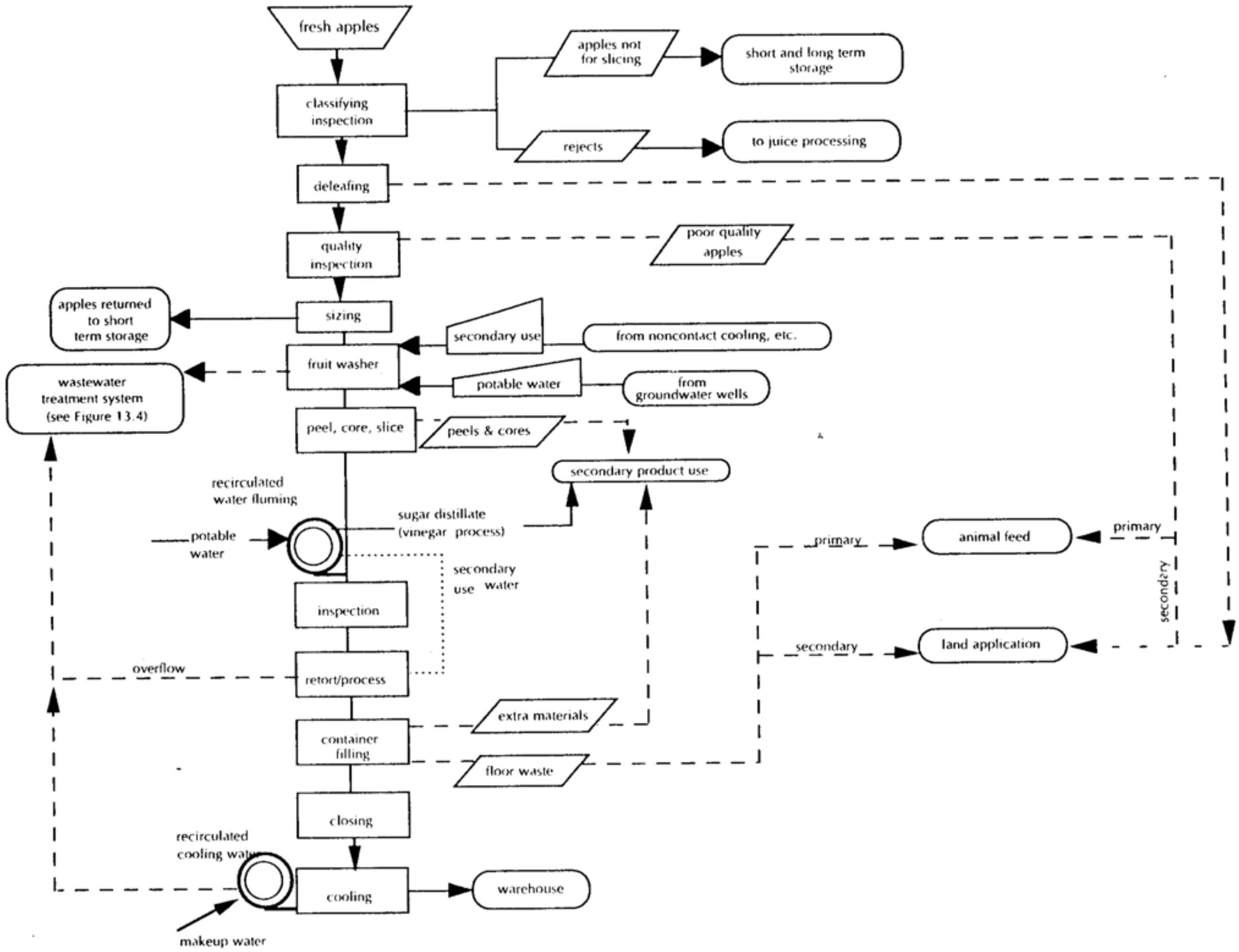


Figure 13.4 Flowchart for wastewater treatment and disposal at a fruit processing plant

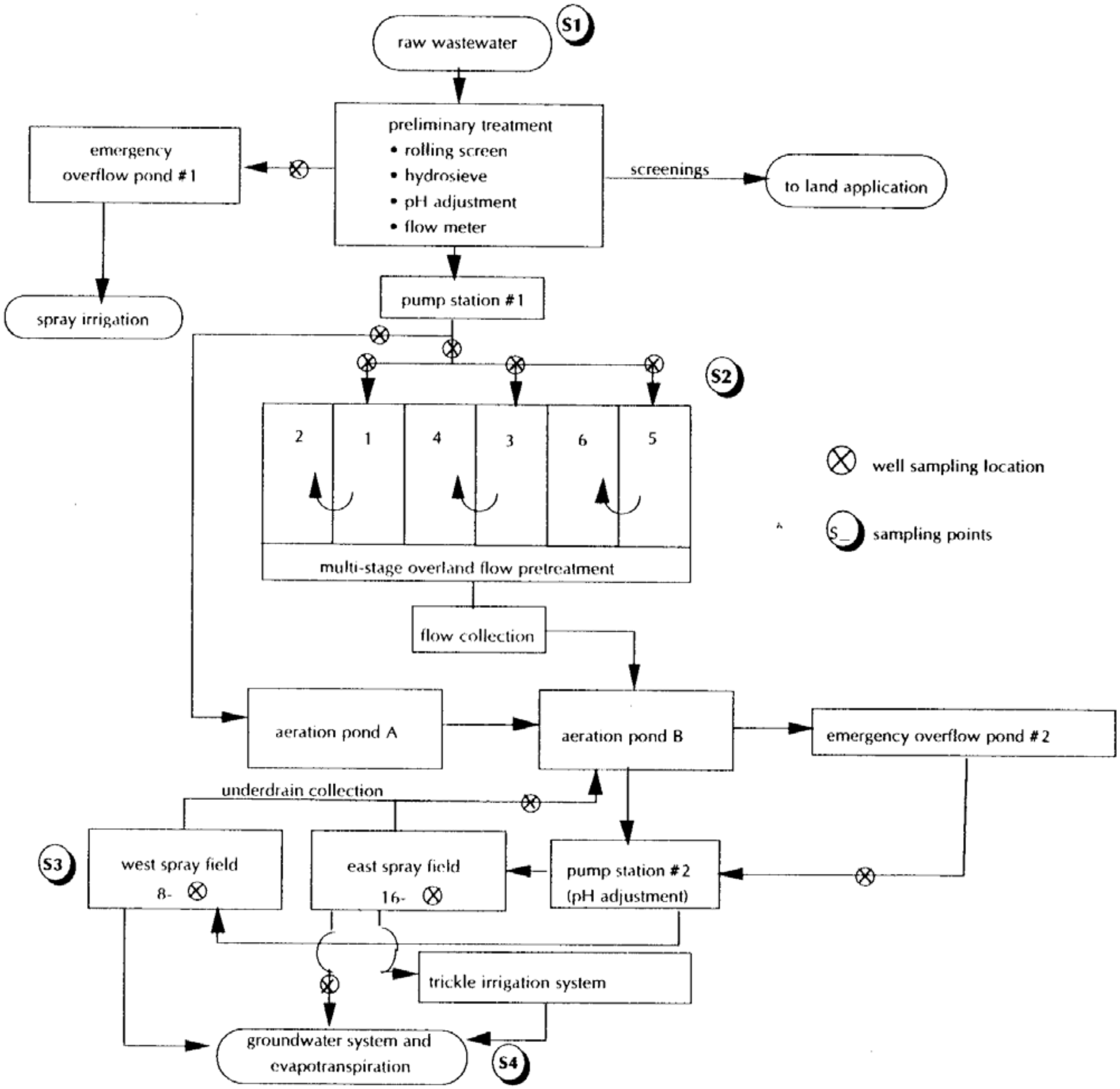


Table 13.2 Average BOD and TSS concentrations for spray irrigated water

Month	Gallons Irrigated[a] (days) x 1,000 gal	BOD (mg/l)	TSS (mg/l)
February	897 (10)	1572	200
March	2209 (20)	1547	293
April	2691 (22)	919	225
May	2116 (19)	531	267
June	1426 (9)	760	260
July	2300 (17)	317	180
August	276 (2)	---	---
September	2829 (22)	83	90
October	2802 (24)	532	755
November	2323 (20)	803	1760
December	1690 (18)	401	1275
January	2346 (21)	663	448

Note: Samples taken during the 1991-1992 season. Sampling point S3 on Figure 13.4.

a) Number of days per month irrigation was conducted.

Local groundwater is used by the food processor for production. This provides another reason for environmental control and another quality check in the system. This plant has a strategic plan for monitoring irrigated water and comparing with the monitoring well network on site. The central processing plant has thirteen monitoring wells that are monitored quarterly for pH, COD, BOD, TSS, and other parameters specific to the spray irrigation permits. The irrigation samples are monitored weekly for these parameters. Table 13.3 shows monitoring well results for one quarter.

The plant also has NPDES stream discharge permits. Only noncontact cooling water is stream discharged. In accordance with these permits, the two tributaries that flow through the spray application fields are monitored weekly for pH and COD.

Because this company draws processing water from local groundwater sources, it has an extensive water conservation, reuse, and monitoring program. The water program is managed by the corporate environmental management group with the plants reporting to them.

Table 13.3 Ranges for parameters measured at the monitoring wells

Parameter	Range (mg/l)
pH	6.85 - 7.72 (Standard Units)
COD	<1.0 - 28.9
BOD	<1.0 - 3.4
TDS	218 - 988

Note: Sampling point S4 on Figure 13.4.

Water conservation begins at the plant management level. The environmental management team conducted water use surveys to determine water needs for process lines at each plant. Based on the numbers obtained, daily production maximum use levels were established, and flow meters were installed. Daily, the plant manager provides the environmental management group with the total water use. Use levels reported at ±20% of the maximum must be accompanied with a reason for the variance.

Plant personnel are also trained in water conservation strategies. This is an ongoing process. Flow meters are often installed to monitor high use areas and/or shifts. For example, by monitoring the cleanup shift the company found that cold-water cleanup used more water than hot-water cleanup. Other practical measures like low flow spray nozzles, advanced cleaning systems, and preliminary dry cleanup have also been implemented.

As the flow charts indicate, water is reused wherever possible in the plant. In juice processing (Figure 13.1), potable water used to cool hydraulic oil in a noncontact, pass by fashion is redirected to the fruit washer at the front of the line. In slice processing (Figure 13.2), about 300 gal/day of water from the recirculating water flume is captured and distilled along with other sources. The concentrated sugar distillate is then used in vinegar processing.

Another ongoing strategy involves monitoring the groundwater supply well draw down. By accessing the water table level at each well on a daily basis, the company plans more effectively for production and cleanup shifts.

Overall, the corporate environmental management team for this company has several strengths which make for an effective management program:

- a separate FPR enterprise established to monitor wastewater treatment, plan conservation strategies, and explore disposal options
- a staged program that implements changes over time and plans for future reduction strategies and in-plant modifications
- a multifaceted disposal/FPR exchange program that doesn't rely on single source management and disposal options
- a commitment to exploring and implementing innovative management strategies
- beneficial use of FPR with recyclers and usable markets
- reliance on several farmers for marketing pomace as an animal feed
- frequent audits to identify recyclable materials
- two emergency storage ponds for use only during extended storms or when regular ponds fail
- a consistent, well-documented monitoring program
- excellent odor control
- an underdrain system
- effective BOD/TSS reductions from pretreatment
- management commitment and clear goals
- metered strategic processes and shifts
- documented water quantities for production lines
- established accountability with the plant managers
- department supervisory involvement
- environmental awareness committees within plants (staff and employees) to identify points of needed attention

13.3 Study 2: Peach Processing

A California peach processing company has successfully marketed peach pits as a raw material for charcoal briquettes. During the peach season, 500 tons per day of pits are delivered to a charcoal manufacturer. Pits are dried for one year during which they are sprayed with deodorant and an insecticide to reduce odors and eliminate vectors.

After screening to remove dirt and foreign matter, the pits are transferred to rotary dryers for moisture reduction. The pits are screened again and then fired in a 2000°F kiln. They emerge from the kiln as charcoal, are aged for two weeks, and then formed into charcoal briquettes. The charcoal company processes 35 tons of charcoal in a 24-hour period using 120 to 140 tons of dried peach pits. For further information contact C.B. Hobbs Corporation, P.O. Box 607, Santa Clara, California 95052.

13.4 Study 3: Apple Processing

Apple processing residuals—apple pomace, filter cake, and an undigested biological sludge—from a juice manufacturer were composted with sawdust.

A compost facility designed by International Process Systems, Inc. was used. The facility consists of concrete open bays sheltered in a building. Each bay is machine agitated, aerated, and composted as the compost moves through it. The agitator-mixer passes through the mixture eighteen times until the agitator reaches the end of the bay, at which point it is discharged as finished compost.

Wet weight of the materials was reduced by 50% and dry weight was reduced about 20%. Total material volume reductions of 30% were also achieved. Table 13.4 shows the quantities and solids analysis of the apple process residuals, sawdust, and finished product.

Table 13.4 Quantities and solids analysis of apple process residuals, sawdust, and finished compost

Materials	Wet wt., mg	Total solids, %	Dry wt., mg	Volatile solids, %	Volatile solids, mg	Biodegr VS, %	Biodegr lost, mg	Fixed solids, %	Fixed solids, %
Sludge	34.4	12	4.1	60	2.48	70	1.73	40	1.65
Filter cake	24.5	38	9.3	13	1.21	70	0.85	87	8.10
Pomace	56.4	14	7.9	90	7.11	70	4.98	10	0.79
Sawdust	62.3	68	42.3	100	42.2	15	6.33	0	0.17
Input mixture	177.6	36	63.7	83	53.0	26	13.9	17	10.7
Compost 18 days	83.5	60	49.8	79	39.1			21	10.7

Note: Volatile solids and fixed solids are expressed as a percent of dry solids.
a) Biodegradable portion of volatile solids estimated from Haug, 1980.

Chapter 14: Meat Case Studies

14.1 Common FPR Management Strategies

Meat processing has historically been a "recycler" of organically based FPR products since the development and growth of the rendering industry. Thousands of tons of shop fat, bones, offal, trap grease, feathers, blood, and other residuals of meat processing are rendered annually and resold to pet food manufacturers, cosmetic companies, and feed companies. Rendering is an excellent example of FPR utilization that eliminates major solid FPRs for meat processors.

Still, meat processing and rendering facilities have FPR management considerations specific to their processes. High strength wastewater flows almost always necessitate wastewater treatment prior to discharge to a stream or even to a municipal system. Wastewater treatment in turn generates sludges that pose their own treatment and disposal problems. Many meat processors often put sludge from their wastewater treatment plant at the top of the FPR stream list. One beef manufacturer handles 1,072 tons/year of sludge. A turkey processor generates 4,500 gal/day. Pork and poultry processors reported 3,000 and 4,000 gal/week, respectively. A traditional sludge disposal method is land application on permitted land application sites. Extensive sampling and monitoring are required. In addition, sludge may not be applied on frozen or saturated cropland. Sludge storage then becomes another burden. Some poultry processing facilities pay 8¢/gal for sludge disposal to a municipal plant rather than cope with the land disposal problems.

Other FPRs pose more expensive disposal dilemmas. Hide trimmings, tails, used salt, and hoofs cost one beef processor an estimated $70,000 a year to landfill. The cost per ton is $65—a common landfill fee in Pennsylvania. Manures are a high quantity FPR for Pennsylvania meat processors. Animal manures from livestock pens range from 200 lb/day to 5 tons/day. Meat processors do not have many options for disposal of sludges and manures. Land application is clearly the most economic, feasible alternative for many processors. The problem then is not one of utilization but rather of management. Meat companies who fail to properly manage land application sites lose them. Land application needs to be practiced under sound hydrologic and nutrient management conditions. The following Study 1 presents an example of one company that established a nutrient management plan for the application of manures and treatment plant sludge.

Sludge and manure management are largely dependent on quantity. Many sludges are high in moisture content. Reducing water content can save sludge transportation and disposal costs. Study 2 describes a facility that effectively reduced sludge moisture content through belt pressing and heat drying.

14.2 Study 1: Beef Processing and Beef/Poultry Rendering

The company studied slaughters and packages beef and renders beef and poultry residuals. The average cattle use is around 1,500 head per day. Rendering uses two continuous cookers and ten batch cookers. The flowchart in Figure 14.1 shows FPR stream flows and treatment processes currently in practice at this plant.

All residuals from the slaughtering process—bones, offal, and blood—are sent directly to rendering for processing into bonemeal, bloodmeal, and tallow. Hides are treated in a separate facility where they are soaked in a brine solution. Barn manure and paunch manure, the undigested residues remaining in the rumen of animals at slaughter, are collected and stored on concrete pads; then they are land-applied. Tables 14.1 and 14.2, respectively, show sample sludge analysis for these two materials. Washwater from the slaughtering plant goes directly to the wastewater treatment plant aeration lagoons. This washwater may contain chlorine and phosphorus constituents from the cleaners used to wash down equipment. The plant uses about 300,000 gallons of fresh water per day.

Figure 14.1 FPR flowchart for wastewater treatment processes at a meat processing and rendering facility

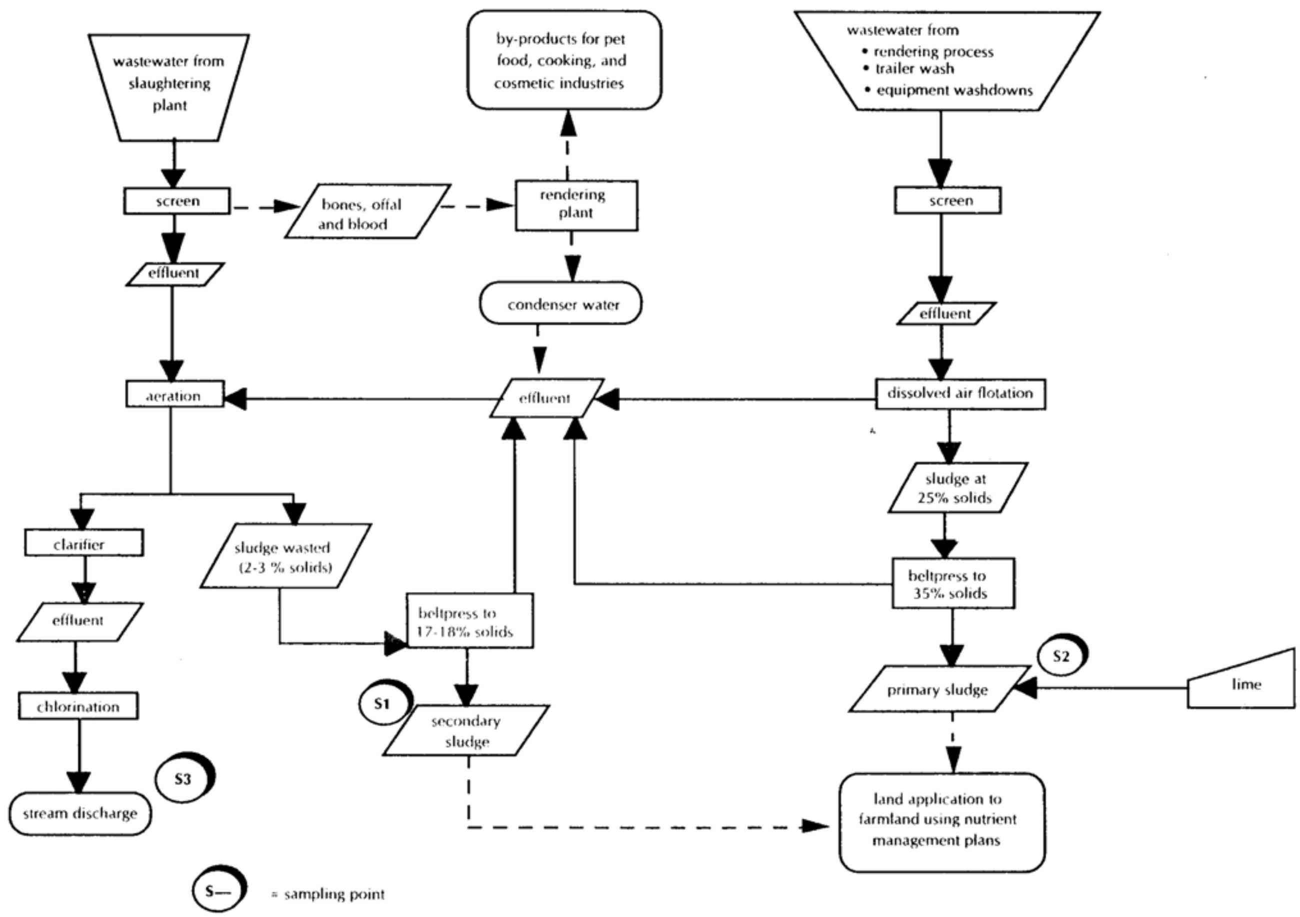


Table 14.1 Characteristics of paunch manure used on cropland at a beef processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
1	1.65	0.88	0.24	1.31	0.09	0.12	0.76	0.21	2.05	2.26	33.39	86.00
2	1.55	0.97	0.23	1.20	0.13	0.21	0.86	0.19	1.71	1.90	34.17	86.10
Average	1.60	0.92	0.24	1.25	0.11	0.16	0.81	0.20	1.88	2.08	33.78	86.05

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd
1	9.0	103.3	15.0	134.8	9.0	1.5	0.1	4.5	0.7
2	8.8	165.3	20.5	159.5	7.3	2.9	0.1	8.8	0.7
Average	8.9	134.3	17.7	147.1	8.1	2.2	0.1	6.6	0.7

Primary nutrient content—percent of dry weight

	Level	Low------- Medium--------------------- ----High
		------------2 ------------4 ----------------- --------8
Total N	2.08	••••••••••
P205	1.87	••••••••
K20	1.11	••••

Non-fertilizer trace element content—lb dry ton

	Level	
Pb	0.02	acceptable as fertilizer
Cr	0.00	" "
Mercury	0.00	" "
Nickel	0.01	" "
Cd	0.00	" "

Fertilizer trace element content—lb dry ton

	Level	
Cu	0.04	acceptable as fertilizer
Zn	0.29	" "

Nutrient value

Equivalent	One dry ton=3 tons of wet sludge
P value	6.16 dry tons to supply 100 lb of phosphorus
N value	2.40 dry tons to supply 100 lb of total nitrogen
Lifetime loading	510 dry tons per acre due to sludge zinc concentration

Table 14.2 Characteristics of barn manure used on cropland at a beef processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
1	0.56	1.59	0.46	1.18	0.14	0.19	0.86	0.34	1.59	1.93	38.43	85.56
2	0.64	2.09	0.46	1.27	0.23	0.32	0.83	0.42	2.77	3.19	33.93	84.88
Average	0.60	1.84	0.46	1.22	0.19	0.25	0.84	0.38	2.18	2.56	36.18	85.22

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd
1	8.5	157.4	29.9	141.8	9.1	2.6	0.3	3.9	0.7
2	8.5	201.9	30.9	216.6	11.8	2.9	0.3	7.4	0.6
Average	8.5	179.7	30.4	179.2	10.4	2.8	0.3	5.6	0.6

Primary nutrient content—percent of dry weight

	Level	Low------- Medium--------------------- ----High
		------------2 ------------4 ----------------- --------8
Total N	2.56	•••••••••• ••
P205	1.94	•••••••••
K20	2.21	•••••••••• •

Non-fertilizer trace element content—lb dry ton

	Level	
Pb	0.02	acceptable as fertilizer
Cr	0.01	" "
Mercury	0.00	" "
Nickel	0.01	" "
Cd	0.00	" "

Fertilizer trace element content—lb dry ton

	Level	
Cu	0.06	acceptable as fertilizer
Zn	0.36	" "

Nutrient value

Equivalent	One dry ton= 2.8 tons of wet sludge
P value	5.92 dry tons to supply 100 lb of phosphorus
N value	1.95 dry tons to supply 100 lb of total nitrogen
Lifetime loading	418 dry tons per acre due to sludge zinc concentration

Since water from the rendering facility is high in blood, fat, and other particulates, washwater and effluent from the prescreening process is sent to a dissolved air flotation unit at the wastewater treatment plant. Rendering recycles approximately 70,000 gallons of water per day. This water is then used for trailer washdowns, first-time cleanup, etc. As Figure 14.1 indicates, condenser water bypasses the dissolved air flotation and goes directly to the aeration tanks at the wastewater treatment plant.

The wastewater treatment plant was constructed in 1976 and has the capacity to treat one million gallons per day. It is a secondary treatment plant with aeration lagoons, dissolved air flotation (DAF), and a clarifier. On an average day the DAF treats about 120,000 gallons of water. An anionic polymer and ferric chloride (500 ppm) are added for coagulation. Solids from the dissolved air flotation unit (6% solids content) are beltpressed to about 35% to produce the primary sludge. After lime stabilization this sludge is land-applied. Table 14.3 shows the characteristics of the primary sludge. Sludge wasted from the aeration tanks is typically 2 to 3% solids. The wasting rate is about 6% of plant flow. Table 14.4 shows secondary sludge characteristics. After chlorination, the effluent is discharged to a stream in accordance with a National Pollution Discharge Elimination System (NPDES) permit. Table 14.5 shows characteristics of the discharge. Finally, Table 14.6 shows average quantities of the various streams and indicates water use and reuse for both the beef and rendering divisions.

Typically, salt and salt brine from hide processing do not enter the wastewater treatment plant. This would not only adversely affect the wastewater treatment system, it would ultimately limit land application of sludges. To maintain efficiency in the wastewater treatment system, the facility established high standards to limit salt contributions to the system. The hide processing facility uses a three-step washdown process to limit salt discharge to the wastewater stream. Also, an evaporation system is used to recover salt, which is then returned to and used back in the hide process. This segregation is significant since high salt concentrations in soil destroy natural soil structure through interactions with soil clay, and thus reduce porosity. Low porosity limits infiltration and makes it difficult for the soil to retain moisture. (See Chapter 8 for a discussion on soluble salts.)

Table 14.3 Characteristics of primary sludge with lime used on cropland at a beef processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
1	0.13	0.05	0.25	32.49	0.34	0.23	0.22	0.05	1.25	1.30	56.24	23.66
2	0.12	0.04	0.26	34.02	0.35	0.21	0.22	0.05	1.62	1.67	58.74	23.14
Average	0.13	0.04	0.26	33.25	0.35	0.22	0.22	0.05	1.43	1.49	57.49	23.40

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd
1	12.6	28.4	73.8	56.0	3.6	5.3	0.2	3.6	1.0
2	12.6	26.4	9.4	53.6	2.6	4.3	0.2	4.3	1.4
Average	12.6	27.4	41.6	54.8	3.1	4.8	0.2	3.9	1.2

Primary nutrient content—percent of dry weight

	Level	Low—— ———2	Medium ———4	———	——High ———8
Total N	1.49	*****			
P205	0.51	***			
K20	0.05	*			

Non-fertilizer trace element content—lb/dry ton

	Level	
Pb	0.01	acceptable as fertilizer
Cr	0.01	" "
Mercury	0.00	" "
Nickel	0.01	" "
Cd	0.00	" "

Fertilizer trace element content—lb/dry ton

	Level	
Cu	0.08	acceptable as fertilizer
Zn	0.11	" "

Nutrient Value

Equivalent	One dry ton = 1.7 tons of wet sludge
P value	22.68 dry tons to supply 100 lb of phosphorus
N value	3.37 dry tons to supply 100 lb of total nitrogen
Lifetime loading	902 dry tons per acre due to sludge zinc concentration

Note: Sample 2 from Figure 14.1.

Table 14.4 Sludge characteristics of secondary sludge from a beef processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
1	1.08	0.53	0.35	1.87	0.24	1.36	2.12	0.79	6.98	7.77	11.82	83.75
2	1.08	0.51	0.34	1.83	0.24	1.30	2.07	0.81	5.53	6.33	11.57	84.36
Average	1.08	0.52	0.35	1.852	0.24	1.33	2.10	0.80	6.25	7.05	11.69	84.05

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd
1	7.7	182.0	46.6	207.4	8.5	29.6	0.4	25.4	1.3
2	7.7	177.2	47.5	233.4	8.6	25.9	0.9	30.3	0.4
Average	7.7	179.2	47.0	220.4	8.6	27.8	0.6	27.8	0.9

Primary nutrient content—percent of dry weight

	Level	Low—— ———2	Medium ———4	———	——High ———8
Total N	7.05	*****			
P205	4.82	***			
K20	0.62	*			

Non-fertilizer trace element content—lb/dry ton

	Level	
Pb	0.02	acceptable as fertilizer
Cr	0.06	" "
Mercury	0.00	" "
Nickel	0.06	" "
Cd	0.00	

Fertilizer trace element content—lb/dry ton

	Level	
Cu	0.09	acceptable as fertilizer
Zn	0.44	" "

Nutrient Value

Equivalent	One dry ton = 8.6 tons of wet sludge
P value	2.38 dry tons to supply 100 lb of phosphorus
N value	0.71 dry tons to supply 100 lb of total nitrogen
Lifetime loading	340 dry tons per acre due to sludge zinc concentration

Note: Sample 2 from Figure 14.1.

Table 14.5 Dry monitoring report for a beef processing facility wastewater treatment plant

Day	Temp-erature °C		pH (Standard Units)		DO (mg/l)		Settleable solids		BOD (mg/l)		NH3 (mg/l)		O&G (mg/l)		P (mg/l) (a)		Cl2 (mg/l)	Coli # 100 ml	Flow
	Influent/Effluent																Effluent Only		
1	30.5	16.6	6.0	6.8	4.5	9.2	40	0.0	3266	6					2.3		0.1		293297
4	24.7	17.2	5.6	6.5	7.4	9.1	40	0.0									0.1		157590
5	29.7	18.3	6.7	6.8	6.2	8.4	25	0.0			128	0.16	331	2	2.3	0.17	0.2	50	280150
6	25.9	19.3	6.9	6.8	7.1	10.2	20	0.0									0.5		465400
7	25.9	19.3	6.9	6.9	6.3	12.0	10	0.0									0.1		429540
8	25.9	20.3	6.6	7.0	6.9	10.3	10	0.0	2132	18							0.1		314030
11	27.1	17.0	6.1	7.0	6.5	11.2	40	0.0									0.1		321890
12	29.2	15.9	6.7	7.0	6.5	10.9	40	0.0			308	1.50	2609	3	2.5	0.36	0.1	0	359560
13	26.5	16.9	6.4	7.0	7.1	9.9	18	0.0									0.1		346950
14	23.6	17.7	6.0	7.0	7.2	9.7	40	0.0									0.1		396470
15	21.9	17.1	6.9	7.1	6.2	7.4	40	0.0	3285	8							0.1		275893
18	23.7	14.3	6.6	7.1	6.2	7.4	25	0.0									0.1		334650
19	25.7	15.8	6.2	6.9	6.1	9.2	40	0.0			403	0.35	1368	6	0.3	0.45	0.1		374930
20	26.3	17.9	6.2	7.0	5.8	9.1	40	0.0									0.1	50	382280
21	22.9	17.9	6.4	6.9	6.5	6.8	10	0.0									0.4		423740
22	22.7	18.8	7.3	7.0	7.1	8.4	12	0.0	4730	18							0.1		301600
25	22.6	16.2	6.9	6.8	6.4	6.6	6	0.0									0.1		196220
26	20.2	16.2	6.4	7.0	6.5	7.3	6	0.0			41	0.19	507	9	30.8	0.28	0.1	0	275980
27	22.3	16.1	6.7	6.9	7.4	7.6	18	0.0									0.1		370440
28	24.3	17.1	6.3	6.9	6.6	7.8	3	0.0									0.1		395410
Aver-age	25.3	17.3	6.5	6.9	6.5	8.9	24	0.0	3353	13	220	0.55	1204	5	9.0	0.32	0.1	25	323774

Note: Daily monitoring report from February 1991. Sample 3 from Figure 14.1.

(a) Phosphorus as PO_4

The company follows nutrient management plans (NMP) for land application of primary and secondary sludges, as well as paunch and animal manure. The programs are computerized to match suitable, available fields with FPR applications that meet the nutrient needs of the crops. Over the past ten years, the company has established the following guidelines for their nutrient management plan:

Table 14.6 FPR Streams and water use/reuse at a beef processing facility

Water Usage	Approximate Flow
Beef Division water use	300,000 gal/day
Rendering division water use	100,000 gal/day
FPR Stream	**Approximate Flow**
Paunch and barn manure	190 tons/week
Primary sludge	56 tons per week
Secondary sludge	100 tons/week
Water Reuse/Recycle	**Approximate Flow**
Rendering Division	70,000 gal/day

Provide a quality product

To provide a quality product, undesirable constituents are removed from the sludges. For example, the company recognized that salt from the hide curing operation would potentially wash into the wastewater stream and could concentrate in the sludge. Salt has no nutrient value to the soil and, in fact, could cause the clay molecules to collapse and make water unavailable to crops even in wet weather. Therefore, the curing process was designed with a closed loop to keep salts from entering the wastewater stream.

Learn farmer needs

Recognizing that farmers involved with the NMP are also running a business, the company strives to learn farmer needs. For instance, in poor weather conditions, FPR materials cannot be applied, so farmers need a properly designed storage area—not merely a dumping site.

Respect concerns of neighbors

The company also tries to respect concerns of neighbors of the land application sites. Materials that cause odors are plowed and disked in.

Determine crop needs

Few food processing FPRs will have the exact ratio of nutrients required by the crop. Farmers will often supplement the FPRs with additional fertilizers. Therefore, the company determines crop needs and informs the farmer of how much FPR is applied. By working with the farmer, crop needs are met and the risk of nutrient migration and pollution is minimized.

Adhere to loading rate guidelines

The company also adheres to all loading rate guidelines. DEP has established maximum allowable loading rates (MALR) for potentially harmful metals. The sludge analysis for each FPR indicated which metals might have MALRs. The NMP manager always adheres to these rates and follows the recommended application site boundaries and restrictions established by DEP.

Maintain excellent records

The company also maintains excellent records. Records include the farmer's name, address, and phone number; the site name, number of fields, and acreage of each; special precautions (e.g., application distances to dwellings); type of crop grown; FPR analysis records; and a nutrient balance sheet. This company maintains a computer database of all solid FPR handling activities and makes these records available to farmers and regulatory agencies.

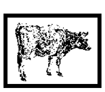
Establish routine sampling and testing program

To maintain FPR quality and meet crop needs, the company has established a routine sampling and testing program that provides a complete sludge analysis.

Provide additional services

Finally, as a public service, the company provides additional services such as soil and forage sampling at all land application sites. Farmers appreciate this information because it helps them identify crop problems—often unrelated to land application of FPRs. By addressing farmer concerns before they become a major problem, this process maintains a trusting relationship between the company and the farmer.

Several aspects of this FPR program could be improved. A small percentage of restroom facility waste was tied into the wastewater treatment plant. The company redirected these lines in the summer of 1991.



The potential exists to move paunch manure up on the FPR hierarchy to a feedable product. A sample of the manure was tested for feedability. Table 14.7 shows the analysis results. The potential for feeding paunch manure is dependent on a number of factors. Paunch manure, the undigested residues remaining in the rumen of animals at slaughter, can be quite valuable in nutrient content, depending on the type of diet that was fed, the amount of time between feeding and slaughter, and other factors. This sample contains protein, digestible dry matter, and fiber values roughly equivalent to a low-quality roughage. With only 18% dry matter, transportation expense is a concern, as is preserving quality over time. Previous research has shown that paunch manure can be ensiled with corn silage or other forages as long as the dry matter of the mixture is kept within reasonable limits. There appear to be no mineral problems with the calcium and phosphorus levels equivalent to the requirements for market steers.

Table 14.7 Feedability profile for paunch manure from a beef processing facility

Parameter	Value
Manganese (ppm)	37
Iron (ppm)	615
Copper (ppm)	13
Boron (ppm)	2
Aluminum (ppm)	310
Zinc (ppm)	54
Sodium	2500
Phosphorus (% of wt)	0.38
Potassium (% of wt)	0.46
Calcium (% of wt)	0.50
Magnesium (% of wt)	0.05
Oven Dry Matter (% of wt)	18.13
In vitro Dry Matter (% of wt)	39.43
Crude Protein (% of wt)	10.99
Acid Detergent Fiber (% of wt)	38.75
Neutral Detergent Fiber (% of wt)	70.73

Note: All samples done on a dry weight basis. Values over 2500 are indicated as 2500.

14.3 Study 2: Pork Processing and Rendering

This company slaughters and packages pork and renders pork residuals. Average production is around 5,500 head per day. The company operates on a five-day workweek. Figure 14.2 shows FPR stream flows and treatment processes currently in practice at this plant. Figure 14.3 indicates residuals from the rendering operation.

All residuals from the slaughtering process—bones, flesh, blood, fats, etc.—are sent directly to the rendering division for processing into bonemeal, bloodmeal, tallow, and fats. Washwater from slaughtering is prescreened at the plant and then sent to the wastewater treatment plant. Animal manure from the hog pens also goes to the wastewater treatment plant. Pituitary, carotid arteries, pancreas, etc. are sent to pharmaceutical companies. Equipment wash-downs are done with phosphorus-based cleaners. At the rendering plant, washwater is sent to the wastewater treatment plant. All other FPRs are sold to feed companies, soap manufacturers, and rolling mill industries.

The wastewater treatment plant was constructed in 1988 and has the capacity to treat 700,000 gallons per day. It is an advanced wastewater treatment plant incorporating DAF, denitrification/nitrification, and activated sludge. On an average day the DAF treats about 600,000 gallons of water. Ferric chloride and polyelectrolyte polymers are used for coagulation. After the DAF effluent goes through biological treatment, it is either discharged to a municipal system or reused within various plant operations. About 300,000 gallons is chlorinated and reused. Table 14.8 characterizes recycled water and water discharged to the municipality. Sludges are belt-pressed from 6% solids to 30 to 35 % solids and then heat dried to form about 90% solids pellets. The heat drying process reduces water content and kills pathogens. Prior to heat drying, lime is added to reduce moisture content. The sludge is sampled and analyzed for feedability and land application characteristics. The results of these analyses are shown in Tables 14.9 and Table 14.10, respectively.

Figure 14.2 Wastewater treatment at a pork processing facility

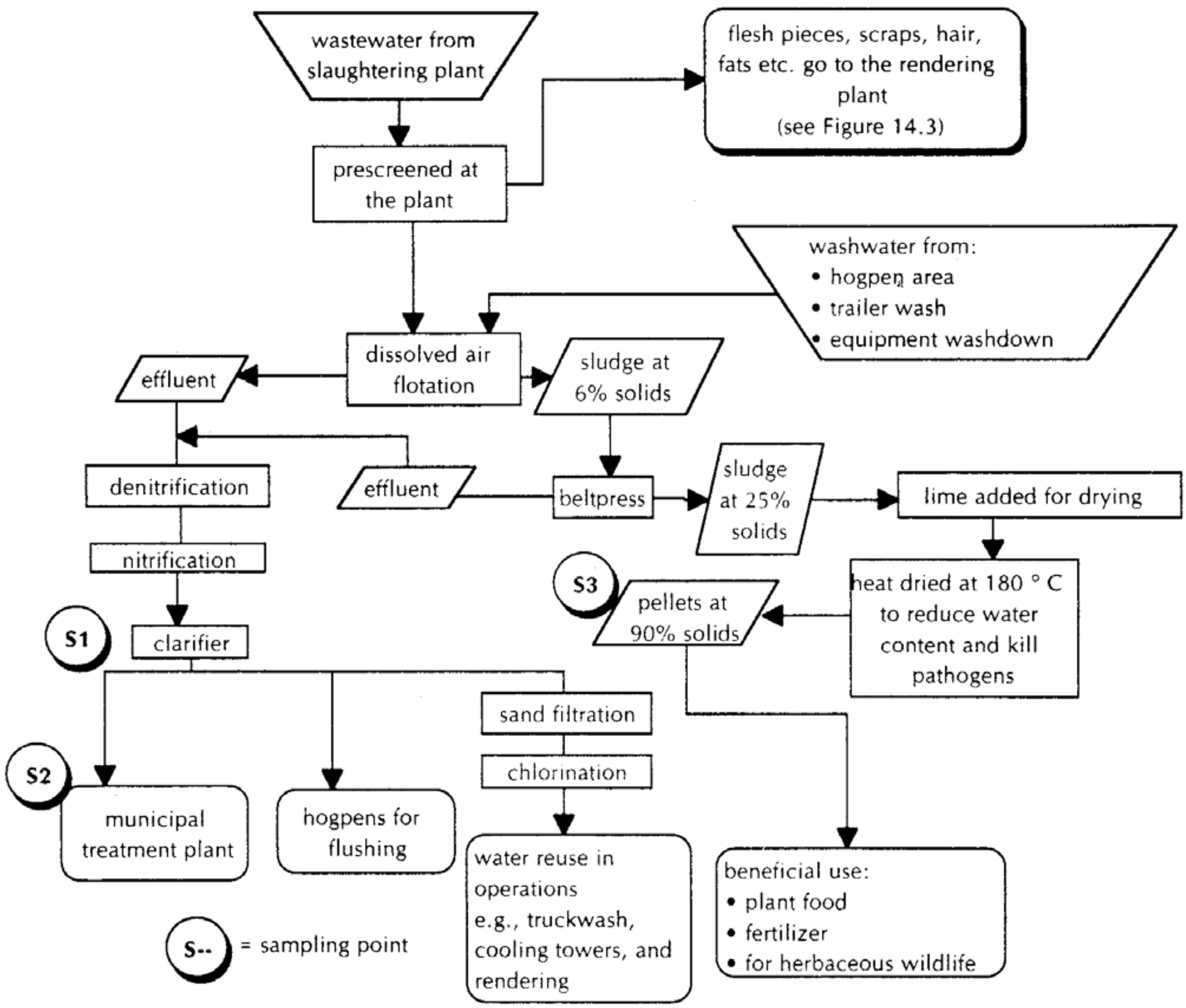


Figure 14.3 FPR flows for a rendering operation at a pork processing facility

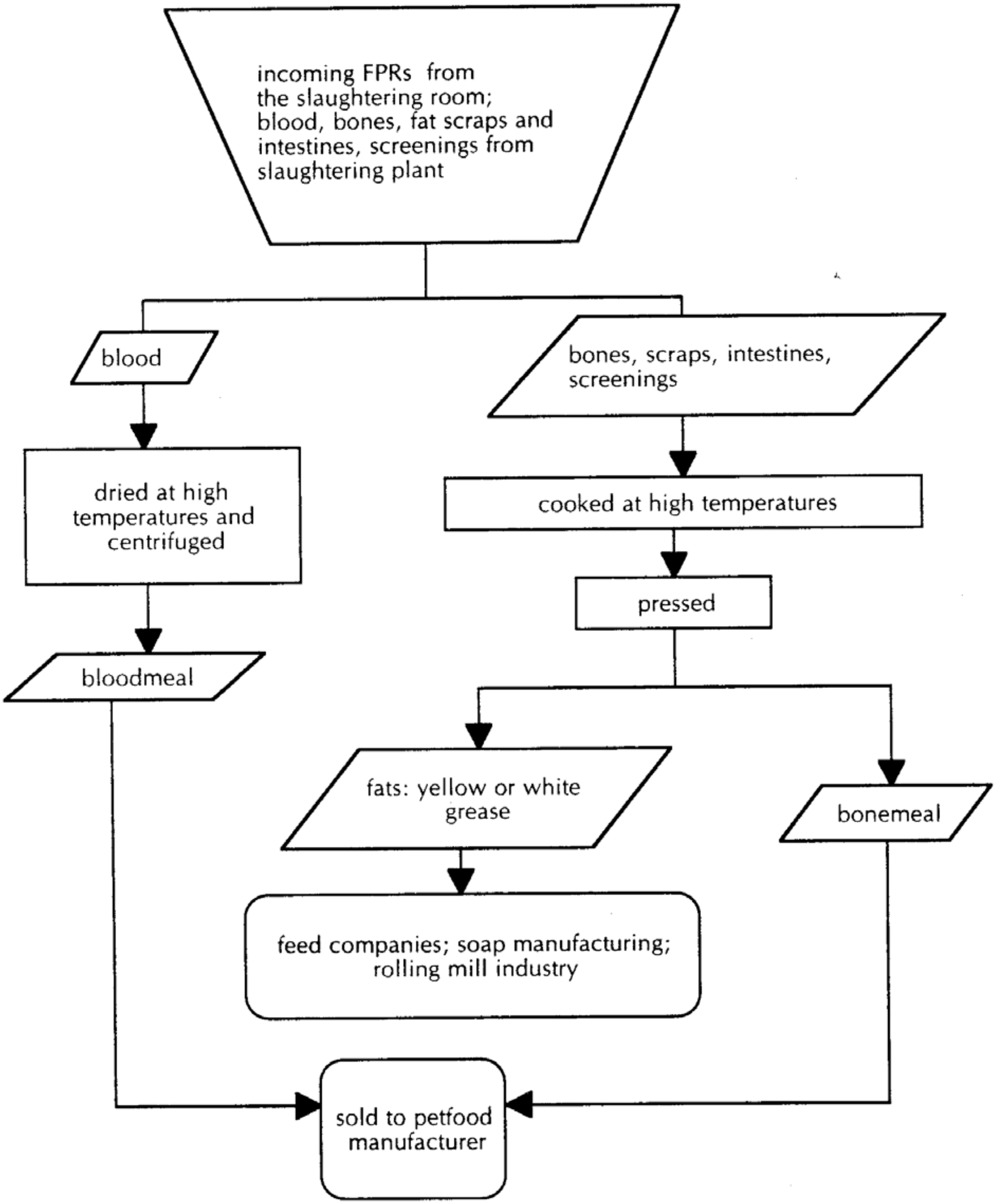


Table 14.8 Wastewater effluent characteristics from a treatment plant at a pork rendering facility

Parameter (mg/l)	Sample A1 (mg/l)	Sample B1 (mg/l)
BOD	<1	<1
Cd	0.018	0.022
Cu	0.011	0.021
Cr	<0.001	0.001
Hg	<0.002	0.002
Ni	0.332	0.340
Pb	0.059	0.057
Zn	0.071	0.116
TSS	0.267	3.30
TP	1.10	1.13
TKN	1.45	0.60
Cl_2	---	2240
pH	7.00	7.53

Note: Samples collected at A1 and B1 in Figure 14.2.

Table 14.9 Feedability profile for heat-dried sludge from a pork processing facility

	90% solids sludge
Manganese (ppm)	210
Iron (ppm)	2500
Copper (ppm)	193
Boron (ppm)	4
Aluminum (ppm)	2500
Zinc (ppm)	383
Sodium (ppm)	2500
Phosphorus (% of wt)	2.30
Potassium (% of wt)	0.29
Calcium (% of wt)	3.36
Magnesium (% of wt)	0.74
Oven Dry Matter (% of wt)	-----
In vitro Dry Matter (% of wt)	38.13
Crude Protein (% of wt)	37.75
Acid Detergent Fiber (% of wt)	11.95
Neutral Detergent Fiber (% of wt)	41.28

Note: Sample S2 on Figure 14.2. All samples done on a dry weight basis. Values over 2500 are indicated as 2500.

Table 14.10 A sample analysis of heat-dried sludge from a wastewater treatment plant at a pork processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
#1	0.47	0.15	0.69	2.59	0.10	7.97	2.23	0.04	4.06	4.10	90.95	72.85
#2	0.46	0.15	0.68	2.59	0.10	7.76	2.18	0.04	4.24	4.28	91.14	73.75
Average	0.46	0.15	0.69	2.59	0.10	7.86	2.21	0.04	4.15	4.19	91.05	73.30

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd	PCB
#1	8.7	241.9	156.1	495.9	6.6	36.3	0.2	11.0	0.1	
#2	8.7	237.0	154.7	488.3	6.6	36.2	0.2	11.0	0.2	
Average	8.7	239.4	155.4	493.1	6.6	36.2	0.2	11.0	0.2	0.0

Primary nutrient content—percent of dry weight

	Level	Low—— ———2	Medium ———4	———	——High ———8
Total N	4.19	*******	*******	*	
P205	5.08	*******	*******	*****	
K20	0.18	*			

Non-fertilizer trace element content—lb/dry ton

	Level	acceptable as fertilizer
Pb	0.01	
Cr	0.07	" "
Mercury	0.00	" "
Nickel	0.02	" "
Cd	0.00	" "

Fertilizer trace element content—lb/dry ton

	Level	
Cu	0.31	Acceptable as a fertilizer
Zn	0.98	" "

Nutrient Value

P value	2.26 dry tons of sludge to apply 100 lb of P
N value	1.19 dry tons of sludge to apply 100 lb of total N
Lifetime loading	152 dry tons per acre due to the zinc concentration in the sludge

This company obtained a beneficial use permit to heat dry wastewater treatment plant sludge and use it for various applications including agricultural utilization, herbaceous wildlife areas, plant food and fertilizer, and habitat strips for wildlife. Since land application sites are far from the plant, a reduced sludge moisture content decreases transportation costs. Heat drying was found to be an economical strategy for reducing sludge disposal costs.

After the water is treated at the wastewater treatment plant, some of the effluent is chlorinated and reused within the evaporative condensers within the plant. Approximately 300,000 gallons per day of effluent are handled in this manner. This reduces flow to the municipal system and decreases overall water use.

There are a few areas where the company is looking at improving FPR management. The company uses salt for curing and processing. Generally, salts are not segregated from the wastewater treatment plant water. Since sludges are used on cropland, there is some concern about the salt content. High salt concentrations can reduce nutrient uptake by crops and cause crusting on the soil surface. This company is exploring alternatives for reducing discharge of salts to the wastewater treatment plant.

Recent studies have shown that at certain concentrations polyelectrolyte polymers used in wastewater treatment can be toxic to animals. This would limit the heat-dried pellets from being used to supplement animal feeds. The company is exploring alternative coagulants.

Chapter 15: Dairy Case Study

15.1 Common FPR Management Strategies

Dairy processing generally produces four FPRs. The largest stream generated on a daily basis is the washwater flowing down the drains at the treatment plant. One company surveyed estimated wastewater quantities of 30,000 gallons/day, a second of 40,000 gallons/day, and a third facility handles 75,000 gallons/day. For most companies, discharge to municipal treatment plants is the most cost-effective means of disposal. But with these liquids being high in BOD, total suspended solids (TSS), and oils and grease, municipalities often tag surcharges onto discharge fees. As regulatory agencies place tighter restrictions on municipal discharge to streams and rivers, municipal plants often pass the cost onto the dairies—their high load discharge customers. This cycle continues until at some point the processors reach a break-even point at which installing an FPR water treatment plant becomes a viable alternative.

A second dairy processing FPR is return products. Grocery and convenience stores return finished product that either is damaged during transport or exceeds the shelf life. One dairy surveyed reported that 16 tons/month of product is returned for these reasons. What disposal options exist for this FPR? One method practiced by many dairies is feeding to animals. Either the company empties return cartons and gives the product to a pig farmer or the farmer simply hauls both product and carton. But the Department of Agriculture imposes stringent regulations to minimize cross-contamination of milk by animals. A few companies have been in violation by allowing potentially contaminated farm equipment at the processing site. Their only disposal alternative is landfills. Unfortunately, in Pennsylvania, landfills are an all-too-common solution to this problem.

A third potential waste stream is cottage cheese whey. For one company this amounts to 6,000 gpd; for another 2,000 gpd. Many companies also landfill this waste. However, one company surveyed effectively integrates the whey into an animal feeding program.

Finally, rejected milk can also pose disposal problems. Though not a common scenario, sometimes milk haulers transport a tanker of milk to the processing plant that is contaminated by antibiotics or is high in bacteria. In some cases, it is the hauler's disposal responsibility; in others, the plant is responsible.

15.2 Study 1: Dairy Processor

Since 1950, this company has treated all FPR water at a primary treatment plant. As production has increased the plant has been expanded to handle increased flows. The plant currently operates at around 60,000 gpd with about 8% of this flow being domestic sewage. Figure 15.1 shows a flowchart of the current wastewater treatment plant. This system is going to be expanded to treat 125,000 gpd.

The treatment plant generates several FPRs. After final clarification, effluent is discharged to the local municipality according to the following surcharge flow restrictions: BOD, 300 mg/l; TSS, 350 mg/l; oil and grease, 100 mg/l; and pH, 6-9. Waste sludge is pumped directly into a tank truck and hauled to a waste management facility; no holding tank exists for this waste. The scum from the clarifiers is temporarily held in the scum shed and then pumped into the tank truck. Waste grease is trapped just before effluent flows to the equilization basin. A final FPR, return product, is given to a pig farmer for feed. Table 15.1 shows results from a waste sludge analysis. Tables 15.2 and 15.3 show various FPR water characteristics and sludge analyses for waste sludge, respectively.

Table 15.1 Sample analysis of stabilized sludge from a treatment plant at a milk processing plant

Parameter	Sample (mg/l)
BOD	1540
Total solids	6600
Total suspended solids	1600
Oil and grease	200

Note: Sample S5 on Figure 15.1. The blank analyzed with this sample contained 0.9 mg/l of oil and grease. The data reported here were corrected for this value. Also, due to interference from the sample matrix, the limit of quantification for the oil and grease determination was increased.

Figure 15.1 Flowchart of a wastewater treatment plant at a dairy processing facility

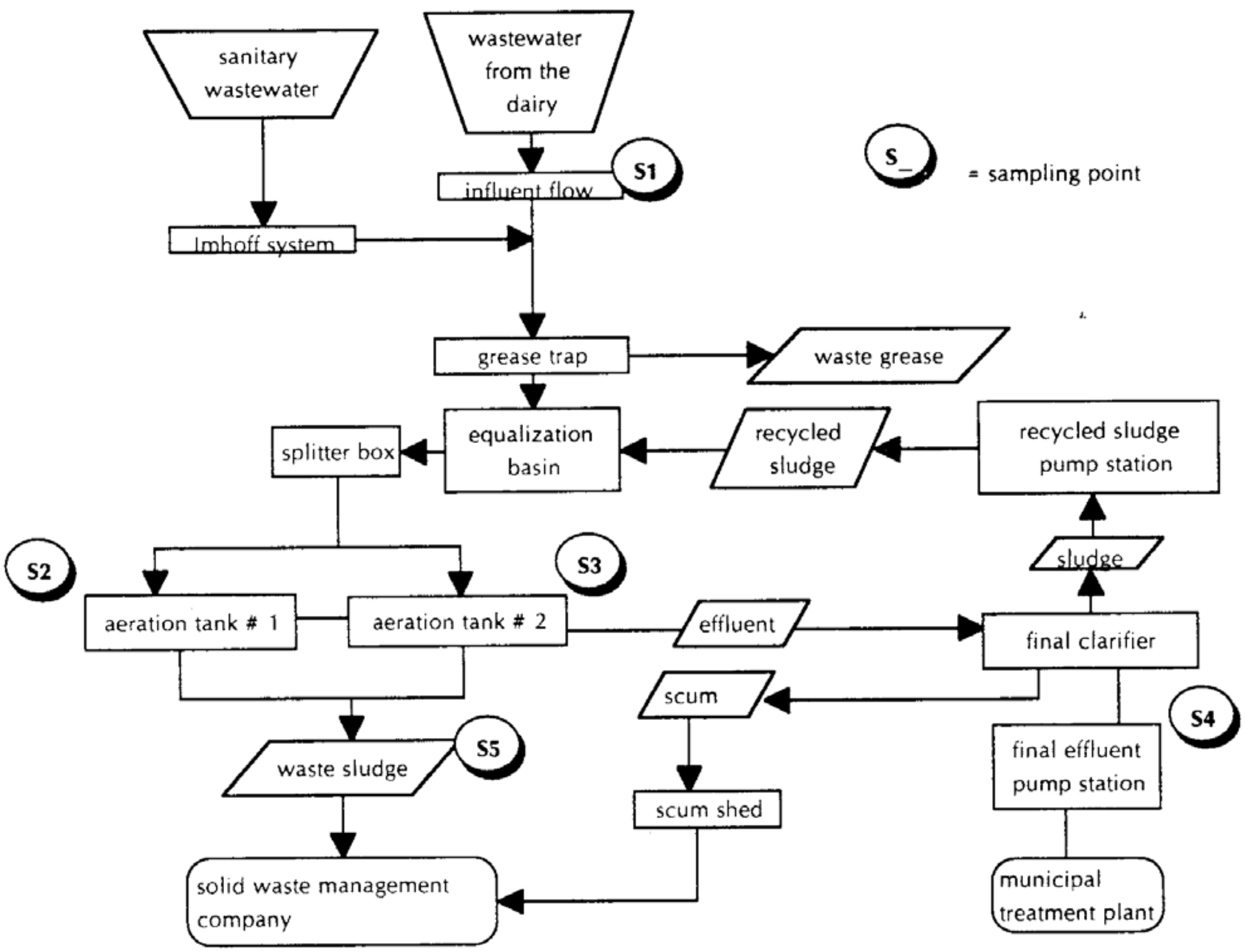


Table 15.2 FPR water characteristics froma treatment plant at a dairy processing facility

	BOD total mg/l	BOD soluble mg/l	COD total mg/l	COD soluble mg/l	TSS mg/l	VSS mg/l	Oil and grease mg/l	pH	Temp degrees F	Recycled sludge TSS
9/11										
•influent										
•AT-1										
•AT-2										
•effluent	20	20	79	17	7.5					
9/12										
•influent										
•AT-1					3930	3570				
•AT-2					4990	4510				
•effluent							0.54			
9/27										
•influent	4915	1085		1750	2240			6.95		
•AT-1					2240	2080		7.5		
•AT-2					1540	1400		7.6		
•effluent							27	7.5	78	
9/28										
•influent	3426		4652		1516			6.8		
•AT-1					2200	2040				3496
•AT-2					1920	1800				
•effluent		60					24	7.6	78	
9/29										
•influent	2491		6100		1230			6.6		
•AT-1					2060	1922				
•AT-2					2140	2040				
•effluent		233		469				7.3	78	

Note: Samples include influent, effluent, and aeration basin samples taken over an 18-day period. These are samples S1-S4 on Figure 15.1. Effluent samples were taken when the clarifiers were not properly settling out solids. For this reason, tests were run on soluble samples.

Although this company has not done an extensive water use survey it is estimated that flows are as follows: 10,000 gallons from first shift, 20,000 from second shift, and 20,000 from third shift.

This plant uses a computerized, fully automated cleanup system for washdowns and equipment cleanup. Such a system will facilitate monitoring and control of water and FPR flows. In addition, this company plans to upgrade the wastewater treatment facility to improve efficiency and effluent quality.

Table 15.3 Wasted sludge characteristics from a treatment plant at a dairy processing facility

Nutrients—data % on dry weight basis

	Na	K	Mg	Ca	Al	Fe	P	NH4-N	Org-N	Tot-N	Solids	Volatile
1	3.86	0.71	0.44	2.86	0.07	0.56	2.19	0.47	6.91	7.37	0.68	80.11
2	4.11	0.66	0.45	2.94	0.14	0.57	2.27	0.48	6.63	7.10	0.68	79.89
Average	3.99	0.68	0.44	2.90	0.10	0.56	2.23	0.47	6.77	7.24	0.68	80.00

Metals—ppm on dry weight basis except for pH

	pH	Mn	Cu	Zn	Pb	Cr	Hg	Ni	Cd
1	7.1	52.7	99.5	175.5	17.6	23.4	0.6	17.6	0.6
2	7.1	76.7	100.2	171.0	17.7	35.4	0.6	17.7	2.9
Average	7.1	64.7	99.9	173.3	17.6	29.4	0.6	17.6	1.8

Primary nutrient content—percent of dry weight

	Level	Low------------	Medium---------------------		----High
		------------2	------------4	----------------	--------8
Total N	7.24	**********	**********	*************	***
P205	5.13	*********	**********	***********	
K20	0.82	***			

Non-fertilizer trace element content —lb dry ton

	Level	
Pb	0.04	acceptable as fertilizer
Cr	0.06	" "
Mercury	0.00	" "
Nickel	0.04	" "
Cd	0.00	" "

Fertilizer trace element content—lb dry ton

	Level	
Cu	0.20	acceptable as fertilizer
Zn	0.35	" "

Nutrient value

Equivalent	146.8 tons wet/1 dry ton
P value	2.24 dry tons of sludge to apply 100 lb of P
N value	0.69 dry tons to supply 100 lb of total nitrogen
Lifetime loading	376 dry tons per acre due to sludge copper concentration

Note: Analysis performed at Soil and Environmental Chemistry Lab, Univeristy Park, Pennsylvania. Samples S5 on Figure 15.1.

The existing treatment plant had a number of problems that were investigated by an outside consulting firm. In addition, the company faced more stringent municipal discharge limits. To eliminate surcharges and potential fines, this company took steps to bring effluent discharge into compliance with municipal guidelines. The consulting firm made the following observations about FPR water treatment improvement:

- The wastewater treatment plant is not capable of consistently meeting the surcharge levels without modifying the plant.
- The conversion of the existing final clarifiers to primary clarifiers will remove a significant amount of oil and grease materials from the water before they enter the aeration basins.
- With the proposed modifications to the pretreatment plant, the oxygen supply to the aeration basins for a flow of 0.125 mgd is expected to be adequate.
- A new final clarifier is needed, with proper dimensions of diameter and side water depth to allow efficient settling of the activated sludge. A 30-ft.-diameter final clarifier will afford a surface settling rate of only 124 gpd/ft^2 at a flow of 80,000 gpd. The final flow capacity of this single clarifier will be determined from actual operation, but is expected to be larger than 80,000 gpd. A second 30-ft.-diameter final clarifier can be added in the future, if needed, for an ultimate capacity of 125,000 gpd.
- The pretreatment plant lacks a storage system for the waste sludges generated in the plant.
- A new gravity sludge thickener will provide a storage system for the scum and waste sludges generated in the system. A 20-ft.-diameter gravity thickener of 12 ft. side water depth will allow several days of sludge storage at the design wastewater flow of 125,000 gpd.
- To prevent odors from escaping into the atmosphere, all new tanks and pumps should be covered and the trapped gases vented through a hypochlorite scrubber solution or through a bed of activated carbon.
- The modifications proposed for the pretreatment plant will enable the plant to meet the municipal surcharge levels.

The quality of the waste sludge and scum also could be upgraded if domestic wastes were kept separate from the dairy FPRs. Currently the sludge must be treated again by the septage hauler before it can be disposed. Information from the waste management firm that treats the sludge prior to disposal indicated that high BODs, total solids, and oils and grease make this sludge difficult to treat. The sludge analysis indicates that this sludge is high in nitrogen, although copper and zinc are both limiting factors for land application. If domestic wastes are separated and oils and grease are reduced, this FPR may be moved up on the waste hierarchy to land application.

This company might consider doing a water use survey to determine wastewater flows. Any reduction in flows will invariably improve treatment plant performance.

Chapter 16: Bean and Grain Case Study

16.1 Study 1: Cocoa Bean Processing

This processing facility is a large generator of chocolate confections and products. The base material used for production is the cocoa bean. Cocoa beans are received daily at the facility from storage warehouses on the East Coast.

The first and most important step in processing the cocoa bean is cleaning. Once the beans are unloaded from the railroad cars and the bags are split and emptied, the beans proceed through an aspiration system. Loose dust and debris is removed from the bag contents so that particles will not contaminate the air during future transportation into the plant. The dust and debris collected at this point represents approximately 0.5 to 0.7% of the cocoa bean weight and is landfilled. The bags are baled and sold.

The aspirated cocoa beans are stored in silos until they are needed for production and are conveyed into the plant. Once in the plant, the beans are cleaned more rigorously. Aspiration, screening, and magnets locate and/or collect stones, ferrous materials, string, dust, dirt, rodent hair, and insect segments. The dust and debris are again discarded at a landfill. The beans are then ready to be roasted.

Roasting takes place at high temperatures and then, the beans are cured in a heated chamber. Once cured, the beans are conveyed at high speeds into the breaking chamber, where they are projected against a steel wall, causing the shells to break. The cracked cocoa beans then proceed to the winnowing stage, where high-speed concentrations of air remove the shell from the nib (roasted bean sections). These combined processes yield three results: whole (prime) nibs, small nib and shell fractions, and various-sized shell fragments.

The prime nibs pass through a scale and into the nib hopper for storage. Nib and shell fractions are run through extensive screening and separating processes by which large nib fractions are separated from small nib fractions and shell. The largest nibs in this screening process are transported into the nib hopper, and the smallest nib and shell fractions are used for cocoa butter recovery.

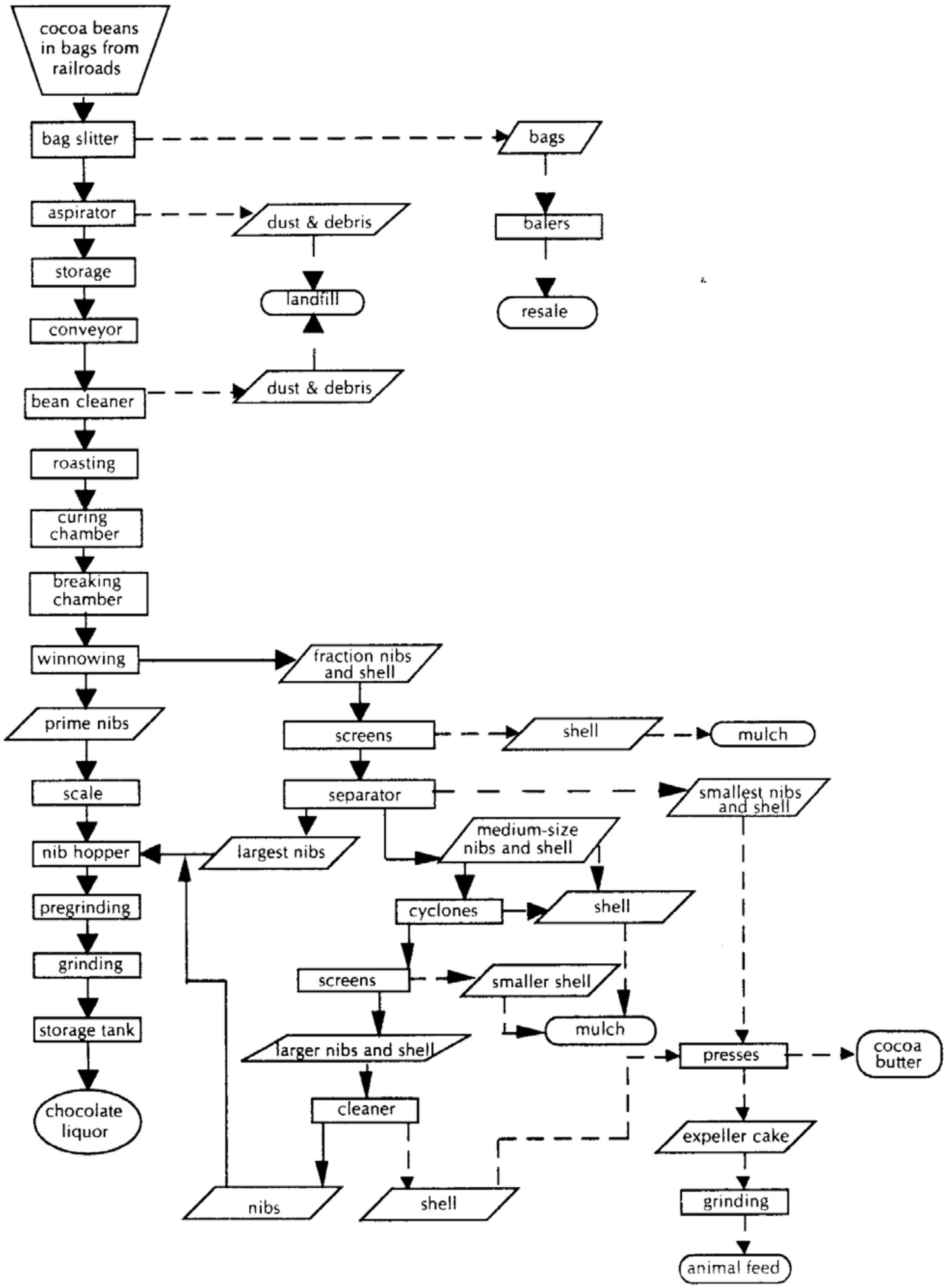
The middle-sized nibs and shells go into cyclones, where high speeds of circulating air remove additional shell. Fragments of this shell are collected and sold for mulch. The nibs and remaining shells then pass through another set of screens for separation. Small shells are collected for resale as mulch, while nibs and large shells are once again cleaned. The cleaned nibs are transported into the nib hopper, and the shells are used for cocoa butter recovery.

All nibs in the nib hopper continue processing by going through pre-grinding and grinding stages. The nibs are ground until they become a liquid known as chocolate liquor, which is used to manufacture chocolate and milk chocolate.

The nibs and shell that were sent to butter recovery are squeezed by presses to extract cocoa butter. Depending upon the intended use, the cocoa butter undergoes separate processing methods. The remaining expeller cake is ground and sold for animal feed.

This facility used to landfill the expeller cake, but by identifying an alternative outlet it has been able to avoid the unfavorable results and costs of landfilling. Now everything but dust and debris is used for either human use, animal use, or resale as a land application product. Figure 16.1 shows the cocoa bean production process.

Figure 16.1 Flowchart of cocoa bean processing related FPRs



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Glossary

***For official definitions of the regulatory terms click on**
http://www.pacode.com/secure/data/025/chapter287/s287.1.html

ASTM—The American Society for Testing and Materials.

Abatement—The restoration, reclamation, recovery, and the like, of a natural resource adversely affected by the activity of a person, permittee or municipality.

Access road—A roadway or course providing access to a residual waste processing or disposal facility, or areas within the facility, from a road that is under Federal, State or local control.

Adjacent area—Contiguous and noncontiguous land located outside the permit area, where air, surface water or groundwater, fish, wildlife, vegetation or other resources protected by this article may be adversely affected by residual waste management.

Adversely affect—In the context of water supplies, the term has the following meaning: to cause or contribute to a measurable increase in the concentration of one or more contaminants in a water supply above background levels, or to cause or contribute to a decrease in the quantity of the water supply.

Agricultural utilization—The land application of solid waste for its plant nutrient value or as a soil conditioner as part of an agricultural operation.

*Agricultural waste**—Poultry and livestock manure, or residual materials in liquid or solid form generated in the production and marketing of poultry, livestock, fur bearing animals and their products, if the agricultural waste is not hazardous. The term includes the residual materials generated in producing, harvesting and marketing of agronomic, horticultural, aquacultural and silvicultural crops or commodities grown on what are usually recognized and accepted as farms, forests or other agricultural lands. The term also includes materials in liquid or solid form generated in the production and marketing of fish or fish hatcheries.

Aquaculture—The practice of raising plants or animals, such as fish or shellfish, in manmade or natural bodies of water.

Aquifer—A geologic formation, group of formations or part of a formation capable of yielding sufficient groundwater for monitoring purposes.

Asbestos-containing waste—Waste that contains asbestos extracted form asbestos ore. As applied to demolition and renovation operations, the term includes friable asbestos and nonfriable asbestos from Asbestos Hazard Emergency Response Act (AHERA) (15 U.S.C.A. §§2601 note, 2614, 2618, 2619, 2641-2654; and 20 U.S.C.A. §§4014, 4014 note, 4021 and 4022) regulated removals. The term also includes asbestos waste collected from pollution control devices.

Attenuating soil—Soil material existing in place or placed beneath solid waste that will provide natural attenuation of leachate emanating from the waste.

Attenuation—A decrease in the maximum concentration or total quantity of an applied chemical or biological constituent of solid waste in a fixed time or distance that results from physical, chemical or biological reactions or transformations.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

*Beneficial use**—Use or reuse of residual waste or residual material derived from residual waste for commercial, industrial or governmental purposes, if the use does not harm or threaten public health, safety, welfare or the environment, or the use or reuse of processed municipal waste for any purpose, if the use does not harm or threaten public health, safety, welfare or the environment.

Biogas—Gas production (mostly methane and carbon dioxide) as a result of the decomposition of biological, or organic matter.

Bulk density—The oven dried mass of a sample divided by its field volume.

Byproduct material—The Federal definition for ‘‘byproduct material’’ in 10 CFR 20.1003 (relating to definitions) is incorporated by reference.

Captive residual waste facility—A residual waste processing or disposal facility that is located upon lands owned by the person or municipality that generated the residual waste and which is operated to provide for the processing or disposal solely of the generator's residual waste.

Chemical Abstract Service Registry Number—A number assigned to a corresponding type of chemical or chemical category as referenced in regulations promulgated under the Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C.A. §§11001—11050). The list of Chemical Abstract Service Registry numbers is codified at 40 CFR 372.65 (relating to chemicals and chemical categories to which this part applies).

Closure—The act of permanently ceasing to accept waste at a residual waste processing, storage or disposal facility, and limiting access to those activities necessary for postclosure care, maintenance and monitoring.

Commercial establishment—An establishment engaged in nonmanufacturing or nonprocessing business. The term includes stores, markets, office buildings, restaurants, shopping centers and theaters.

Composting—The process by which organic solid waste is biologically decomposed under controlled anaerobic or aerobic conditions to yield a humus-like product.

Composting facility—A facility for processing solid waste by composting.

Composting pad—An area within a composting facility where compost or solid waste is processed, stored, loaded or unloaded.

Confined aquifer—An aquifer in which the uppermost surface is at greater than atmospheric pressure.

Construction material—The engineered use of residual waste as a substitute for a raw material or a commercial product in a construction activity, if the waste has the same engineering characteristics as the raw material or commercial product for which it is substituting. The term includes the use of residual waste as a road bed material, for pipe bedding, and in similar operations. The term does not include valley fills, the use of residual waste to fill open pits from coal or other fills, or the use of residual waste solely to level an area or bring the area to grade where a construction activity is not completed promptly after the placement of the solid waste.

*Coproduct**—

(i) A material generated by a manufacturing or production process, or a spent material, of a physical character and chemical composition that is consistently equivalent to the physical character and chemical composition of an intentionally manufactured product or produced raw material, if the

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

use of the material presents no greater threat of harm to human health and the environment than the use of the product or raw material. A material may not be compared, for physical character and chemical composition, to a material that is no longer determined to be waste in accordance with § 287.7 (relating to determination that a material is no longer a waste). A coproduct determination, which shall be made in accordance with § 287.8 (relating to coproduct determinations), only applies to materials that will be applied to the land or used to produce products that are applied to the land, including the placement of roadway aggregate, pipe bedding or construction materials, or that will be used for energy recovery as is with a minimum BTU value of 5,000/lb. as generated or as fired. If the proposed coproduct material is oil, a determination may only be made for oil refined from crude oil or synthetically produced oil, not contaminated by physical or chemical impurities, that will be used for energy recovery if the material has a minimum heat content (BTU value) comparable to the petroleum fuel it will replace.

(ii) The term only applies to one of the following:

(A) If the material is to be transferred in good faith as a commodity in trade, for use in lieu of an intentionally manufactured product or produced raw material, without processing that would not be required of the product or raw material, and the material is not accumulated speculatively. Sizing, shaping or sorting of the material will not be considered processing for the purpose of this definition.

(B) If the material is to be used by the manufacturer or producer of the material in lieu of an intentionally manufactured product or produced raw material, without processing that would not be required of the product or raw material, and the material is not accumulated speculatively. Sizing, shaping or sorting of the material will not be considered processing for the purpose of this definition.

(iii) If no product or produced raw material exists for purposes of chemical and physical comparison, the Department will review, upon request, information provided and determine whether the material is a coproduct because it is an effective substitute for an intentionally manufactured product or produced raw material, based on the criteria in subparagraph (ii) and whether the material presents a threat of harm to human health and the environment in accordance with § 287.8.

(iv) A waste may become a coproduct after processing if it would otherwise qualify as a coproduct.

(v) Persons producing, selling, transferring, possessing or using a material who claim that the material is a coproduct and not a waste shall demonstrate that there is a known market or disposition for the material, and that they meet the terms of this definition and § 287.8. In doing so, they shall provide appropriate documentation, such as contracts showing that a second person uses the material as an ingredient in a production process, to demonstrate that the material is not a waste.

Corrosivity—A characteristic of a material that exhibits either of the following properties:

(1) aqueous substance with a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter; (2) liquid that corrodes steel at a rate greater than 6.35 millimeters per year at test temperatures of 55 C.

Crude material—A naturally occurring material in its unrefined or natural state.

Dispersal agent—A chemical substance that causes the dispersion of chemical constituents of a waste material e.g., sludge, slurry).

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Disposal—The deposition, injection, dumping, spilling, leaking, incineration or placing of solid waste into or on the land or water in a manner that the solid waste or a constituent of the solid waste enters the environment, is emitted into the air or is discharged to the waters of this Commonwealth.

Environmental protection acts—The Clean Streams Law, the Air Pollution Control Act (35 P. S. § § 4001—4015), the Surface Mining Conservation and Reclamation Act (52 P. S. § § 1396.1—1396.31), the Noncoal Surface Mining Conservation and Reclamation Act (52 P. S. § § 3301—3326), the Dam Safety and Encroachments Act (32 P. S. § § 693.1—693.27) and other State or Federal statutes relating to environmental protection or the protection of the public health, including statutes adopted or amended after July 4, 1992.

Facility—Land, structures and other appurtenances or improvements where municipal or residual waste disposal or processing is permitted or takes place or where hazardous waste is treated, stored or disposed. The term includes land thereby used or affected during the lifetime of operations, including areas where solid waste management actually occurs, support facilities, offices, equipment sheds, air and water pollution control and treatment systems, access roads, associated onsite or contiguous collection, transportation and storage facilities, closure and postclosure care and maintenance activities, contiguous borrow areas and other activities in which the natural land surface has been disturbed or used as a result of or incidental to operation of the facility.

Final closure—The date after which no further treatment, maintenance or other action is or will be necessary at a residual waste processing or disposal facility to ensure compliance with the act and this article.

Flocculants—The agglomeration of finely divided suspended solids into larger, often gelatinous particles. Also the development of a "floc" after treatment with a coagulant by gentle stirring or mixing.

*Food processing residual**—An FPR is an incidental organic material generated by processing agricultural commodities for human or animal consumption. The term includes food residuals, coproducts, food processing sludges, or any other incidental material whose characteristics are derived from processing agricultural products. Examples include process wastewater from cleaning slaughtering areas, rinsing carcasses, or conveying food materials; process wastewater treatment sludges; blood; bone; fruit and vegetable peels; seeds; shells; pits; cheese whey; off-specification food products; hides; hair; and feathers.

*Food processing sludge**—A solid, semisolid or liquid waste generated by a food processing water treatment or wastewater treatment facility, containing food processing waste and additional materials. The additional materials may include detergents, dispersal agents, flocculants, disinfectants and biological agents.

*Food processing waste**—Residual materials in liquid and solid form generated in the slaughtering of poultry and livestock, or in processing and converting fish, seafood, milk, meat and eggs to food products. The term includes residual materials generated in the processing, converting or manufacturing of fruits, vegetables, crops and other commodities into marketable food items. The term also includes vegetative residuals from food processing activities that are usually recognizable as part of a plant or vegetable, including cabbage leaves, bean snips, onion skins, apple pomace and grape pomace.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Food processing wastes used for agricultural purposes—The use of food processing wastes in normal farming operations.

Free liquids—Liquids which readily separate from the solid portion of a waste under ambient temperature and pressure.

Garbage—Solid waste.

Generator—A person or municipality that produces or creates a residual waste.

Groundwater—Water beneath the surface of the ground that exists in a zone of saturation.

Groundwater degradation—A measurable increase in the concentration of one or more contaminants in groundwater above background concentrations for those contaminants.

Hazardous waste—

(i) The term includes garbage, refuse or sludge from an industrial or other wastewater treatment plant, sludge from a water supply treatment plant or air pollution control facility, and other discarded material, including solid, liquid, semisolid or contained gaseous material resulting from municipal, commercial, industrial, institutional, mining or agricultural operations, and from community activities, or a combination of these materials, which because of its quantity, concentration or physical, chemical or infectious characteristics may do one of the following:

(A) Cause or significantly contribute to an increase in mortality or increase in morbidity in either an individual or the total population.

(B) Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed.

(ii) The term does not include coal refuse as defined in the Coal Refuse Disposal Control Act (52 P. S. § § 30.51— 30.101); treatment sludges from coal mine drainage treatment plants, disposal of which is being carried on under and in compliance with a valid permit issued under the Clean Streams Law; solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act (33 U.S.C.A. § § 1342) or source, special nuclear or byproduct material as defined by the Atomic Energy Act of 1954 (42 U.S.C.A. § § 2011—2394). The term is further defined in Chapter 261a (relating to identification and listing of hazardous waste) and 40 CFR Part 261 (relating to identification and listing of hazardous waste) to the extent incorporated in § 261a.1 (relating to incorporation by reference, purpose and scope).

Hydrogeologist—A trained professional who studies and provides information pertaining to the various geologic factors relating to subsurface and surface waters.

Ignitability—A solid waste is ignitable if it exhibits any one of the following properties*:*

- A liquid (other than an aqueous solution containing less than 24 percent alcohol by volume) with a flash point less than 60 ºC as determined by an ASTM Standard test method
- It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture, or spontaneous chemical changes, and, when ignited, burns so vigorously and persistently that it creates a hazard
- It is defined by US DOT regulations as an ignitable compressed gas
- It is defined by US DOT regulations as an oxidizer

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Impoundment—A facility or part of a facility which is a natural topographic depression, manmade excavation, or diked area formed primarily of earthen materials although it may be lined with synthetic materials, and which is designed to hold an accumulation of liquid wastes or wastes containing free liquids. The term includes holding, storage, settling and aeration pits, ponds and lagoons. The term does not include injection wells.

Incinerator—An enclosed device using controlled combustion for the primary purpose of thermally breaking down solid waste, which is equipped with a flue as defined in § 121.1 (relating to definitions).

Incorporating—Injecting solid waste beneath the surface of the soil or mixing solid waste with the surface soil.

Industrial establishment—An establishment engaged in manufacturing or processing, including factories, foundries, mills, processing plants, refineries, mines and slaughterhouses.

Infiltration—The downward movement of water into the soil, or other subsurface layers.

Intermittent stream—A body of water flowing in a channel or bed composed primarily of substrates associated with flowing water, which during periods of the year, is below the local water table and obtains its flow from both surface runoff and groundwater discharges.

Ion—An element or compound that has gained or lost an electron, so that it is no longer neutral electrically, but rather, carries a charge.

Land application—The management of solid waste through agricultural utilization or land reclamation. The term does not include the disposal of solid waste in a landfill or disposal impoundment.

Landowner—The person or municipality in whom legal title to the surface of the land is vested.

Land reclamation—The land application of solid waste for its plant nutrient value or as a soil conditioner to restore or enhance the soil to establish vegetative growth.

Leachate—A liquid, including suspended or dissolved components in the liquid, that has percolated through or drained from solid waste.

Liquid waste—Residual waste that contains free liquids as determined by Method 9095 (paint filter liquids test), as described in the EPA's ''Test Methods for Evaluating Solid Waste, Physical/Chemical Methods'' (EPA Publication No. SW-846.)

Local captive residual waste facility—A captive facility which is located at one of the following locations:

(i) On the same tract of land where the waste was generated.

(ii) On a tract of land that is contiguous to the tract where the waste was generated.

(iii) On a tract of land that is connected to the tract where the waste was generated by a right-of-way controlled by the generator to which the public does not have access.

(iv) On a tract of land that is separated from the tract where the waste was generated by only a public or private right-of-way and access between the two tracts is by crossing rather than traveling along the right-of-way.

MCL—Maximum contaminant level.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Management—The entire process or a part thereof, of storage, collection, transportation, processing, treatment and disposal of solid wastes by a person engaged in the process.

Monofill—A facility that disposes solely of waste which is generated by the same industrial or manufacturing process and which has the same, or substantially similar, physical and chemical characteristics and composition.

Municipality—A city, borough, incorporated town, township, county or an authority created by one or more of the foregiong.

Municipal waste—Garbage, refuse, industrial lunchroom or office waste and other material, including solid, liquid, semisolid or contained gaseous material resulting from operation of residential, municipal, commercial or institutional establishments and from community activities, and sludge not meeting the definition of ''residual'' or ''hazardous waste'' under this section from a municipal, commercial or institutional water supply treatment plant, wastewater treatment plant or air pollution control facility.

NPDES—National Pollutant Discharge Elimination System.

Noncaptive facility—A residual waste processing or disposal facility that is not a captive residual waste facility.

*Normal farming operations**—The customary and generally accepted activities, practices and procedures that farms adopt, use or engage in year after year in the production and preparation for market of poultry, livestock and their products; and in the production, harvesting and preparation for market of agricultural, agronomic, horticultural, silvicultural and aquacultural crops and commodities, if the operations are conducted in compliance with applicable laws, and if the use or disposal of these materials will not pollute the air, water or other natural resources of this Commonwealth. The term includes the storage and utilization of agricultural and food processing wastes, screenings and sludges for animal feed, and the agricultural utilization of septic tank cleanings and sewage sludges which are generated offsite. The term includes the management, collection, storage, transportation, use or disposal of manure, other agricultural waste and food processing waste, screenings and sludges on land where the materials will improve the condition of the soil, the growth of crops or in the restoration of the land for the same purposes.

Operate—To construct a residual waste management facility in anticipation of receiving solid waste for the purpose of processing or disposal; to receive, process or dispose of solid waste; to carry on an activity at the facility that is related to the receipt, processing or disposal of waste or otherwise uses or affects land at the facility; to conduct closure and postclosure activities at a facility.

Operator—A person or municipality engaged in solid waste processing or disposal by operating a facility. If more than one person is engaged in a single operation, all persons shall be deemed jointly and severally responsible for compliance with this article.

Osmotic pressure—The pressure created by the diffusion of a solution through a membrane (as in plant roots and tissues).

Owner—The person or municipality who is the owner of record of a facility or part of a facility.

Perennial stream—A body of water flowing in a channel or bed composed of substrates associated with flowing waters and is capable, in the absence of pollution or other manmade disturbances, of supporting a benthic macroinvertebrate community which is composed of two or more recognizable taxonomic groups of organisms which are large enough to be seen by the unaided

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

eye and can be retained by United States Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings) and live at least part of their life cycles within or upon available substrates in a body of water or water transport system.

Permanent water supply—A well, interconnection with a public water supply, extension of a public water supply, similar water supply or a treatment system determined by the Department to be capable of restoring the water supply to the quantity and quality of the original unaffected water supply.

Permit—A permit issued by the DEP to operate a residual waste disposal or processing facility or to beneficially use residual waste. The term includes a general permit, permit-by-rule, permit modification, permit reissuance and permit renewal.

Permit area—The area of land and water within the boundaries of the permit, which is designated on the permit application maps as approved by the DEP. The term includes areas, which are or will be used or affected by the residual waste processing or disposal facility.

Person—An individual, partnership, corporation, association, institution, cooperative enterprise, municipal authority, Federal government or agency, State institution and agency—including the Department of General Services and the State Public School Buildings Authority— or another legal entity which is recognized by law as the subject of rights and duties. In the provisions of this article pertaining to a fine or penalty, or both, the term includes the officers and directors of a corporation or other legal entity having officers and directors.

pH—A measure of the acidity or alkalinity of a solution. The value of pH is numerically equal to seven for neutral solutions, increasing with increasing alkalinity, and decreasing with increasing acidity.

Pollution—The contamination of air, water, land or other natural resources of this Commonwealth which will create or is likely to create a public nuisance or render the air, water, land or other natural resources harmful, detrimental or injurious to public health, safety or welfare, or to domestic, municipal, commercial, industrial, agricultural, recreational or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other life.

Postclosure—Activities after closure which are necessary to ensure compliance with the act and this article, including application of final cover, grading and revegetation; groundwater, surface water and gas monitoring; erosion control and gas control; leachate treatment, and abatement of pollution or degradation to land, water, air or other natural resources.

Processing—

(i) The term includes one or more of the following:

(A) A method or technology used for the purpose of reducing the volume or bulk of municipal or residual waste or a method or technology used to convert part or all of the waste materials for offsite reuse.

(B) Transfer facilities, composting facilities and resource recovery facilities.

(ii) The term does not include a collection center that is only for source separated recyclable materials, including clear glass, colored glass, aluminum, steel and bimetallic cans, high-grade office paper, newsprint, corrugated paper and plastics.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

*Product**—A commodity that is the sole or primary intended result of a manufacturing or production process

Raw material—Material, including crude material, that can be converted by manufacture or processing into a product.

Reactivity—A solid waste is reactive if it has any one of the following properties:

- Normally unstable and readily undergoes violent change without detonating
- Reacts violently with water
- Forms potentially explosive mixtures with water
- When mixed with water, generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment
- It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2.0 and 12.5, can generate toxic gases, vapors, or fumes in quantity sufficient to present a danger to human health or the environment
- It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement
- It is readily capable of detonation, explosive decomposition, or reaction at standard temperature and pressure
- It is a defined explosive

Reclaimed—A material is "reclaimed" if it is used, reused or reclaimed.

Regional groundwater table—The fluctuating upper water level surface of an unconfined or confined aquifer, where the hydrostatic pressure is equal to the ambient atmospheric pressure. The term does not include the perched water table or the seasonal high water table.

Related party—A person or municipality engaged in solid waste management that has a financial relationship to a permit applicant or operator. The term includes a partner, associate, officer, parent corporation, subsidiary corporation, contractor, subcontractor, agent or principal shareholder of another person or municipality, or a person or municipality that owns land on which another person or municipality operates a solid waste management facility.

Rendering—The process of removing water from food processing residuals and recovering the solid and fat portions for use in animal feeds and other industrial applications. Since the finished products of rendering are used in animal feeds, quality of the raw material is critical. A high-quality raw material is one that contains no chemicals (except normal amounts of USDA-approved compounds); has a minimum of water; and has inherent value in its makeup-e.g., fat, carbohydrate, or protein value. Typical raw materials include kitchen grease, offal from slaughtering operations, fat and bones from supermarkets, feathers, and blood. Not all rendering facilities are designed to handle all types of FPRs.

*Residual waste**—Garbage, refuse, other discarded material or other waste, including solid, liquid, semisolid or contained gaseous materials resulting from industrial, mining and agricultural operations and sludge from an industrial, mining or agricultural water supply treatment facility, wastewater treatment facility or air pollution control facility, if it is not hazardous. The term does not include coal refuse as defined in the Coal Refuse Disposal Control Act. The term does not include treatment sludges from coal mine drainage treatment plants, disposal of which is being carried on under and in compliance with a valid permit issued under the Clean Streams Law.

Residual waste disposal impoundment—A facility for disposing of residual waste by impoundment.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Residual waste disposal or processing facility—A facility for disposing or processing of residual waste.

Residual waste landfill—A facility for disposing of residual waste. The term does not include a residual waste disposal impoundment or a facility for the land application of residual waste. The term also does not include a facility at which municipal waste, other than industrial lunchroom or office waste generated by the operator, construction/demolition waste generated by the operator, or certain special handling waste is disposed.

Salvaging—The controlled removal of material from a solid waste processing or disposal facility.

Seasonal high water table—The minimum depth from the soil surface at which redoximorphic features are present in the soil.

Sewage—Any substance that contains any of the waste products or excrement or other discharge from the bodies of human beings or animals; any substance harmful to public health, to animal or aquatic life, or to the use of water for domestic water supply or recreation; or any substance which constitutes pollution under the Clean Streams Law.

Site—The area where a residual waste processing or disposal facility is operated. If the operator has a permit to operate the facility, and is operating within the boundaries of the permit, the site is equivalent to the permit area.

Soil additive or *soil substitute*—The land application of coal ash or residual waste, at specified loading or application rates, to replace soil that was previously available at the site, to enhance soil properties or to enhance plant growth. The term does not include structural fills, construction material, valley fills, or the use of coal ash or residual waste to fill open pits from coal or noncoal mining or the disposal of coal ash.

Soil mottling—Irregularly marked spots in the soil profile that vary in color, size and number.

Solid waste—Waste, including, but not limited to, municipal, residual or hazardous waste, including solid, liquid, semisolid or contained gaseous materials. The term does not include coal ash that is beneficially used under Subchapter H (relating to beneficial use) or drill cuttings.

*Source reduction**—The reduction or elimination of the quantity or toxicity of residual waste generated, which may be achieved through changes within the production process, including process modifications, feedstock substitutions, improvements in feedstock purity, shipping and packing modifications, housekeeping and management practices, increases in the efficiency of machinery and recycling within a process. The term does not include dewatering, compaction, waste reclamation or the use or reuse of waste.

Special handling waste—Solid waste that requires the application of special storage, collection, transportation, processing or disposal techniques due to the quantity of material generated or its unique physical, chemical or biological characteristics. The term includes dredged material, sewage sludge, infectious waste, chemotherapeutic waste, ash residue from a solid waste incineration facility, friable asbestos-containing waste, PCB-containing waste, waste oil that is not hazardous waste, fuel contaminated soil, waste tires and water supply treatment plant sludges.

Storage—The containment of waste on a temporary basis in a manner that does not constitute disposal of the waste. It shall be presumed that containment of waste in excess of 1 year constitutes disposal. This presumption can be overcome by clear and convincing evidence to the contrary.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Storage impoundment—An impoundment that is designed to hold an accumulation of liquid waste for storage, processing or treatment, but not disposal.

Structural fill—The engineered use of coal ash as a base or foundation for a construction activity that is completed promptly after the placement of the coal ash, including the use of coal ash as a backfill material for retaining walls, foundations, ramps or other structures. The term does not include valley fills or the use of solid waste to fill open pits from coal or noncoal mining.

Surety bond—A penal bond agreement in a sum certain, payable to the Department, executed by the operator and a corporation licensed to do business as a surety in the Commonwealth and approved by DEP, which is supported by the guarantee of payment on the bond by the surety.

Surface land disposal—Application of solid waste to the land surface for purposes other than agricultural utilization or land reclamation.

Tank—A stationary containment device which provides its own structural support and is constructed entirely of nonearthen and nonwood materials.

Temporary water supply—Bottled water, a water tank supplied by a bulk water hauling system and similar water supplies in quantities sufficient to accommodate normal usage.

Toxicity—A solid waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure (TCLP), the extract from a representative sample of the waste equals or exceeds any of the toxic contaminant concentrations listed in Table 1 of 40 CFR §261.24. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering, is considered to be the extract. The TCLP test method (Method 1311) is described in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," US EPA Publication SW-846.

Transfer facility—A facility which receives and processes or temporarily stores municipal or residual waste at a location other than the generation site, and which facilitates the transportation or transfer of municipal or residual waste to a processing or disposal facility. The term includes a facility that uses a method or technology to convert part or all of the waste materials for offsite reuse. The term does not include a collection or processing center that is only for source separated recyclable materials, including clear glass, colored glass, aluminum, steel and bimetalic cans, high-grade office paper, newsprint, corrugated paper and plastics.

Transportation—The offsite removal of solid waste after generation.

Treatment—A method, technique or process, including neutralization, designed to change the physical, chemical or biological character or composition of waste to neutralize the waste or to render the waste nonhazardous, safer for transport, suitable for recovery, suitable for storage or reduced in volume. The term includes an activity or process designed to change the physical form or chemical composition of waste to render it neutral or nonhazardous.

Unconfined aquifer—An aquifer in which the uppermost surface is at atmospheric pressure.

Used or *reused*—A material that meets one of the following conditions:

(i) The material is employed as an ingredient, including use as an intermediate, in an industrial process to make a product. A material will not satisfy this condition if distinct components of the material are recovered as separate end products, as when metals are recovered from metal-containing secondary materials.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

(ii) That material is employed in a particular function or application as an effective substitute for a commercial product.

Waste—

(i) Discarded material which is recycled or abandoned. A waste is abandoned by being disposed of, burned or incinerated or accumulated, stored or processed before or in lieu of being abandoned by being disposed of, burned or incinerated. A discarded material includes contaminated soil, contaminated water, contaminated dredge material, spent material or by-product recycled in accordance with subparagraph (iii), processed or disposed.

(ii) Materials that are not waste when recycled include materials when they can be shown to be recycled by being:

(A) Used or reused as ingredients in an industrial process to make a product or employed in a particular function or application as an effective substitute for a commercial product, provided the materials are not being reclaimed. This includes materials from the slaughter and preparation of animals that are used as raw materials in the production or manufacture of products. Steel slag is not waste if used onsite as a waste processing liming agent in acid neutralization or onsite in place of aggregate. Sizing, shaping or sorting of the material will not be considered processing for the purpose of this subclause of the definition.

(B) Coproducts.

(C) Returned to the original process from which they are generated, without first being reclaimed or land disposed. The material shall be returned as a substitute for feedstock materials. When the original process to which the material is returned is a secondary process, the materials shall be managed so that there is no placement on the land and the secondary process takes place onsite.

(iii) The following materials are wastes, even if the recycling involves use, reuse or return to the original process (as described as follows):

(A) Except for coproducts, materials used in a manner constituting disposal, or used to produce products that are applied to the land.

(B) Except for coproducts, materials burned for energy recovery, used to produce fuel or contained in fuel.

(C) Materials accumulated speculatively.

(iv) Discarded or recycled material may not be waste if a determination is made by the Department in accordance with §287.7.

(v) In enforcement actions implementing the act, a person who claims that the material is not a waste in accordance with subparagraph (ii) shall demonstrate that there is a known market or disposition for the material, and that the terms of the exclusion have been met. In doing so, appropriate documentation shall be provided (such as contracts showing that a second person uses the material as an ingredient in a production process) to demonstrate that the material is not a waste. In addition, owners or operators of facilities claiming that they actually are recycling materials shall show that they have the necessary equipment to do so.

Water source—The site or location of a well, spring or water supply stream intake which is used for human consumption.

* For an informal definition or examples, see the Getting Started: Understanding FPR Terms section of this Manual.

Water supply—Existing, designated or planned sources of water or facilities or systems for the supply of water for human consumption or for agricultural, commercial, industrial or other legitimate use, protected by the applicable water supply provisions of § 93.3 (relating to protected water uses).

Well drawdown—The distance between the static water table level and the cone of depression formed around a pumping well.

Additional Resource A
Seven-Step Program Review Worksheets

These worksheets correspond with the seven-step program review in Chapter 1. They can be photocopied and used to keep track of changes in your FPR management program.

Worksheet 1: Input Inventory

		Vendor	Estimated Typical Volume		Storage		MSD*?	
Input ID	**Input Name**	**Name, Address, Phone**	**In Storage**	**Consumption Rate**	**Location**	**Method**	**Yes**	**No**
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐

*Material Safety Data Sheet Available

Worksheet 2: Output Inventory

Output ID	Output Name	Estimated Typical Volume		Storage		Physical State*	Analysis Available?	
		In Storage	Generation Rate	Location	Method		Yes	No
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐

Worksheet 3: Inputs vs. Outputs

Input ID & Name	Output ID & Name

Worksheet 4: Transport, Resuse, and Disposal

Output ID	Output Name	Transport Method & Capacity	Transporter Name, Address, Phone	Destination Name, Address, Phone	How Reused? How Disposed Of? Minimum Quality Criteria?

Worksheet 5: Limiting FPR Characteristics

Output ID	Output Name	Suspected Constraints ie . High pH, High Soluble Sales, Odors, etc.	Date Analyzed	Characteristics Confirmed by Lab Reports

Worksheet 6: Estimate of Current Management Costs

Output Name & ID	Energy Costs	Transport-ation Costs	Tipping Fees	Penalty Fees	Labor Costs	Capital Amortiz-ation	Chemical Costs	Other Costs	Total Costs	Income	Net Cost

Worksheet 7: Estimate of Current Management Costs

Output ID	Output Name	Alternative Minimization, Segregation & Combination Strategies

Additional Resource B
Flow Measurement Instrumentation*

Flow meter devices are the most widely used process monitoring instruments in wastewater treatment. Careful consideration must be exercised during selection of flow meters to avoid equipment misapplication that can result in operational problems and equipment failure. It is the responsibility of the designer to select the appropriate type of flow meter device and to integrate the instrumentation design into the treatment plant design.

A flow measurement system consists of a primary element and a converter device to provide flow reading. The primary element is a sensor or detector that is exposed to and affected by the rate of flow. The converter device changes the sensor reading to a usable flow reading. Because of the broad scope of the subject, this document only presents information concerning the selection and proper application of the primary element of flow meter devices. Details on design and selection of flow meter devices are in the references for this document.

Flow Meter Devices

There are a wide variety of devices that use various methods to measure flow rate. The devices most frequently used and their application are indicated in Table 1. It should be noted that partially filled conduits are considered to be open channels and that closed conduits are usually pressurized systems.

In open channels or partially filled conduits, the head generated by an obstruction, (for example, a flume or weir plate) or the cross-sectional wetted area and associated liquid velocity determine the flow rate. In a closed conduit, where the fluid occupies the entire pipe volume, three basic techniques are used to measure flow: an obstruction creates a predictable head loss; the moving fluid produces a measurable effect, such as momentum change, sonic wave transmittance, or magnetic field shift; or incremental units of fluid volume are counted. The first technique includes orifices, used to produce a flow obstruction and resultant head loss, and venturi tubes, flow tubes, pitot tubes, and rotameters-all of which measure pressure differentials that can be directly correlated to flow. Magnetic, ultrasonic, target, and vortex meters are included in the second technique. Magnetic meters measure the induced voltage generated by the flow through a magnetic field. Ultrasonic meters measure either the time difference between sonic pulses traveling across a section of pipe (transmissive), or the frequency shift of sonic waves reflecting off suspended particulates or gas bubbles (doppler). Finally, the third technique includes turbine and propeller meters in pipelines. These measure the speed of rotation and correlate it with velocity and flow rate.

Selection Criteria

When selecting a flow meter device, both operating and maintenance considerations must be assessed. These considerations include device size, fluid composition, required level of accuracy, head loss, installation, and operating environment.

Sizing

The most common deficiency experience with in-line flow instrumentation is improper sizing. The primary element of in-line meters should be able to measure a wide range of conduit capacity from

* *Source: Journal WPCF, Vol. 58, Number 10. October 1986. Used with permission.*

initial minimum flow to design maximum flow. Additionally, the meter openings must be large enough to allow passage of the solids typically found in wastewater. It should be noted that if meters are installed in oversized piping, flow velocity will be reduced. This results in solids deposition and scaling that will adversely affect meter accuracy.

Fluid composition

The applicability of a flow meter device depends on the characteristics of the fluid to be measured. These include type of fluid; type, size, and concentration of solids; temperature; viscosity; abrasive and corrosive properties. Table B-1 summarizes the applicability of various flow meter devices to fluids found in wastewater treatment plants.

Solids

The type and size of solids carried in wastewater must be considered when flow meters are selected. Where the meter element penetrates a full flowing conduit or the meter cross-sectional area is less than the cross-sectional area of the pipe, rags may hang-up on the element or accumulate in the meter restriction and eventually cause a complete obstruction. When weirs and orifices are used, solids can lodge upstream of the element and cause false readings because the size of the weir or orifice opening is changed. The minimum restriction, that is, throat diameter of a differential producer type flow meter depends on the maximum solids size, flow rate, and fluid velocity. Meters should be sized to conform to recommended minimum pipe sizes in wastewater treatment plants. To avoid or minimize obstruction by solids, the rule-of-thumb minimum pipe sizes are 10.2 cm (4 in.) for wastewater and 15.2 cm (6 in.) for sludge.

A final consideration when assessing the impact of solids on flow meter devices is the solids characteristics in the fluid. The accuracy of some devices is affected by solids content. For example, doppler-type ultrasonic meters need a sufficient solids content, but transmissive type ultrasonic meters can be adversely affected by solids that obstruct the sonic wave signal path. In general, each flow meter application should follow manufacturer's recommendations on solids characteristics for the fluid and flow meter device involved.

Abrasion and corrosion

The abrasive and corrosive characteristics of solids carried must be considered when a flow meter device is selected. The primary element must be either constructed of or coated with abrasion-resistant or nonreactive materials suitable for service in the particular fluid.

Accuracy and repeatability

Instrumentation accuracy is defined by the following terms:

- Accuracy-the degree of conformity of an indicated value to a recognized standard value.
- Measured accuracy-the maximum positive or negative deviation from a standard value observed in testing a device under specific conditions.
- Repeatability-the maximum positive or negative variation observed in testing a device under specific and constant conditions.
- Range-the region within which a quantity is measured. The range is usually expressed by stating the upper and lower limits. The range of an instrument is usually fixed.
- Full scale-the upper limit of the range value.
- Span-the algebraic difference between the upper and lower values at which an instrument is set. Span is adjustable and must lie between the upper and lower range limits.

Table B-1
Flow meter devices

Class	Type	Open chan-nel	Closed conduit	Application (a) Raw waste-water	Primary effluent	Secondary effluent	Primary sludge	Return activated sludge	Thick. Sludge	Mixed liquor	Process water
Head/ pressure	Orifice		X								X
	Venturi		X	(b)	(b)	X	(b)	(b)	(b)	X	X
	Flow tube		X	(b)	(b)	X	(b)	(b)	(b)(c)	X	X
	Pitot tube		X								
	Rotameter		X								X
Head/ area	Weir	X			X	X					
	Flume	X		X	X	X					
Positive displace -ment	Propeller		X								X
	Turbine		X								X
Other	Magnetic (tube type)		X	X	X	X	X	X	X	X	
	Magnetic (insert tube)	X	X								
	Ultrasonic (Doppler)		X	X			X	X	(d)		
	Ultrasonic (transmissive)		X		X	X				X	X
	Vortex shedding		X								X
	Volocity head	X									
	Target		X								

a) The information in this table is based on industry practice and engineering judgment.
b) Flushing or diaphragm seated connections recommended.
c) Use with in-line reciprocating pumps not recommended.
d) solids content less than 4°.

Instrumentation accuracy is usually expressed as either ± some percent of maximum flow or ± some percent of actual flow. To illustrate, a meter with an accuracy of ± I% of maximum flow and a full-scale capacity of 1000 m^3/d could read between 990 and 1010 m^3/d when the actual flow is exactly 1000 m^3/d. It could read between 490 and 5 1 0 m^3/d when the flow is 500 m^3/d, and between 190 and 210 m^3/d when the flow is 200 m^3/d. The deviation is ± I m^3/d in every case.

By contrast, percent of actual flow means that the value of the deviation becomes less and less as the flow rate is decreased. The ratio between deviation and actual flow rate that results is constant throughout the instrument's range. For example, a meter with an accuracy of ±1% of actual flow rate and a maximum flow of 1000 m^3/d has a ±10 m^3/d deviation at maximum flow (990 to 1010 m^3/d). It has a ± 5 m^3/d deviation at half flow (495 to 505 m^3/d), and only ±2 m^3/d deviation flow (198 to 202 m^3/d).

The accuracy of a component in a system must also be considered within the context of the overall system accuracy. The systems can be no more accurate (and is usually less accurate) than the least accurate component. For example, consider a flow monitoring system that includes a flume with an ultrasonic transmitter and analog indicator. The accuracy of the flume is approximately ±5 % of maximum flow, the transmitter ±1% of maximum flow, and the indicator ±3% of maximum flow. Overall system accuracy is estimated at:

$$(5^2 + 1^2 + 3^2)^{0.5} = \pm 5.9\% \text{ of maximum flow rate}$$

The accuracy of some meters is also affected by such variables as ambient temperature, power source voltage, electronic interference, and humidity. These factors should be considered when flow meter devices are selected or evaluated.

When applying flow meter devices to wastewater treatment plants, repeatability is sometimes more important than accuracy. For example, it is important to accurately measure plant influent and effluent flows, chemical, and sludge for discharge permit reporting, and for pacing chemical addition for wastewater treatment and sludge conditioning. When flow is split among process units, however, actual flow measurement is not important, but repeatability is. In this case, repeatability is essential to maintain constant flow in the process units. It is the responsibility of the designer to determine which device has the range required for accurate measurement and the required level of accuracy, or whether repeatability is the overriding factor for the particular flow to be measured. The range, accuracy, and repeatability of a number of flow Metering devices are shown in Table B-2.

Head loss

The allowable head loss (as determined by process hydraulics) should be considered when flow meter devices are selected. For many devices, a reduction in cross-sectional area or a change in flow direction is necessary. These velocity changes often result in unrecoverable head loss. The amount of head loss that will occur is highly variable and depends on the conditions of service. Manufacturers data or hydraulic handbooks, or both should be consulted to determine expected losses.

Table B-2
Flow meter device characteristics

Instrument	Range (a)	Accuracy (a)	Repeatability (a)	Upstream unobstructed straight run recommended
Orifice	4:1	±1% of actual rate	±1%	5 diameters (b)
Venturi	4:1	±1% of actual rate	±0.5%	4-10 diameters (c)
Flow tube	4:1	±3% of actual rate	±0.5%	4-10 diameters (c)
Pitot tube	3:1	±3% of actual rate	1% (b)	10 diameters (b)
Rotameter	10:1	0.5-10% of actual rate	1% (b)	5 diameters (b)
Target	10:1	±5% of actual rate	1% (b)	20 diameters
Weir	500:1	•	±0.5%	NA (f)
Flume	10:1-75:1 (e)	•	±0.5%	NA
Propeller	10:1	±2% of actual rate	±0.5%	5 diameters
Turbine	10:1	±0.25% of actual rate	±0.5% of actual rate	10 diameters (g)
Magnetic	10:1	±1-2% of full scale	±0.5% of actual rate	5 diameters
Ultrasonic (Doppler)	10:1	±3% of actual rate	±1% of actual rate	7-10 diameters
Ultrasonic (Transmissive)	10:1	±2% of actual rate	±1% of actual rate	7-10 diameters
Vortex shedding	15:1	±1% of actual rate	±0.5% of actual rate	10 diameters

Note: The information in this table is based on industry practice and engineering judgment.

a) Considering both the primary element and primary converter device.
b) Figures shown are estimates based on engineering judgment. Data could not be found to confirm thse figures.
c) Depends on type of flow disturbing obstruction.
d) Parshall flumes accurate to –5% of actual flow. Palmer-Bowlus flume accurate to –105 of full scale.
e) Depends on type of flume.
f) NA-Not applicable.
g) Assuming flow straightening element is used (25 to 30 pipe diameters, otherswise).

Installation considerations

The choice of location for flow meter devices depends on several factors: installation (piping) configuration, placement, and access. Most flow meter devices require that the flow profile in the device be uniform and consistent throughout the flow range to achieve their greatest accuracy. To satisfy this requirement, sufficient length to allow a straight approach pipe or channel must be provided prior to the meter. The accuracies of some meters such as universal venturi tubes, positive displacement meters and, in most cases, magnetic flow meters are less affected than others by upstream piping configurations. Minimum recommends straight runs ahead of various devices are shown in Table B-2. Straight run distances shorter than the tabulated values may be used where accuracy is not a concern. With respect to placement of meters in relation to other equipment, flow meters in general should be installed upstream of flow control valves and downstream of pumps.

Instrumentation servicing requirements must also be considered. Access to flow meters should be unobstructed and test connections should be provided and readily accessible. Ample room to allow inspection and cleaning of the inlets to flow instrumentation should also be provided. In instances when the meter and instrumentation cannot be serviced with continued flow through the element, bypass piping and valving should be provided to isolate the meter. It should be noted that venturi tubes and flow tubes are in-line devices that do not require bypass piping, but, magnetic flow meters require bypass piping for inspection and servicing. In addition to bypass facilities, inspection ports and quick-disconnect couplings should be used to reduce the time required for maintenance. In general, an installation that provides ease of service is usually the best maintained and the most reliable.

Operating environment

A primary consideration in the application of flow meter devices and associated transmitters is the environment in which the instrument will be located. The electrical classification and requirements of the location as described by the National Electrical Code is of particular concern. The general classification relates to protection against ignition of gas or dust by the heat or sparking associated with electrical equipment. Equipment in these areas must have a rating for service equal to or better than that required for the specific area classification.

Corrosive environments also dictate that special precautions be taken. The presence of corrosive gas required special protective coatings for the flow meter device and associated instrumentation.

Temperature extremes should be avoided or compensated for. All devices have a maximum operating temperature range. When operated within that range, the devices maintain their stated accuracy. The range relates primarily to the limits of the electronics within the device. Exceeding the upper temperature limit may cause component failure. A supplemental enclosure that incorporates heating to counteract low temperatures and fan cooling to reduce high temperatures can protect instruments from damage caused by extreme temperatures. Low wattage heaters or heat tracing may be used to keep hydraulic tubing from freezing.

Moisture and electronics are virtually incompatible. The use of proper equipment enclosures is imperative in wastewater treatment plants. Supplemental low wattage heaters may be used inside instrumentation cabinets to reduce condensation. Moisture resistant coatings for electronic components are also available. Seals should be used in all conduits connected to flow instrumentation to prevent the infiltration of moist air through the conduits into instrument enclosures. Another way to protect panel instruments from moisture is to purge the control cabinets. An internal positive pressure is created in the control cabinet by injecting dry instrument air into the cabinet.

Maintenance Considerations

Maintenance considerations include cleaning, calibration, and record keeping.

Cleaning

An essential part of instrumentation maintenance is cleaning. Dirt prevents heat from dissipating around electrical components. It increases friction and tends to absorb moisture, which accelerates corrosion and increases the potential for electrical shortcircuits. Primary flow elements must also be kept clean and free of debris. Provisions should be made for cleaning the meter and tap lines by flushing or rodding. In sludge applications where intermittent operation is expected, the ability to flush the meter and associated piping, and to fill them with clean water should be provided. Selfcleaning electrodes that use either high frequency ultrasonic waves or heat are available for use with magnetic flow meters. Installations where the meter is subject to low flow velocities will require more frequent cleaning because of solids and grease accumulation.

Calibration

Flow meters are factory calibrated prior to delivery to the wastewater treatment plant. Upon installation, an in-place calibration should be performed to assure specifications are met and to establish a reference that may be used for future monitoring and periodic maintenance calibration. Calibration test equipment as well as fixtures required to field calibrate instruments should have an accuracy at least twice that of the instrument being tested or calibrated. Whether the device is factory or field calibrated, it is essential that calibration data be obtained as soon as the initial calibration is set. These data are the basis for instrument performance evaluation.

Records

Two records are essential for evaluating flow meter performance: records of the original calibration data, and current operating and maintenance data. The calibration data provide a reference against which the actual operating data can be checked. Current data include records of maintenance and calibration checks. Checks made without follow-up actions must also be recorded because these checks provide information that concerns equipment performance and effective scheduling of routine calibration.

Summary

The correct design, application, and maintenance of flow instrumentation are critical to the efficient operation of a wastewater treatment facility. These criteria are summarized in the form of a checklist in Table B-3.

Acknowledgments

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References

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Table B-3
Flow instrumentation selection checklist

Item	Issue
Application	Is the device suitable for open channel/closed conduit flow? Is the device compatible with the fluid being monitored?
Selection Criteria	Is the device appropriately sized for the entire range of flow to be monitored?
Sizing	Are proper flow velocities maintained?
Fluid composition	Does the device have the recommended minimum clear opening for the fluid being monitored? Is the solids content of the fluid compatible with the measuring device? Are the wetted components constructed of materials nonreactive with the fluid?
Accuracy	Is the accuracy and repeatability of the device consistent with the application? Is the stated accuracy of the component consistent with overall system accuracy? Has the effect of environmental factors on the stated accuracy been considered?
Head loss	Is the headloss caused by the device within constraints of the hydraulic profile?
Installation considerations	Is sufficient straight length of pipe or channel provided ahead of the meter? Is the device located properly with respect to valves and pumps? Are the flow meter devices accessible for service? Are quick disconnect couplings and bypass piping provided?
Operating environment	Is the equipment associated with the flow meter device appropriately rated for its intended application to prevent explosion hazard? Where necessary, is the equipment resistant to moisture and corrosive gases? Have provisions been made to ensure operation of the device within an acceptable temperature range?
Cleaning	Are provisions made for flushing or rodding the meter and tap lines?

Additional Resource C
Odor Characterization

The 146-descriptor odor quality characterization table provided in this section is excerpted directly from Dravnieks, et.al. (1978). This table represents a significant expansion over previous characterization tables. Formerly, the most widely used table contained only 44-descriptors (Harper et.al., 1968). The need for such an expansion became evident when researchers found that many characterized odors were in fact quite different from each other.

The use of so many terms should not be viewed as overly burdensome. Careful characterization of an FPR should not take more than 5-10 minutes. The comprehensive nature of the table gives an advantage of some redundancy so that the person conducting an evaluation who is unfamiliar with certain odors may find others which are familiar.

Use of this table involves smelling the odor to be evaluated and then running through the list identifying appropriate descriptors and designating the degree of presence of that odor. More than one descriptor may be used for a single FPR.

To use the descriptor table, go through the list on the attached table. In the box next to each descriptor, write in the degree of presence according to the following rating scale.

Rating Scale

1	**2**	**3**	**4**	**5**
slightly		moderately		extremely

COMMON	sweet		CHEMICALS	sharp, pungent, acid		MEATS	meat seasoning	
	fragrant			sour, acid, vinegar			animal	
	perfumery			ammonia			fish	
	floral			camphor			kippery, smoked fish	
	cologne			gasoline, solvent			blood, raw meat	
	aromatic			alcohol			meat, cooked good	
	musky			kerosene			oily, fatty	
	incense			household gas		FRUITS	cherry, berry	
	bitter			chemical			strawberry	
	stale			turpentine, pine oil			peach	
	sweaty			varnish			pear	
	light			paint			pineapple	
	heavy			sulphidic			grapefruit	
	cool, cooling			soapy			grape juice	
	warm			medicinal			apple	
FOUL	fermented, rotten fruit			disinfectant, carbolic			cantaloupe	
	sickening			ether, anaesthetic			orange	
	rancid			cleaning fluid, carbona			lemon	
	putrid, foui, decayed			mothballs			banana	
	dead animal			nail polish remover			coconut	
	mouse-like						fruity, citrus	
							fruity, other	

BODY MATERIALS	
dirty linen	
sour milk	
sewer	
fecal, manure	
urine	
cat urine	
seminal, like sperm	
dry, powdery	
chalky	
cork	
cardboard	
wet paper	
wet wool, wet dog	
rubbery, new	
tar	
leather	
rope	
metallic	
burnt, smoky	
burnt paper	
burnt candle	
burnt rubber	
burnt milk	
creosote	
sooty	
fresh tobacco smoke	
stale tobacco smoke	

OUTDOORS SPICES	
hay	
grainy	
herbal, cut grass	
crushed weed	
crushed grass	
woody, resinous	
bark, birch	
musty, earthy, moldy	
cedarwood	
oakwood, cognac	
rose	
geranium leaves	
violets	
lavender	
laurel leaves	
almond	
cinnamon	
vanilla	
anise, licorice	
clove	
maple, syrup	
dill	
caraway	
minty, peppermint	
nut, walnut	
eucalyptus	
malt	
yeast	
black pepper	
tea leaves	
spicy	

VEGETABLES FOODS	
fresh vegetables	
garlic, onion	
mushroom	
raw cucumber	
raw potato	
bean	
green pepper	
sauerkraut	
celery	
cooked vegetables	
buttery, fresh	
caramel	
chocolate	
molasses	
honey	
peanut butter	
soupy	
beer	
cheesy	
eggs, fresh	
raisins	
popcorn	
fried chicken	
bakery, fresh bread	
coffee	

Additional Resource D
Laboratory Listing

The code letter next to a laboratory name indicates that the laboratory tests for at least one of the parameters listed under the respective code descriptions below.

<table>
<tr><td>F</td><td>Animal Feedability Profiles
Only specialized labs usually perform these tests on solids or sludges.
• dry matter
• digestible energy concentration
• metabolize energy concentration
• net energy of maintenance
• net energy of gain
• energy of lactation
• neutral detergent fiber
• acid detergent fiber
• fat (crude)
• minerals
• microbiological</td></tr>
<tr><td>G</td><td>General Water Chemistry
FPRs commonly requiring this analysis: wastewaters, recycled water.
• BOD
• pH
• solids (all types)
• COD
• soluble salts
• oil and grease
• metals (all types)
• microbiology</td></tr>
<tr><td>L</td><td>Leaching Tests
These are highly specialized tests required by regulatory agencies. A solid or sludge is scanned for its potential to leach a wide range of compounds into soil and groundwaters.
• TCLP (Toxic Characteristics Leaching Potential)
• water extraction (ASTM)</td></tr>
</table>

SL	**Sludge/Solids Chemistry** FPRs commonly requiring this analysis: wastewater sludges, solid wastes like vegetable parts, composted materials, etc. • solids content • pH • organic matter • heavy metals • primary nutrients • secondary nutrients • micronutrients • bulk density • soluble salts • sodium • chlorides • oil and grease • SAR (sodium absorption ratio) • CCE (calcium carbonate equivalent)
SO	**Soils Chemistry & Fertility** Labs with this code perform tests on soils. • primary nutrients • secondary nutrients • micronutrients • trace elements • all metals, including cadmium, copper, chromium, lead, nickel, mercury, zinc • solids content • pH • organic matter • heavy metals • all forms of nitrogen • phosphorus • potassium • soluble salts
SY	**Synthetic Organics** These labs will test either water, soils, or solids for synthetic organics. • organic solvents • PCBs • pesticides • trihalomethanes

ADAMS

Microbac Labs, Inc., — G
Hanover Division
Ronald M. Barber
701 3rd St.
Hanover, PA 17331
(717)633-6011

Myers Analytical — F,G,SO,SL
504 Mehring Road
Littlestown, PA 17340
(717)359-4126

ALLEGHENY

ChesterLab — G,L,SL,SO,SY
Robert Helwick
P.O. Box 15851
Pittsburgh, PA 15244
(412)269-5700

Chester LabNet-Monroeville — G,L,SL, SY
Kenneth A. Brown
3000 Tech Center Drive
Monroeville, PA 15146
(412)825-9600

Enseco-Wadsworth Alert, Inc. — G,L.SL,SO,SY
John M. Flaherty
450 William Pitt Way, Bldg. 6
Pittsburgh, PA 15238

Killam Associates, DLA Division — G,L,SL,SO,SY
T'homas E. Orr
100 Allegheny Drive
Warrendale, PA 15086-7565
(412)772-0200

Mack Laboratories, Inc. — G,L,SL,SO,SY
John D. Mack
2199 Dartmore Avenue
Pittsburgh, PA 15210
(412)885-2900

Microbac Laboratories, Inc. — G
Mark A. Matrozza
4580 McKnight Road
Pittsburgh. PA 15237
(412)931-5851

Microbac Laboratories, Inc., — G,L,SL,SO,SY
Senate Anal. Div.
David J. Danis
U-PARC, 545 William Pitt Way
Pittsburgh, PA 15238\
(412)826-3700

Microbac Labs-Schiller Lab, Inc. — G,L,SL,SY, F(minerals)
David J. Danis
449 Rochester Road
Pittsburgh, PA 15237-1733
(412)369-4830

NUS Laboratory — G,L,SL,SO,SY
Joanne C. Simanic
5350 Campbells Run Rd.
Pittsburgh, PA 15205
(412)747-2500

PACE, Inc. — G,L,SL,SO
Diane Waldschmidt
100 Marshall Drive
Warrendale, PA 15086-7554
(412)772-4046

Professional Service Industries, Inc. — G
Chris Kazakos
850 Popular Street
Pittsburgh, PA 15220
(412)922-4000

R. F. Mitall and Associates — G
Robert F. Mitall
117 Sagamore Hill Road
Pittsburgh, PA 15239
(412)327-7474

RJ Lee Group, Inc. — G,L,SL,SO,SY
Gary A. Cooke
350 Hochberg Rd.
Monroeville, PA 15146
(412)325-1776

SSS Environmental Services — G
J. Robert McNair
921 Saw Mill Run Blvd.
Pittsburgh, PA 15220
(412)381-3622

ARMSTRONG

CWM Laboratories — G
David Kohl
131 McKean St,
PO Box 916
Kittanning, PA 16201
(412)543-3011

Ecotec Laboratory — G
Frank T. Baker
P.O. Box 220
Elderton, PA 15736
(412)354-2656

BEAVER

Aliquippa Municipal Water Authority — G
Dennis Bires
120 Hopewell Avenue
Aliquippa, PA 15001
(412)375-5259

Ambridge Water Authority G
Robert E. Bires, Jr.
1001 Merchant Street
Ambridge, PA 15003
(412)266-3360

Baker/TSA, Inc. G,SL,SO,SY
George K. Hanne
4301 Dutch Ridge Road
Beaver, PA 15009
(412)495-7711

BERKS

A&S Environmental Testing, Inc. G,L,SL,SO.SY
Stephen P. Stupp
1050 Spring St.
Wyomissing, PA 19605
(215)375-3888

Analytical Hydrology Associates, Ltd. G,L,SL,SO,SY
Dr. Harpal Singh
R.D. #1, P.O. Box 247
Bernville, PA 19506
(215)488-7112

Blue Marsh Laboratory G
Laurel A. Schwindt
85 Benjamin Franklin Highway
Douglassville, PA 19518
(215)327-8196

Hydro-Analysis Associates, Inc. G,L,SL,SO,SY
Randy S. Haring
57 Noble Street
Kutztown, PA 19530
(215)683-7474

M. J. Reider Associates G,L,SL,SO,SY
Barbara R. Coyle
107 Angelica Street
Reading, PA 19611
(215)374-5129

MDS Laboratories G
Craig R. Achenbach
4418 Pottsville Pike
Reading, PA 19605
(800)345-4026

PRC Environmental Laboratory, Inc. G,L,SL,SY
Karen L. Merrill
2909 Windmill Road
Sinking Spring, PA 19608
(215)670-8500

Spotts, Stevens. & McCoy Inc. G,L,SL,SO,SY
Steven N. Delp
30 Noble Street
Reading, PA 19611
(215)376-4595

Suburban Water Testing Labs, Inc. G
Richard C. Stump
4600 Kutztown Rd.
Temple, PA 19560
(215)929-3666

Wissahickon Spring Water, Inc. G
Albert D. Lear
240 Broad St.
Kutztown, PA 19530
(215)824-3434

BLAIR

Blair Chemical Laboratories G
David J. Menza
2714 Oak Avenue, P.O. Box 1710
Altoona, PA 16603
(814)942-0937

Fairway Laboratories, Inc. G,SO,SY,SL
Michael Tyler
2900 Fairway Drive, P.O. Box 1925
Altoona, PA 16602
(814)946-4306

Kendall Dairy Laboratories G
Clifford P. Kendall
3614 Beale Ave.
Altoona, PA 16601
(814)943-3975

Mountain Research, Inc. G,L,SL,SO,SY
Timothy M. Rea
825 25th St.
Altoona, PA 16601
(814)949-2034

BRADFORD

Eastern Laboratory Services, Inc. G,L,SL,SO,SY
Sharon L. McHenrv
387 Fulton St.
South Waverly, PA 18840
(717)888-0169

BUCKS

Analytical Laboratories, Inc. G,L,SL,SO
Geoffrey W. Kinka
4208 Old Bethlehem Pike
Telford, PA 18969
(215)345-8366

Aqua-Pure Labs, Inc. G
Leo Metzger
602 Airport Blvd.
Doylestown, PA 18901
(215)345-6349

Hydrodyne Analyses — G
Jade Snyder
6 Audrey Lane, P.O. Box 96
Silverdale, PA 18962
(215)257-7542

Purity Standard Labs — G
George Getz
127 Limekiln Pike
Chalfont, PA 18914
(215)822-3337

QC, Inc. — G,L,SL,SO,SY
Thomas J. Hines
1205 Industrial Hwy, P.O. Box 514
Southampton, PA 18966
(215)355-3900

Quakertown Veterinary Clinic — F,G
Marilyn J. Thomas
2250 Old Bethlehem Pike
Quakertown, PA 18951
(215)536-6245

BUTLER

R & R Associates, Inc. — G
Raymond D. Bowman, Ph.D.
227 West Brady Street
Butler, PA 16001
(412)283-3540

Water Labs — G
Thomas H. Steble
RD#2, Box 507A
Valencia, PA 16059
(412)586-9490

CAMBRIA

Cardan Laboratories — G,L,SL,SO,SY
Daniel R. Antos
South Ninth Street, P. 0. Box 541
Spangler, PA 15775
(814)948-8650

Laurel Management Co. — G,SL
Michael Gregovich
111 Roosevelt Blvd.
Johnstown, PA 15906
(814)533-5700

Microbac Labs-Strand Testing Div. — G
Gerard M. Hrzic
P. 0. Box 1447,1248 Rear Scalp Ave.
Johnstown, PA 15907-0447
(814)266-9548

Norac Laboratory — G
Ronald R. Babik
622 Central Avenue
Johnstown, PA 15902
(814)536-8506

Standard Laboratories, Inc. — G,L,SL,SO
Lori Patney
P.O. Box 214
Cresson, PA 16630
(814)886-4115

CARBON

Palmerton Hospital
Suzanne M. Garszczynski
135 LaFayette Avenue
Palmerton, PA 18071
(215)826-3141

CENTRE

Centre Analytical Laboratories, Inc. — G,L,SL,SO,SY
M. Michael Arjmand, Ph.D.
3048 Research Dr., CATO Park
State College, PA 16801
(814)231-8032

Todd Giddings & Associates, Inc. — G
Anal. Lab
Mark R. Ralston
3049 Enterprise Drive
State College, PA 16801
(814)238-5927

CHESTER

Biometrics/Longwood Laboratories — F,G,L,SL,SO,SY
Richard C. Croyle
RR 2 Box 475, Hepburn Road
Avondale, PA 19311
(215)869-3950

Brandywine Science Center. Inc. — G,SL.SO
William J. Tinker
204A Line Road
Kennett Square, PA 19348
(215)444-9850

Cedar Grove Laboratories — G,L,SL,SO,SY
Thomas J. McCaffrey, Jr.
100 Gallagherville Road
Downingtown, PA 19335
(215)269-6977

H. O. Thompson Testing Laboratory — G
Gar Shoemaker
R. D. #2 ' Box 104 Valley View Dr.
Parkesburg, PA 19365
(215)593-5030

Kennett Laboratories, Inc. — G,SL,SO,SY
John L. Frank, Jr.
209 1/2 E. Maple St.
P.O. Box 162
Kennett Square, PA 19348
(215)444-3900

Roy F. Weston, Inc. G,,SL,SO,SY
J. Peter Hershey
208 Welsh Pool Road
Lionville, PA 19341-1313
(215)524-7360

Sigma Scientific Services, Inc. SL (organics), SO,SY
Robert King
6 Winding Way
Malvern, PA 19355
(215)640-4059

West Chester Area Mun. Auth. G
Craig A. Lutz
990 Fem Hill Road
West Chester, PA 19380
(215)692-8410

CLARION

Stewart Laboratories G,L,SL,SO,SY
Margie H. Stewart
R. D. #1
Strattanville, PA 16258
(814)379-3663

CLEARFIELD

Hess & Fisher Engineers, Inc. G,,SL,SO
Wilson Fisher, Jr.
36 North Second Street
Clearfield, PA 16830
(814)765-7541

Mahaffey Laboratory G,L,SL,SO
Carlton R. McCracken, Jr.
P.O. Box L, Main Street
Grampian, PA 16838
(814)236-3540

CLINTON

CDS Laboratories GL,SL,SO,SY
Charles D. Sweeney
R.D. #2 Box 234
Loganton, PA 17747
(717)725-3411

CRAWFORD

Free-Col Laboratories, Inc. G,L,SL,SO,SY
Andrew Ecklund
P.O. Box 557, Cotton Road
Meadville, PA 16335-0557
(814)724-6242

CUMBERLAND

Aqua Treatment Service G
Alan J. Lopez
P.O. Box 1331,194 Hempt Road
Mechanicsburg, PA 17055
(717)697-4998

Carlisle Region ATCF G
David K. Runkle
53 West South Street
Carlisle, PA 17013
(717)249-4422

Johnston Laboratory, Inc, G,L,SL,SO,SY
Edward Willenbacher
4705 E. Trindle Rd., P.O. Box 339
Mechanicsburg, PA 17055
(717)737-7136

Spectra Laboratories, Inc. G,L,SL.SO,SY
Edward Kellogg
4705 East Trindle Road
Mechanicsburg, PA 17055
(717)737-7158

DAUPHIN

Analytical Labs of Skelly & Loy G,L,SL,SO,SY
Michael S. Farlling
2601 North Front Street
Harrisburg, PA 17110
(717)257-1335

Animal Diagnostic Laboratory F
Pa. Dept. of Agriculture, BAI
P.O. Box 367
Summerdale, PA 17093
(717)787-8808

Environmental Microbiology Associates, Inc. G,SL,SO
Katherine H. Baker
2001 N. Front St.
Bldg. 1, Suite 217
Harrisburg. PA 17102
(717)238-7930

Gannett Fleming, Environ. Lab G.L,SL,SO,SY
David W. Lane
209 Senate Ave.
Camp Hill, PA 17011
(717)763-7211

Wright Lab Services, Inc. G,L,SL,SO,Y
]an M. Milnes
34 Dogwood Lane
Middletown, PA 17057
(717)944-5541

DELAWARE

Talbot Laboratories, Inc. G,SL
Richard S. Talbot, Ph.D.
600 Upland Avenue
Upland, PA 19015
(215)499-7474

United Engineers & C Environmental Laboratory — G,L,SL,SO,SY
Joe C. Watt
301 Chelsea Parkway
Boothwyn, PA 19061
(215)497-8000

Wayne Analytical & Environmental Services, Inc. — G,L,SL,SO,SY
Mohan K. Palat
992 Old Eagle School Road
Wayne, PA 19087
(215)688-7485

ELK

Ridgway Bacti Lab — G
James G. Armagost
Box 12, 312 St. Marys Road
Ridgway, PA 15853
(814)772-6423

ERIE

Analytical Laboratories — G,L
Jody Timer
Eight Gibson Street
North East, PA 16428
(814)725-8659

Church Laboratory, Inc. — G,L,SL,O,SY
Robert W. Stallbaum, Jr.
7397 Chestnut Street, P.O. Box 83
Fairview, PA 16415
(814)474-2044

Microbac Labs, Inc.-Eric Testing Div. — G,L,SL,SO,SY
Robert W. Morgan
1962 Wager Road
Erie, PA 16509
(814)825-8533

FRANKLIN

American Analytical Testing Services — G,L
Howard E. Holzman
5424 Buchanan Trail East
Waynesboro, PA 17268
(717)762-9127

Cumberland Analytical Labs, Inc. — G,,SL,SO
Donald R. Richner, Jr.
56 North Second Street
Chambersburg, PA 17201
(717)263-5943

GREENE

H & H Water Controls, Inc. — G,SL
Edgar A. Harris, Jr.
102 Olympic Street
Carmichaels, PA 15320
(412)966-2278

INDIANA

Aquatest Laboratory — G
Robert K. Alico, Ph-D,
245 Philadelphia St.
Indiana, PA 15701
(412)349-3766

Environmental Service Labs, Inc. — G,L,SL
Beth Gregg
P.O. Box 696, 650 S. 13th St.
Indiana, PA 15701
(412)357-6498

JEFFERSON

Analytical Services, Inc. — G,L,SO,SY
Randal L. Davido
R. D. #2, Box 282, Ferrmantown Rd.
Brockway, PA 15824
(814)265-8749

Brockway Analytical Inc. — G,L,SL,SO
David L. Strong
P.O. Box 265
Dubois-Brockway Road
Brockway, PA 15824
(814)371-6030

G&C Coal Analysis Lab, Inc. — G,SO
Michael J. Chestnut
RD#1, Box 324
Summerville, PA 15864
(814)849-6780

LACKAWANNA

Aqualabs Co. — G
C. G. Vlassis
Keystone Junior College
LaPlume, PA 18440
(717)945-5141

Northeastern Environmental Assoc. — G,L,SL,SO,SY
Jerome X. Loftus
1620 North Main Avenue
Scranton, PA 18508
(717)348-0775

Penna. Gas and Water Company — G
Joseph F. Calabro, Ph.D.
135 Jefferson Avenue
Scranton, PA 18503-1799
(717)348-3821

LANCASTER

Agri-Analysis Laboratory — F,SL,O
Box 266
Bird-in-Hand, PA 17505
(717)397-9185

American Testing Labs, Inc — G,SL,SO
John S. Kassees
784 Flory Mill Road, PO Box 4014
Lancaster, PA 17604
(717)569-0498

Howard L. Cummings Lab — G
H. L. Cummings
106 North Spruce Street
Elizabethtown, PA 17022
(717)367-1645

Lancaster Laboratories, Inc. — F,G,L,SL,SO,SY
Dr. Wilson Hershey
2425 New Holland Pike
Lancaster, PA 17601-5994
(717)656-2301

Shields Laboratories — G
Ian B. Shields
13 Ridge Drive
Lititz, PA 17543
(717)627-2520

LAWRENCE

Biotec, Inc. — G
Robert J. Taylor
P.O. Box 283, W. Main St.
Hillsville, PA 16132
(412)667-1211

Environmental Lab Services — G,L,SL,SO
Mark Swansiger
1135 Butler Avenue
New Castle, PA 16101
(412)652-5770

Freedom Associates — G
Russell D. Freed
1425 Woodside Avenue
Ellwood City, PA 16117
(412)752-6642

Microbac Labs/New Castle Division — G
Florence Bowser
R.D. #8, Box 626, Old Pulaski Road
New Castle, PA 16105
(412)654-4212

LEBANON

Pure-Test Water Laboratory — G
Dennis Martin
740 E. Lincoln Avenue
Myerstown. PA 17067
(717)866-2234

LEHIGH

ASW Environmental Consultants, Inc. — G,SL
John P. Dougherty
847 N. Gilmore St.
Allentown, PA 18103
(215)434-1870

Lehigh Valley Labs, Inc. — G
John H. Mandel
1740 Allen Street
Allentown, PA 18104
(215)435-6776

Town & Country Labs — G,SO
Lynn K. Kuka
109 S. 8th St.
Allentown, PA 18101
(215)435-2365

LUZERNE

Aqua-Tech Laboratory — G
Joseph F. Calabro, Ph.D.
1 Wilderness Drive
Mountaintop, PA 18707
(717)868-5346

Farmers Cooperative Dairy, Inc. — G
Jacqueline A. Homack
32nd & North Church St., Box 309
Hazleton, PA 18201
(717)454-0821

Kirby Memorial Health Center — G,L,L,SO,SY
John O. Turner, Ph.D.
71 North Franklin Street
Wilkes-Barre, PA 18701
(717)822-4278

LYCOMING

Seewald Laboratories — G,L,SL,SO,SY
Robert E. Chianelli
1403 West Fourth Street
Williamsport, PA 17701
(717)326-4001

MCKEAN

Microbac Labs, Inc, J-Labs Division — G,SL,SO
Bradley S. Mitchell
P.O. Box 489
Bradford, PA 16701
(814)368-6087

Penn Ecowater Laboratory — G
John Neburka
19 Chestnut Street
Bradford, PA 16701-2015
(814)362-3871

MERCER

Brenner's Ecological Service — G
Fred J. Brenner
132 North Liberty Road
Grove City, PA 16127
(412)748-4310

Shenango Valley Water Co. — G
Eric Buzza
100 Shenango Ave., Box 572
Sharon, PA 16146
(412)347-7418

MIFFLIN

Water Quality Laboratory — F,G,L,SL,SO,SY
Samuel C. Norris
68 North Pine St.
Lewistown, PA 17044
(717)242-3114

MONROE

Hess Environmental Labs — G
Michael Klusaritz
112 N. Courtiand St., P. O. Box 268
East Stroudsburg, PA 18301
(717)421-1550

Prosser Laboratories — G,L,SL,SO,SY
George W. Prosser, Jr.
P. O. Box 118
Effort, PA 18330
(717)629-2981

MONTGOMERY

Applied Geotechnical & Environ. Serv. — G,L,SL,O,SY
Jane Clarke-James
1151 S. Trooper Road
Norristown, PA 19403
(215)666-7404

BCM Eastern, Inc. — G,L,SL,SO,SY
Rocco T. Alessandro
1850 Gravers Road
Norristown, PA 19401
(215)275-0281

Lehigh Valley Dairies, Inc. — G
Leanne Rezabek
880 Allentown Road
Lansdale, PA 19446
(215)855-8205

Phila. Suburban Water Co.
Charles D. Hertz
762 Lancaster Ave.
Bryn Mawr, PA 19010
(215)525-1400

RMC Analytics — GL,SL,SO,SY
Twila E. Dixon
88 Robinson Street
Pottstown, PA 19464
(215)327-4850

Wastex Industries, Inc. — G,L,SL,SO,SY
Timothy M. Heath
28 South Hanover Street
Pottstown. PA 19464
(215)327-0880

NORTHAMPTON

A-B-E Laboratory — G
Bradley S. Niper
569-B Bath Pike
Bath, PA 18014
(215)837-7721

Benchmark Analytics — G,L.SL,SO,SY
Stephanie A. Olexa
1776 Main Street
Hellertown, PA 18055
(215)974-8100

Cooperative Ventures, Inc. — G,L,SL,SO,SY
Susan Kon
P.O. Box 796
Easton, PA 18042
(215)746-3431

Lehigh Valley Analytics — G,L,SL,SO
Barbara J. Davies
22 South Commerce Way
Bethlehem, PA 18017
(215)866-4434

NORTHUMERLAND

Wilson Testing Laboratories — G,L,SL,SO,SY
Annette Witcoskie
Route 61
Shamokin, PA 17872-3845
(717)648-2216

PERRY

Lenker Laboratory. Inc. — G
Mafia M. Lenker
RD# 1, Box 17
Honey Grove, PA 17035
(717)438-3986

PHILADELPHIA

Dalare Associates, Inc. — G,L,SL,SO,SY
Joseph J. Strug, Jr.
217 South 24th Street
Philadelphia, PA 19103
(215)567-1953

PIKE

F. X. Browne Associates, Inc. G
F. X. Browne
P. O. Box 1398
Marshalls Creek, PA 18335
(717)588-7900

SCHUYLKILL

Hawk Niountain Labs, Inc. G,L,SL,SO
David Gittleman
P.O. Box 1357
511 N. Progress Ave.
Pottsville, PA 17901
(717)628-4295

Pottsville Environmental Testing Lab, Inc. G
Michael C. Fabian
164 E. Bacon Street
Palo Alto, PA 17901
(717)622-7315

SOMERSET

Geochemical Testing G,L,SL,SO,SY
Timothy W, Bergstresser
R.D. #2 Box 124
Somerset. PA 15501
(814)443-1671

Skyview Labs F
P.O. Box 273, Rt. 30
Jennerstown. PA 15547
(814)629-5441

WAYNE

Lynn K. Simons G
P.O. Box 307
Honesdale, PA 18431
(717)253-3230

WESTMORELAND

Antech Ltd. G,L,SO,SY
David W. Miller
Triangle One Office Bldg.
Export, PA 15632
(412)733-1161

ITAS Corporation-Export G,L,SL,SO,SY
William S. Davis
5103 Old William Penn Hwy.
Export, PA 15632
(412)731-8806

Security Resource Management, Inc. G
Dayna L. Green
U.S. Route 30, Box 188
Latrobe, PA 15650
(412)537-0328

Teaco Laboratories, Inc. G
Thomas E. Arnold
P.O. Box 612
Leechburg, PA 15656-0612
(412)845-6648

Victor P. Regola & Associates, Inc. G
Richard R. Bourg, Jr.
2 Clawson Ave.
Youngwood, PA 15697
(412)834-0734

Westmoreland Mechanical Testing and Research G,L,SL,SO,SY
James B. Dague
P.O. Box 388
Youngstown, PA 15696-0388
(412)537-8686

YORK

B-H Laboratories G,L,SL,SO,SY
Scott A. Brunk
978 Loucks Mill Rd.
York, PA 17402-1999
(717)943-5561

Eastern Laboratory Serv. Assoc. F,G,L,SL,SO,SY
K. G. Rao, Ph.D.
517 North George Street
York, PA 17404
(717)846-4953

Enviro-Lab GL,SL,SO,SY
Robert L. Weaver
1221 Hanover Road
York, PA 17404
(717)225-5686

FEEDABILITY ANALYSIS NEARBY STATE LABORATORIES

A & L Eastern Laboratory 7621 Whitepine Road Richmond, VA 23237 (804)743-9401	F
C. H. Mitchell Laboratory New Berlin, NY 13411 (607)847-6175	F
Jefferson Laboratories Box 211 Jefferson, MD 21755 (301)473-4066	F
New Jersey Feed Laboratory U.S. Postal Address: USPO Caller No. 06650 Trenton, NJ 08650 UPS and Other Deliveries: 910 Pennsylvania Avenue Trenton, NJ 08638 (609)392-8818	F
Northeast DHIA Forage Testing Lab 730 Warren Road Ithaca, NY 14850 (607)257-1272	F
Real Laboratory Ohio Agricultural Research and Development Center Wooster, OH 44691 (216)263-3760	F

Additional Resource E
Sampling Procedures and Methods of Analysis

Collection Preservation Analysis Method

BOD$_5$

Collect in either plastic or glass containers. Sample should be at least 1000 ml.

Samples kept on ice in the field, or refrigerated at 4 ^{0}C. Analyze within 6 to 48 hours.

EPA$_1$ 405.1[1] Biochemical Oxygen Demand-5 Day
SM 5210 B[2] 5-Day BOD Test

Bulk Density

Sample collection depends upon the viscosity of the sample. For runny samples, plastic or glass containers may be used. However, for pasty or thick sludge samples, take a sample core of known volume.

Refrigerate to prevent moisture loss and the growth of any bacteria that may change the sample mass.

MSA2-133 Bulk Density

Cadmium

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH<2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 213.1 Atomic Abspt-Direct Aspiration
EPA$_1$ 213.2 Atomic Abspt-Furnace Technique
SM 3500-Cd B. Atomic Absorption Spectrophotometric Method
SM 3500-Cd C. Inductively Coupled Plasma Method
SM 3500-Cd D. Dithizone Method
MSA 19 Nickel, Copper, Zinc, and Cadmium

Calcite Equivalent

(Calcium Carbonate Equivalent)

Sludge, soils or other samples may be collected in glass containers.

No preservative added. Samples may be refrigerated at 4°C.

MSA2 11 Carbonate and Gypsum
MSA2 11-2 Carbonate

Chromium

Collect samples in either plastic or glass containers that have been washed with 1 + 1 nitric acid ($HN0_3$).

Preserve to pH<2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months. Acid is not added to samples to be analyzed for Hexavalent chromium, however, they are to be refrigerated at 4°C and must be analyzed within 24 hours.

EPA_1 218.1 Atomic Absorption-Direct Aspiration Technique
EPA_1 218.2 Atomic Absorption-Furnace Technique
EPA_1 218.3 Atomic Absorption-Chelation Extraction
EPA_1 218.4 Atomic Absorption-Chelation Extraction (Hexavalent Chromium)
EPA_2 3.3 Methods for Determination of Metals
Method 7195 Chromium Hexavalent coprecipitation
Method 7196 Chromium Hexavalent calorimetric
Method 7197 Chromium Hexavalent chelation/extraction
Method 7198 Chromium Hexavalent differential pulse polarometry
MSA 20 Chromium
SM 3500-Cr C. Inductively Coupled Plasma Method
SM 3500-Cr D Colorimetric Method

Copper

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid ($HN0_3$).

Preserve to pH < 2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 0 months.

EPA_1, 220.1 Atomic Absorption-Direct Aspiration Technique
EPA_1 220.2 Atomic Absorption-Furnace Technique
EPA_2 3.3 Methods for Determination of Metals
MSA 19 Nickel, Copper, Zinc, and Cadmium
SM 3030 A-J. Sample Digestion Methods
SM 3500-Cu C. Inductively Coupled Plasma Method
SM 3500-Cu D Neocuproine Method

Electrical Conductivity

Mix FPR with soil from the site at the proposed land application loading rate. The FPR/soil ratio should be made on a dry weight basis. Begin by selecting an application rate appropriate for the most limiting FPR characteristic. This is usually nitrogen.

Example: Assume that the nitrogen content of the FPR indicates that a maximum application rate is 10 dry tons per acre. If the plow layer contains 2,000,000 pounds (1000 tons) of soil per acre, a 10-dry ton per acre of FPR is equivalent to a soil/FPR mixture of 100 parts of soil to one part FPR. This is the ratio you would use to prepare your sample for Electrical Conductivity Analysis.

None

Two methods commonly used. The saturated (paste) extract method involves wetting the sample to the consistency of moist putty and extracting water using vacuum equipment. The second method, used by Penn State Agricultural Analytical Services Laboratory, involves mixing two parts of distilled water with one part of solid material and performing an electrical conductivity analysis on that mixture.

Lead

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH <2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 239.1 Atomic Absorption-Direct Aspiration Technique
EPA$_1$ 239.2 Atomic Absorption-Furnace Technique
SM 3500-Pb C. Inductively Coupled Plasma Method
SM 3500-Pb D Dithizone Method

Mercury

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH<2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 249.2 Atomic Absorption-Furnace Technique
EPA$_2$ 3.3 Methods for Determination of Metals
EPA$_2$ Method 7470 Mercury in Liquid Waste (Manual Cold Vapor Technique)
EPA$_2$ Method 7471 Mercury in Solid or Simi Solid Waste Manual Cold Vapor Technique
SM 3030 A-J. Sample Digestion Methods
SM 3500-Hg C. Dithazone Method

Nickel

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH<2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 249.1 Atomic Absorption-Direct Aspiration Technique
EPA$_1$ 249.2 Atomic Absorption-Furnace
MSA 19 Nickel, Copper, Zinc, and Cadmium
SM 3030 A-J. Sample Digestion Methods
SM 3500-Ni C. Inductively Coupled Plasma Method
SM 3500-Ni D Heptoxime Method (General)
SM 3500-Ni E. Dimethylclyozime Method (General)

Nitrogen (Ammonia)

Collect samples in either plastic or glass containers. For ammonia-nitrogen, the minimum sample size is 500 ml.

Preserve with sulfuric acid (H_2SO_4), refrigerate and store for up to 7 days.

EPA$_1$ 350.1 Colorimetric-Automated Phenol
EPA$_1$ 350.2 Colorimetric-Titrimetric Potentiometric-Distillation Procedure
EPA$_1$ 350.3 Potentiometric-Ion Selective
MSA 32-2 Recovery of Nitrogen as Ammonia by Steam Distillation Electrode Method
SM-NH$_3$ B. Preliminary Distillation Step

SM-NH_3 C. Nesslerization Method (Direct and Following Distillation
SM-NH_3 D. Phenate Method
SM-NH_3 E. Titrimetric Method
SM-NH_3 F. Ammonia Selective Electrode Method
SM-NH_3 G. Ammonia Selective Electrode Method Using Known Addition
SM-NH_3 H. Automated Phenate Method

Nitrogen (Nitrate)

Collect in either plastic or glass containers. For nitrate-nitrogen, the minimum sample size is 100 ml.

Samples for nitrate-nitrogen should be analyzed as soon as possible. In the field they should be placed on ice, or refrigerated at 4°C.

EPA$_1$ 352.1 Colorimetric Method
MSA 33-8 Nitrate by Colorimetric Methods
SM 4500-NO_3 B. Ultraviolet Spectrophotometric Screening Method
SM 4500-NO_3 C. Ion Chromatographic Method
SM 4500-NO_3 D. Nitrate Electrode Method
SM 4500-NO_3 E. Cadmium Reduction Method
SM 4500-NO_3 F. Automated Cadmium Reduction Method
SM 4500-NO_3 G. Titanous Chloride Reduction Method (Proposed)
SM 4500-NO_3 H. Automated Hydrazone Reduction Method (Proposed)

Nitrogen (Nitrate-Nitrite)

Collect in either plastic or glass containers. For total nitrate-nitrite-nitrogen, the minimum sample size is 200 ml.

Preserve by addition of sulfuric acid (H_2SO_4) to a pH of <2, and refrigerate at 4°C.

EPA$_1$ 353.1 Colorimetric-Automated Hydrazine Reduction
EPA$_1$ 353.2 Colorimetric Automated Cadmium Reduction
EPA$_1$ 353.3 Spectrophotometric Cadmium Reduction

Nitrogen (Nitrite)

Collect in either plastic or glass containers. For total nitrate-nitrite-nitrogen, the minimum sample size is 100 ml.

Samples for nitrite-nitrogen should be analyzed as soon as possible. In the field they should be placed on ice, or refrigerated at 4°C.

EPA$_1$ 354.1 Spectrophotometric
MSA 33-9 Nitrite by Colorimetric Methods
SM 4500-NO_2 B. Colorimetric Method
SM 4500-NO_2 C. Ion Chromatographic Method

Nitrogen (Total Kjeldahl)

Collect in either plastic or glass containers. For total Kjeldahl-nitrogen, the minimum sample size is 500 ml.

Preserve by adding sulfuric acid (H_2SO_4) to a pH of <2, and refrigerated at 4°C.

EPA$_1$ 351.1 Colorimetric-Automated Phenate
EPA$_1$ 351.2 Colorimetric-Semiautomated Black Digester
EPA$_1$ 351.3 Colorimetric-Titrimetric Potentiometric

EPA$_1$ 351.4 Potentiometric-Ion Selective Electrode
MSA 31 Nitrogen - Total
SM 4500-N$_{org}$ B. Macro-Micro Kjeldahl Method
SM 4500-N$_{org}$ C. Semi-Micro Keldahl Method

Odor

Collect in glass containers, with a minimum sample size of 500 ml. If only gas samples are taken for analysis, collect in glass gas bottles.

Store on ice in the field and analyze within 6 hours.

EPA$_1$ 140.1 Threshold Odor-Consistent Series
SM 2150 B. Threshold Odor Test

Oil and Grease

Collect in wide-mouth glass containers, with a minimum sample size of 11.

Preserve with sulfuric acid (H_2SO_4) to a pH of < 2, then refrigerate. Samples may be held up to 28 days.

EPA$_1$ 413.1 Gravimetric-Seperatory Funnel Extraction
EPA$_1$ 413.2 Spectrophotometric-Infrared
EPA$_2$ Method 9071 Oil and Grease Gravimetric Separatory Funnel Extraction
SM 5520 B. Partition-Gravimetric Method
SM 5520 C. Partition-Infrared Method
SM 5520 D. Soxhlet Extraction Method
SM 5520 E. Extraction Method for Sludge Samples
SM 5520 F. Hydrocarbons

Organic Matter

Collect sludge samples in wide mouthed glass containers, and liquid samples in glass containers. Rinse glass containers in a solvent as preparation for field collection.

No preservative added. Keep refrigerated; however, if organic compounds are highly volatile, samples should be kept frozen.

MSA2 30 Organic Matter Characterization
MSA2 30-2 Extraction of Soil Organic Matter
MSA2 30-4 Purification of Humic and Fulvic Acids
MSA2 30-5 Characterization of Humic Materials by Chemical Methods
MSA2 30-6 Characterization of Humic Materials by Spectrometric Methods
SM 5000 Determination of Aggregate Organic Constituents
SM 5310 A-D. Total Organic Carbon
SM 5320 A-B. Dissolved Organic Halogen
SM 5510 A-C. Aquatic Humic Substances
SM 5530 A-D. Phenols
SM 5540 A-D. Surfactants
SM 5550 A-B. Tannin and Lignin
SM 5560 A-B. Organic and Volatile Acids
SM 5710 1-E. Trihalomethane Formation
SM 6000 Determination of Individual Organic Constituents
SM 6010 C. Analytical Methods Hydrocarbons
SM 6040 A-C. Constituent Concentration by Gas Extraction
SM 6040 B.
SM 6210 A-D. Volatile Organics
SM 6211 A-C. Methane
SM 6220 A-E. Volatile Aromatic Organics
SM 6230 A-E. Volatile Halocarbons
SM 6231 A-D. 1,2-Dibromoethane (EDB) and 1,2-Dibromo-3- Chloropropane (DBCP)
SM 6232 A-D. Trihalomethanes

SM 6410 A-C. Extractable Base/Neutrals and Acids
SM 6420 A-C. Phenols
SM 6431 A-C. Plychlorinated Biphenyles (PCBS)
SM 6440 A-C. Polynuclear Aromatic

Pathogens

Collect samples in either plastic or glass containers.

Analyze as soon as possible. If they cannot be analyzed immediately upon arrival at the lab, they may be refrigerated at 4°C.

SM 9260 A. Detection of Pathogenic Bacteria
SM 9260 B. General Qualitative Isolation and Identification Procedures for Salmonella
SM 9260 C. Immunofluoroescence Identification Procedures for Salmonella
SM 9260 D. Quantitative Salmonella Procedures
SM 9260 E. Shigella
SM 9260 F. Pathogenic Escherichia Coli
SM 9260 G. Campylobacter Jejuni
SM 9260 H. Vibrio Cholerae
SM 9260 I. Pathogenic Leptospires
SM 9260 J. Legionet laceae (Legionares' Disease)
SM 9260 K. Yersinia Enterocolitica

Pesticides

Collect samples in glass containers with Teflon caps that have been rinsed in organic solvents. Solvent used in rinse depends upon the particular analyte being tested.

Preserve with 1000 mg/l of ascorbic acid if there is residual chloride present, then refrigerate at 4'C. Samples may be held for up to 7 days before extraction, and up to 40 days after extraction.

EPA$_1$ 504 1.2-Dibromoethane (EDB) and 1,2-Dibromo-3-Chloropropane (DBCP) in Water by Micro extraction and Gas Chromatography
EPA$_1$ 505 Analysis of Organohalide Pesticides and Commercial Polychlorinated Biphenyl Products in Water by Micro Extraction and Gas Chromatography
EPA$_1$ 507 Determination of Nitrogen and Phosphorus Containing Pesticides in Water by Gas Chromatography with a Nitrogen Phosphorus Detector
EPA$_1$ 508 Determination of Chlorinated Pesticides in Water by Gas Chromatography with an Electron Capture Detector
EPA$_2$ 4.3.1,Gas Chromatographic Methods
EPA$_2$ Method 8140 Organophosphorus Pesticides

pH

Collect samples in plastic (polyethylene or equivalent) or glass containers.

No preservation is needed. Analyze samples immediately. The maximum holding time is 2 hours.

EPA$_1$ 150.1 pH-Electrometric
EPA$_2$ Method 904 1: pH Paper Method
EPA$_2$ Method 9045: Soil pH
MSA 12 Soil pH and Lime Requirement
MSA 12-2 Soil pH Hydrogen Ion Activity: Intensity Factor of Soil Acidity

Phosphorus

Collect samples in nitric acid washed plastic or glass containers, with a minimum sample size of 100 ml.

Refrigerate at 4°C. Maximum holding time is 48 hours. Samples to be analyzed for ortho-phosphorus are to be filtered immediately, then refrigerated.

EPA$_1$ 365.1 Colorimetric-Automated Ascorbic Acid Method
EPA$_1$ 365.2 Colorimetric-Ascorbic Acid Single Reagent Method
EPA$_1$ 365.3 Colorimetric-Ascorbic Acid Two Reagent Method
MSA 24-2 Total Phosphorus
MSA 24-3 Organic Phosphorus
MSA 244 Fractionation of Soil Phosphorus
MSA 24-5 Available Indices
SM 4500-P C. Vanadomolybdophosphoric Acid Colorimetric Method
SM 4500-P D. Stannous Chloride Method
SM 4500-P E. Ascorbic Acid Method
SM 4500-P F. Automated Ascorbic Acid Reduction Method

Potassium

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve by adding nitric acid (HNO_3) to a pH of <2, then refrigerating at 4°C. Preserved samples may be stored for up to 6 months.

EPA$_1$ 258.1 Atomic Absorption-Direct Aspiration
MSA 13 Lithium, Sodium, and Potassium
SM 3500-K C. Inductively Coupled Plasma Method
SM 3500-K D. Flame Photometric Method

Sodium

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH <2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 273.1 Atomic Absorption, Direct Aspiration
MSA 13 Lithium, Sodium, and Potassium
MSA 13-2 Total Analysis
MSA 13-4 Exchangeable and Soluble Sodium
SM 3500-Na C. Inductively Coupled Plasma Method
SM 3500-Na D. Flame Emission Photometric Method

Sodium Absorption Ratio (SAR)

Collect samples in glass, plastic or metal containers.

No preservation is needed. Refrigerate at 40°C.

SC 8.2.4[5] Sodium Hazard

Solids Content

Collect samples in either plastic (polyethylene or equivalent) or glass.

Refrigerate at 4°C. In the field, they should be kept on ice. Maximum storage time is 7 days.

SM 2540 B. Total Solids
SM 2540 C. Total Dissolved Solids
SM 2540.D. Total Suspended Solids
SM 2540 E. Fixed and Volatile Solids
SM 2540 F. Settleable Solids
SM 2540 G. Total, Fixed and Volatile Solids in Solid and Semisolid Samples

Soluble Salts (Salinity)

Collect samples in glass containers with a minimum sample size of 250 ml. If the samples are not analyzed immediately, then wax seal the containers.

Sealed samples may be refrigerated at 4°C for up to 6 months, while unsealed samples should be analyzed immediately upon arrival at the lab.

SM 2520 B. Salinity – Electrical Conductivity Method

Toxic Characteristics Leaching Potential

Collect samples in wide-mouthed containers of a composition that is suitable to the nature of the solid waste and the analysis to be performed. About 41 containers should be used with 140 g samples and 2 liter containers for 70 g samples.

Refrigerate at 4°C.

EPA$_2$[4] - 2.4 Characteristics
EPA$_2$[4] - 2.4.1 EP and TCLP Extracts

Total Organic Carbon

Collect 100 ml. samples in glass containers.

If samples are not to be analyzed immediately, preserve to a pH of <2 with HCL (hydrochloric acid) and refrigerate at 4°C. The recommended storage time is 7 days with a maximum of 28 days.

SM 5310-B. Combustion-Infrared Method
SM 5310-C. Persulfate-Ultraviolet Oxidation Method
SM 3510-D. Wet-Oxidation Method
MSA2 29-3 Organic Carbon

Trihalomethanes

Collect samples in glass containers with Teflon-lined lids that have been rinsed in organic solvent.

Analyze samples immediately, however, they may be refrigerated at 4°C for up to 7 days. Preserve with 1000 mg/l of ascorbic acid only if residual chlorine is present.

SM 6232-B. Liquid-Liquid Extraction Gas Chromatographic Method
SM 6232-C. Purge and Trap Gas Chromatographic/Mass Spectrometric Method
SM 6232-D. Purge and Trap Gas Chromatographic Method

Zinc

Collect samples in either plastic or glass containers that have been washed with 1+1 nitric acid (HNO_3).

Preserve to pH <2 with nitric acid. Samples for dissolved metals should be filtered immediately, then preserved with nitric acid. Samples may be stored up to 6 months.

EPA$_1$ 289.1 Atomic Absorption-Direct Aspiration Technique
EPA$_1$ 289.2 Atomic Abspt-Furnace Technique
MSA 19 Nickel, Copper, Zinc, Cadmium
SM 3500-Zn C. Inductively Coupled Plasma
SM 3500-Zn D. Dithazone Method 1
SM 3500-Zn E. Dithazone Method 2

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Additional Resource F
Comprehensive Bibliography

The following bibliography is categorized according to the following:

- **General Overview** lists articles that provide overviews of waste management or incorporate many food groups.
- **Animal Products**
- **Brewery/Distillery/Winery Products**
- **Dairy Products**
- **Vegetable and Fruit Products**
- **Specialty Products**
- **Treatment Technologies** lists articles pertaining to treatment technologies including removal efficiencies for food wastes in general.

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Additional Resource G
Alternative Methods for Disposal/ Utilization of Organic By-Products from the Literature

by
Christina A. Merlo
Research Technologist

Walter W. Rose
Associate Director, Research

National Food Processors Association
6363 Clark Avenue
Dublin, California 94568

Presented at the 1992 Food Industry Environmental Conference,
Atlanta, Georgia

1992 Food Industry Environmental Conference
Georgia Institute of Technology, Atlanta, Georgia 30332

Abstract

Solid vegetable, fruit, and other organic wastes are by-products of food processing. A recent search of literature for alternative methods for handling these solids yielded methods which can be grouped into eight categories.

Research on anaerobic digestion to yield methane has been performed on wastes from fruit, vegetable, coffee, sugar beet, and tuna processing. In making animal feed or silage, the solids may need to be pressed or dried prior to use as feed, or they may be preserved by ensiling.

Composting of dewatered sludge, fruit, vegetable, and chocolate processing wastes has been studied; a humus-like material that can be used as a soil conditioner is produced. Edible fiber has been extracted from apple, pear pomace, or oat and other seed hulls. Fermentation of solids may yield alcohol, acid, or biodegradable plastics depending upon feedstock (apple pomace, whey concentrate, potato, cornstarch, and sugar beet wastes, and biomass) and microorganisms utilized.

Incineration makes use of organic waste by burning it as fuel. Pyrolysis utilizes pits, shells from fruits, nuts which are charred under controlled conditions, ground, mixed with starch, and formed into briquettes. Soil amendment employs the fertilizing and conditioning characteristics of fruit and vegetable food residuals.

Introduction

The objective of this literature search was to learn of methods that could be used for disposal of or utilization of organic byproducts and to obtain information about the methods. We have included the main methods found grouped into eight categories, along with information, which may be of use to food processors who wish to consider implementing them.

Anaerobic Digestion

Organic matter is digested by a mixed population of bacteria to yield methane and carbon dioxide. The process is thought to take place in three stages. In the first stage, fermentative stage, organic polymers are broken down to lower molecular weight molecules like glucose, amino acids, glycerol and then to organic acids, ethanol, hydrogen, carbon dioxide. In the second stage, acidogenic stage, acids and alcohols are converted to acetate, carbon dioxide and hydrogen. Finally, in the third stage, methanogenic stage, methane-producing bacteria obtain metabolism energy by converting acetate, carbon dioxide and hydrogen to methane and carbon dioxide. (45) This process is widely used in sewage treatment plants. Some laboratory and pilot plant work has been done on food wastes. It makes use of waste with low crude protein content (3.5-4.5%).

To utilize the methane end product, improvements are needed in boiler/burner systems to be able to use the digester gas. Cleaver-Brooks has a digester gas system with a dual canister burner that seems to solve this problem. (2 1)

Laboratory Scale-Apple, Orange, Corn, Sugarbeet, Pineapple, Asparagus

Laboratory scale (8 l) work was done on hammer milled waste apple-peels, cores, rejected fruit-com cobs, apple press cake, extracted sugarbeet pulp, pineapple pressings, and asparagus waste (the fibrous lower ends) with 3.5-4.25 kg total solids (TS)/ M^3/day feed, giving conversions of 88-96% of organic solids to gas (methane and carbon dioxide, 50-60% methane) (0.4-0.6 1 gas/ gram of organic solids). For no apparent reason, after 63 days gas yields from apricot waste decreased by more than half. (42)

Laboratory scale work (10 l fermenters) was done at 37°C with comminuted orange peel (8nun screen, 10% solids) at 3.5 kg TS/M3/day. This was supplemented with $(NH4)_2$ PO4 and other inorganic nutrients. If peel oil is < 0.075 g/l digestion liquor per day (with commercial oil recovery equipment) the system will yield gas which is 50-55% methane (0.5 m^3/kg of TS); the conversion of solids to gas approaches 100%. (39)

Pilot Scale-Apple, Apricot, Peach, Pear, Orange

A pilot scale digester (23 M3 capacity) operated for three years at an Australian fruit and vegetable processor (Letona Co-operative Cannery Ltd., Leeton) obtaining 79-96% destruction of organic solids. Energy produced, as gas was 1.6-2.7 times the electrical energy consumed; average methane content of gas produced was 55%; higher energy returns are expected at higher loading rates and with digesters of simpler design. It was operated on a day-to-day basis, with 0.5-1 ton (metric ton) of wet waste per day (2.4-4.6 kg dry weight solidS/M^3/day) for 37-203 days. It was operated at 30-40'C (85-105'F). Thermophilic conditions at 55-65-C (130-150'F) were not successful. Feeds were from apple press cake from juice extraction, apricot fiber from brush finisher during pulp manufacture, peach/pear waste such as peels, cores, trimmings, and reject fruit from canning, and orange peels after extraction of oil and juice. Experimenters supplemented the feeds with $(NH4)_2$HP04 for nitrogen and NaHCO3 to maintain a pH > 6.8. An alternative is to use pig or poultry manure (see Plug-Flow Reactor below). (43, 44, 45)

Laboratory scale (2.5 1 and 6 1) and pilot scale (775 1) studies were done with apple pomace that had a pH=4.1, TS > 20%, and low nitrogen and alkalinity. The lab scale was done at mesophilic (35'C) and thermophilic (55°C); the pilot scale was done at thermophilic. A 60-day hydraulic retention time gave total volatile solids removal efficiency of 70% and biodegradable volatile solids removal of 90%. Methane content of gas was 60%. (25, 30)

Laboratory Scale-Plug-Flow Reactor-Apple

Laboratory scale work was done on apple press cake of 10% organic solids w/w in a three-stage horizontal plug-flow reactor. This reactor was lower cost with a total operating volume of 4 1. In this type of reactor no intentional mixing takes place; the contents are discharged gradually by successive charges of feed. Experimenters had to inoculate the daily charge of feed with digester liquor to get a microbial population into the feed. Using 2.2 kg organic solids/m3/day with weekly addition of dried poultry manure (4 kgTS/M3) gave 78% conversion of organic solids, with gas yield of 0.51 m3/kg organic matter. The average methane content of gas produced was 60%. Experimenters recommended that this be studied on a pilot scale with a two-stage reactor. (40)

Laboratory Scale-Sludge from DAF of Tuna Wastewater

Laboratory scale work was done on the sludge from DAF (dissolved air flotation) of tuna processing wastewater. This was a relatively salt free sludge with 700 ppm NACL, approximately 8% total solids, 139,400 mg/l total COD, and 9600 mg/l soluble COD. It was used in 2 *l* flasks with 8-, 12-, and 15-day detention times. Gas produced had a relatively high methane content. Reductions occurred in the following parameters after 12 days retention: total solids-54%, volatile solid-65%, COD-59%, lipid-77%, protein 47%. The authors recommended that this be studied on a much larger scale. They anticipate 86% reduction of total solids (dry basis) if solids are centrifuged. If gas produced is 78% methane, it is valued at $15,500/year in 1977 dollars. If this process were implemented, tuna would need to be thawed in fresh water during processing to keep salt levels from becoming too high in the digester. (35)

Laboratory Scale-Coffee Grounds

Laboratory scale work was done with spent coffee grounds homogenized to a smooth cream and supplemented with a source of ammonia and phosphorus and inorganic nutrients in 250 n-11 and 10 *l* fermenters. Use of 2 kg/M3/day feed achieved 99% conversion of solids to gas which was 56-63% methane, but gas production declined over the 80 days from 1.7 to 0.45 *l*/*l*/day. Researchers could not identify the component causing the problem. It was not heavy metal, caffeine, or melanoid pigment. They could not acclimate the feed to overcome the toxicity in a 3-month period. The authors suggested the need to develop a good method of separating the sludge solids and overcoming the inhibition of gas production. (41)

Commercial System

A commercial system has been developed for anaerobic digestion or fermentation of strong or warm wastes such as high strength wastewaters. (1)

Animal Feed

Using food-processing by-products as animal feed has been a common practice. The by-product may need to be pressed or dried prior to use as feed, or it may be ensiled to preserve it. Or other means of treating by-products may produce animal feed. Some wastes have good nutrients and are incomplete as animal feed, but they make good feed supplements.

Animal Feed-General

Fruit and vegetable processing by-products are used as animal feed. They may need to be pressed and/or dried prior to use. Fruit and vegetable wastes, such as partially air dried corn waste, dehydrated pineapple waste, and waste from citrus and potatoes, are produced year-round and are an especially good and dependable source of animal feed. If wastes are not generated year-round, they are a less reliable source of animal feed and may require some treatment for storage. Peaches, pears, tomatoes, and cherries are seasonal, low in nutrient content, and often require long hauling distances. (20)

A study was done of animal feeds from various commodities including citrus pulps, almond hulls, fresh peaches, dried peaches, fresh pears, dried pears, fresh prunes, dried prunes, fresh grapes. and dried raisins. A nutritive analysis was done. (23)

Research was done on cauliflower stems and leaves. In the past, cauliflower waste has been returned to the fields and dumped on the ground, causing fly and odor problems. Research was done on pressing and drying cauliflower stems and leaves for ruminant and poultry feed, respectively. Stems have good fiber and protein content similar to alfalfa with possibly higher digestibility (86% vs. 50-60%). Leaves have xanthophylls, which is needed for skin pigmentation in broilers and the orange color of egg yolks; leaf meal is excellent for ruminant feed with up to 28% protein and 12.5% fiber. (37)

There has been some concern expressed that chemicals (pesticides) may be in higher levels in the waste being fed to animals, which then become human food.

Diet Supplement

Some food processing by-products have good nutrients but are incomplete as animal feed. Such by-products make good feed supplements. For example, waste activated sludge from citrus processing is high in vitamins and can be dried and used as an animal feed supplement. (20)

Silage

Green forage is ensiled for approximately 70-190 days to allow bacterial fermentation producing lactic and other acids which prevent growth of undesirable bacteria. Fermentation sometimes results in biochemical changes that enhance the nutrient quality. (54, 55)

Animal Feed and Starch from Cull Potatoes

Starch is extracted from cull potatoes; pulp left behind is dried for animal feed; juice left is coagulated and dried for food or animal feed (70% protein dry basis); remaining juice is concentrated and/or evaporated to 65% solids (molasses like) for ruminant feed (43% protein dry basis).

Maintaining a viable starch industry is important to the potato industry. The starch industry allows a greater return to growers for cull potatoes than would be obtained if sold for raw or dried animal feed alone. However, recent advances in potato-based products such as flours and granules have upgraded small potatoes to food use which could make this process less economical. The starch market may depend upon the price of unmodified starches which can be modified to meet traditional uses of potato starch.

A pilot scale study was done in 1978. The process requires a relatively constant supply of culls, approximately 500 tons/day. Equipment needed for the pulp includes a screen, dewatering method such as a screw press, and a tray drier. For starch, the study requires a cyclone(s), centrifuge, and flash or tray drier. For juice, a heat exchanger, steam injection, centrifuge, spray drier, reverse osmosis, and multiple stage evaporator are used.

Based on 200 days/year at 20 hours/day, the first year return on investment is 40.1 %. If processing is located near a ruminant feedlot (≥ 2500 dairy cows), the return on investment is 43.9% because pulp and coagulated juice drying and evaporation of concentrated juice from reverse osmosis is eliminated. Return on investment is critically dependent upon the income from starch. (61, 62)

Treatment of Cereal Straws with Alkali to Improve Digestibility

Cereal straws such as alfalfa stems, wheat straw, corn cobs, grass straw from seed production, and rice straw contain lignin, which decreases their digestibility. By processing with alkali, the digestibility of a relatively neglected agricultural resource is improved. This produces incomplete animal feed which needs protein and other supplementation.

Bench scale work and pilot plant equipment have been used which are capable of processing 1.5 cu. ft. at a time with steam pressure of up to 600 psig. Researchers used <u>in vitro</u> testing (enzyme) to determine digestibility. All straws tested were improved by treatment; some almost doubled digestibility, others increased digestibility by 120%. (37)

Use of Chitin/Chitosan in Animal Feed

Chitin waste is converted to some usable form, if necessary, and added as a diet supplement to animal feed in specified proportions.

Several animals have been successfully fed diets with chitin or chitosan supplements. In broiler chicken it helps to control diarrhea when diet contains whey. In red sea bream, Japanese eel, and yellow tail fish, a supplemented diet shows superiority over a nonsupplemented diet. In hens, chitin decreased animal serum cholesterol levels. Other animals that have been fed chitin or chitosan include rabbits, cattle, gerbils, and rats. (36)

Composting

Composting is a natural microbiological process that biologically decomposes, under controlled aerobic conditions, the organic component of a solid waste to a stable humus-like material. This material can be recycled to the land as a soil conditioner/low-grade fertilizer without adversely affecting the environment. There are generally three types of composting systems: windrow, static pile, and in-vessel. (67)

The composting process takes place in stages. First, ingredients are mixed and held. Next, native microbes multiply and their respiration and other reactions can increase temperatures up to approximately 160'F which can HI pathogenic fungi and viruses. Finally, biochemical activity is reduced. The mix is stable, but microbial activity continues indefinitely. (19)

All composting processes require periodic aeration and maximum surface area for efficient microbial degradation. Bulking agents or admixtures such as rice hulls, sawdust, coffee grounds, or municipal compost can be added to decrease moisture content and increase aeration. Time, temperature, pH (neutral), moisture content, and aeration must be carefully monitored. The proper ratio of carbon to nitrogen is important in order to control odor. Particle size is also important.

Dewatered Sludge

Hydrolyzed Plant Protein

A large pilot plant for composting dewatered sludge from wastewater digesters was designed at FIDCO Inc., a subsidiary of Nestle, in New Milford Farms, New Milford, Connecticut. The wastewater is from their hydrolyzed plant protein facility. The pilot plant is currently producing approximately 6 tons of compost per day, but processing might triple or quadruple in size. FIDCO also uses chocolate by-products from Fulton, New York, and coffee grounds from Freehold, New Jersey. FIDCO's entire process takes 30 days with compost being turned daily. FIDCO finds that coffee grounds and other food wastes raise their solids content to approximately 40% which is desirable. The process facility covers 10,240 sq. ft. and cost <$2 million. (5, 19)

Brewery Waste

International Process Systems, Inc. (IPS) built a facility designed to handle 60 wet tons of dewatered sludge from the wastewater treatment plant from the Anheuser-Busch Brewery, Baldwinsville, New York. Sawdust and recycled compost are used as bulking agents/admixtures. A biofilter is used to treat all exhausted air to control odor. The compost is marketed to landscapers, soil distributors, and others by AllGro, Inc. (13)

Fruit and Vegetable Wastes

Studies have also been conducted to compost fruit waste, mostly peach and apricot residuals, some tomato, and some produce-house waste, using bins and windrows. With closed windrows and high-temperature composting, air-injection was necessary. Bins and open windrows were turned for aeration. Fly breeding and odors were not a problem. Addition of nitrogen helped to shorten composting cycles. Rice hulls were a good bulking agent/admixture. Lime was added to raise pH of fruit/ compost mixture to enhance microbial growth. (48, 49, 50, 51, 57, 58, 60) This research was closely duplicated in bin trials with pear waste. (33, 34) IPS did two full-scale demonstration studies of composting residuals of apple juice and chocolate in a vessel-type system. The bulking agent was sawdust. They produced an end product with 60% dry solids to be used as a soil amendment. (38)

Gelatin Wastes

A forced aeration method of composting was explored using gelatin company wastes. The wastes were 25-30% solids and were the residue from animal skin extractions plus the diatomaceous earth used in filtrations. Wood chips were used as a bulking agent. This was found to be an economical alternative to landfilling. The end product could be used as a horticultural soil amendment. Further tests were continuing. (29)

Edible Fiber

Edible fiber is a relatively new method for utilizing organic solids. Our search revealed two main types of by-products from which edible fibers have been extracted.

Apple/Pear Pomace

Fibers are extracted from apple or pear pomace by filtering and dehydrating. Tree Top has marketed apple and pear fiber. Apple fiber has 56% dietary fiber; pear fiber has 77% dietary fiber.

They were produced by separating solids from juice by an improved mechanical filter, solids were dehydrated and screened through 32-mesh screens. The products have the consistency of rough flour, $\leq$5% moisture, free flowing, brown to brownish red in color, and bland in taste. Tree Top is marketing its product in the areas of variety breads, baked goods, cereal and granola products, pharmaceuticals, laxatives, and pet foods. (53)

Another method of extraction being developed on a laboratory scale is by alkaline treatment and/or other solvent extractions. First, the apple pomace was washed free of sugars. It was air-dried to 11% moisture and milled to pass a U.S. No. 10 sieve. Portions of 100 gm of air-dried pomace were extracted with NAOH, then with ethanol to produce an α-cellulosic fraction with 39% crude fiber (26% of the air-dried pomace), or extracted with different aqueous solvents to produce water-dispersible, uronide fractions (10-18% of the air-dried pomace). (25, 68)

Oat or Other Seed Hulls

There are about 360,000 tons of oat hulls produced in the U.S. per year that are considered waste. Oat hulls and other seed hulls such as corn, soybean, rice, pea, and sunflower can be processed by delignification using an alkali agent to soften the lignin. Hydrogen peroxide is injected through a catalyst into a reactor vessel with heat and pressure causing eruption of the cell wall; lignin becomes solubilized. Most of lignin and hemicelluloses are hydrolyzed out during a washing phase, pH is adjusted to neutral, and dietary fiber product is dried to produce a total dietary fiber of 80% or more. For oats, dietary fiber is 92%. This product is ground to 120 or 180 mesh. The wastewater produced from the washing process has 90% or more of the BOD and COD converted to fuel, apparently by fermentation of biomass using bioengineered bacterium; little remains at the still bottoms.

This process is covered by U.S. Patent #4,842,877, by Xylan, Inc. (Poly-Fi™). It is soon to be produced in Cedar Rapids, Iowa; marketing of product was anticipated for November 1991. The cost of the process is confidential at this time. The patented technology is marketed for a royalty fee. (4, 65, 47)

Fermentation

Parallel Products in Rancho Cucamonga, California, ferments starch, sugar, and alcohol-bearing substances. These byproducts are fermented, distilled, purified, evaporated, and dried to yield . ethanol for fuel and industrial use, dry brewer's yeast for pet food high protein ingredient, and liquid protein concentrate for dairy feed supplement. (18)

Apple Pomace

Apple pomace has been successfully fermented to produce citric acid. In a laboratory scale study, apple pomace was used as a substrate for microbial production of citric acid under solid-state fermentation conditions-cultivation of microorganisms on solid materials in the absence of free liquid. The substrate was inoculated with a mold spore suspension Aspergillus niger. Experimenters used 500 ml flasks with 40 gm pomace, and incubated it at 30'C for 5 days. Methanol was added. Citric acid yields were dependent upon the amount of methanol, the strain of Aspergillus niger, the fermentation time and temperature, and the variety of apple. Citric acid yields of 90 gm per kg of pomace were obtained. (25)

A laboratory scale study was conducted in 1/2-gal jars and inoculated with wine yeast Saccharomyces cerevisiae at 30'C for 96 hours. Yields of 29-40 gm of ethanol per kg of pomace were obtained, depending upon the initial sugar content. The alcohol was separated from the spent apple pomace by rotary evaporation. The ethanol produced could have served as a substrate for vinegar production. The spent pomace may have made a better animal feed supplement because it had more protein from the yeast. (25, 26)

Biomass-Using Bioengineered Bacterium

A genetically engineered bacterium based on Escherichia coli can convert all of the basic six-carbon and five-carbon sugar building blocks found in biomass-agricultural wastes, wood, and garbage-into ethanol. The process generates ethanol at half the cost of current processes. The license to commercialize was granted to BioEnergy, Inc. in Gainesville, Florida, by the University of Florida Research Foundation, Inc. A pilot program has begun on selected feedstocks; researchers plan to utilize strategic partnerships to transfer technology on an international scale. (6, 9, 47)

Concentrated Whey

A large-scale 15,000-gal study was conducted where whey lactose was fermented into a high protein yeast cellular material by Saccharomyces fragilis. A metabolic product formed during the fermentation was ethanol. (66)

Potato Waste

A study was done at a potato processor on alcohol production from potato waste. Stillage wastes and selected waste streams from potato processing operations were put through an anaerobic filter to reduce effluent BOD and to produce methane. The potato processing operation produced enough waste processing energy to supply nearly all the alcohol production process energy. (2)

Sugar from Cornstarch, Sugarbeets-Producing Biodegradable Plastic

Sugar from Cornstarch and sugarbeet has also been successfully converted by microorganisms to biodegradable polymers. Polyhydroxybutyrate (PHB) and polyhlydroxybutyrate-valerate (PHBV) biodegrade to carbon dioxide and water when enzymes, which are seated by microorganisms in soil break down their polymer chain. These plastics are, made without petroleum, a primary raw material for other plastics, but are several years from commercial production. Eventual costs of these materials are estimated to be 10-20% of the cost of producing bulk PET (polyethylene) and PS (polystyrene). Several companies and universities are developing PHBV and PHB including: IC! Biopolymers; Agri-Tech Industries Inc.; University of Illinois-Urbana; Massachusetts Institute of Technology; University of Massachusetts-Boston; Office of Naval Research-Arlington, Virginia; Michigan State University-East Lansing; University of Virginia-Charlottesville. (11)

Potato or Cornstarch Waste-Producing Biodegradable Plastic

Starch from potato or cornstarch waste is hydrolyzed to glucose by means of high-temperature alpha amylase to solubilize the starch, and glucoamylase to break it down into glucose. The glucose is fermented to lactic acid by bacterium lactobacillus. Lactic acid with equal amounts of hydroxyl and carboxyl groups can self-condense to form linear thermoplastic polyesterpolylactic acid (PLA), a biodegradable plastic. The process is now three to five years from being offered to farmers as timed-release coatings for fertilizers, pesticides, and agricultural mulch films, which degrade in the soil. (7, 12, 14, 32, 64)

Incineration

During incineration, biomass such as fruit pits, tea leaves, nut shells, tree pruning, etc., is burned as fuel, often for boilers. The biomass must be relatively high in solids, approximately 50% or more. Incineration requires a burner designed to combust the biomass and handle the gases, ashes, and emissions produced. Fuel drying must be carefully monitored for consistent bum. Examples of commercial installations of this process are described below.

A fluidized bed pit burner was installed at Lindsay Olive Growers, Lindsay, California, in 1977. It burned olive pits of almost 50% moisture to provide 25% of energy needed for steam. One hundred twenty-five tons of olive pits yielded 30 gallons of ashes for disposal. (10)

Nestle's Granite City, Illinois, plant dries spent tea leaves of 80% moisture to approximately 10% moisture. The dried leaves then serve as fuel for the dryer burner and are being used with wood from tea chests to provide fuel for production of 30,000 lb of steam per hour-approximately one-third of the plant's needs. (46)

Diamond Walnut in Stockton, California, bums ground walnut shells to fuel a cogeneration plant. Previously they had unsuccessfully tried gasification. They produce 26,000-33,000 tons of walnut shells annually, burning 4 tons/hr. They are now producing power at up to 32 million kwh/yr, using approximately one-third of the power and selling the rest. The cogeneration plant cost $3.7 million with $1.2 million savings/yr. (22)

S&W Fine Foods in Modesto, California, is an entirely biomass fueled major process plant. Forty percent of the biomass is generated internally; the rest is acquired from outside. The cogeneration unit supplies 50,000-60,000 pounds of steam per hour, and powers a 4500 KWH capacity electric generator. The electricity is sold to a utility company. The fuel is gasified (Cyclo-blast). The cost was $3 million with 3.1-year payback. (3, 8, 16)

Tri/Valley Growers in Modesto, California, fires one of its plant boilers almost entirely with crushed peach pits (80% pits, 20% conventional fuel). Plans were underway to fire another boiler. Air quality has to be maintained by means of scrubbers and other costly pollution control equipment. Fuel drying must be carefully monitored. The cost was $447,000 with payback under 3 years. (15)

Pyrolysis

Nut shells and fruit pits with an average moisture content of 10-15% are turned into charcoal briquettes in a Pyrolysis unit.

A briquette experiment began in 1964 with peach pits. The demand for briquettes increased to the point in the early 1970s where an average annual volume of 150,000 tons of peach, apricot and olive pits, and almond and walnut shells were used to produce 35,000 tons of high quality charcoal briquettes at the C.B. Hobbs Corp. in Elk Grove, California.

The first stage of this process is a controlled charring process in an oxygen poor atmosphere. The product then proceeds through three more hearths. Temperature of the fourth hearth is raised to 1500'F. As the product is discharged, it is quenched by water spray. It is then called char. The char is ground, screened, and then mixed with a starch binder in proportions of 95% char to 5% starch. The byproduct is formed into briquettes, dried, and bagged. The Pyrolysis unit has natural gas fueled exhaust stack preheat burners to completely bum the flue gases. (17, 20) To our knowledge, this process is not being utilized commercially anymore.

Soil Amendment

Converting food wastes to soil amendments and fertilizers for land application is a common technology. It takes advantage of the fertilizing and conditioning characteristics of food residuals. If the residuals are applied directly to the land, they are spread thinly, allowed to dry, and finally disked. This process may be repeated depending on the waste characteristics.

In areas with clay soils, or soils low in nutrients and organic matter, this is particularly advantageous. At relatively low annual loadings of between 3-10 dry tons/year, it has been shown to greatly improve soil friability, the ability of the soil to crumble, and make nonarable land suitable for agriculture. Operations can occur during the non-rainy season.

Cherries, apricots, peaches, pears, and tomatoes tend to be acidic, so they will change the pH of the soil. These materials also have low nitrogen relative to carbon, which is unfavorable to crop growth since inorganic nitrogen in soil will be immobilized by soil microorganisms, leaving the soil nitrogen deficient.

Ground and surface water contamination are potential problems, but are minimized by the low nutrient and metal content of fruit residuals. Planting crops immediately following spreading and prior to rains appears to utilize the nitrogen, phosphorus, potassium, sulfur, and micronutrients in residuals. Rapid planting prevents ground water contamination. Improved permeability of soil can lead to solubility of upper subsoil salts leaving less alkaline soil.

A case study of peaches, pears, and tomatoes was done in Gilroy, California. The fruit residuals were low in nutrients, heavy metals, and pesticide residue, and high in carbohydrates and water; hence they were an excellent soil conditioner, particularly advantageous to clay soils. They required 700 acres for disposal at 140-150 cubic yards/acre loading rate. During 1972 to 1978, operating costs were \$0.90/cubic yard for the first year, \$0.65/ cubic yard for the second year, and \$0.50/cubic yard for successive years. Hauling costs were between \$1.50-\$3.00/cubic yard.

In land application programs, odor, fly, and rodent problems must be addressed. The site must be within an economically feasible hauling distance yet away from densely populated areas and large enough to handle the waste. High temperatures aid in the quick drying of the wastes. Quick drying and close super-vision of the spreading operation are keys to success.

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Soil must be prepared before spreading waste by disking to a depth of 8- 1 0". Large clumps of soil should be broken and the soil leveled to avoid paddling. Timing of preparation is critical to attain maximum dryness prior to spreading. Spreading is done in a 4-8" layer. As soon as possible after spreading, the layer is further spread to 14" and crushed by tandem drag. This is left to dry 48 hrs. This makes the next disking operation easier and aids in aerobic decomposition. The area is disked to 6-8" and dried 48 hrs more; tandem drag is passed again. The site dries for 48 hrs more and is then disked and dried again. The soil is leveled prior to planting. The total process takes approximately one week before land is ready for crop planting. (20)

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Additional Resource H
Source Reduction Strategy Manual

by
Pennsylvania Department of Environmental Protection
Bureau of Waste Management
Commonwealth of Pennsylvania

July 1, 1992
Revised May 28, 1993

For the Source Reduction Strategy Manual, Forms, and related documents click on:

http://www.dep.state.pa.us/dep/deputate/airwaste/wm/mrw/SRS_Manual/SRS_Manual.htm

Additional Resource I
Compliance Materials for Generators of Residual Waste

by
Pennsylvania Department of Environmental Protection
Bureau of Waste Management
Commonwealth of Pennsylvania

http://www.dep.state.pa.us/dep/deputate/airwaste/wm/MRW/MRW.htm

Scroll to Residual Waste, Generator's Residual Waste Biennial Report, and then click on Biennial Report

Additional Resource J
Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed

by
Department of Health and Human Services
Public Health Service
Food and Drug Administration 200 C Street, S.W.
Washington. DC 20204

August 1992

For Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed click on: http://www.cfsan.fda.gov/~lrd/fdaact.html

Additional Resource K
Regulatory Agency Contacts

Contact addresses and phone numbers by region are provided on the following pages for the Pennsylvania Department of Environmental Protection and the Pennsylvania Department of Agriculture.

For DEP Regional Office Contacts click on:

http://www.dep.state.pa.us/dep/deputate/fieldops/default.htm

For Department of Agriculture Home Page click on:

http://www.pda.state.pa.us

Additional Resource L
Field Application of Manure

Field Application of Manure is a supplement to the Manure Management for Environmental Protection manual published by the Pennsylvania Department of Environmental Protection.

Field Application of Manure (Document No. 361-0300-002): Published October 1986 and revised December 1999 For the manual click on:

http://www.dep.state.pa.us/dep/subject/All_Final_Technical_guidance/bwqm/bwqm.htm

Additional Resource M
FPR Application Vehicle:
Calibration of Application Rate

Calibrating the FPR application rate distributed by field vehicles is critical to proper implementation of the FPR nutrient management program.

The amount of FPR to be applied is dependent on the moisture and nutrient contents of the FPR, and the anticipated crop need for nutrients. The application rate of FPR is usually limited by the nitrogen requirement for crop production. The calibration procedure in this section assumes that N is the limiting factor. If this is not the case, substitute the limiting maximum application rate for the material referring to the maximum N application rate (step 1.a on the next page).

An FPR applied in the field always contains a certain amount of moisture and is defined here as wet FPR. The moisture content of the FPR to be land applied should be determined as it is loaded for transportation to the field. It is not necessary that every load leaving the plant be checked if the material is relatively consistent. However, care should be taken to insure that the FPR analyzed for moisture content is truly representative of the material actually being field applied.

Total nitrogen content of the FPR is obtained from the most recent applicable chemical analysis. It is important to use chemical analyses which are representative of the FPR to be applied.

The rate of FPR application for field vehicles is adjusted by either altering the ground speed of the vehicle or by modifying adjustments on the spreader device. The initial steps in calibrating FPR application involve determining the distance traveled by the vehicle while applying a known volume of FPR material. Use of a hand-operated distance measuring wheel is suggested.

The following method of FPR application vehicle calibration applies to the use of either a manure spreader for solid FPR, or a liquid FPR application vehicle.

Step 1: Determine the target FPR application rate

Apply the FPR for a short distance, approximately 100 feet and measured the width of the application using a tape or measuring wheel.

a. The FPR application rate can be expressed as either gallons per acre or wet tons per acre, depending on the form of stabilized FPR to be spread. The application rate is dependent on the desired amount of nitrogen to be supplied to the crop, the average concentration of total nitrogen in the FPR, and the solids content of the FPR. Calculate the dry tons of FPR required per acre using the following formula:

$$\text{Dry Tons of FPR per acre} = \frac{\text{Lbs. Of Available N to be Applied per Acre}}{\text{Avg. FPR-N Content (\%) x N Availability Factor (\%) x .20}}$$

b. Next, calculate the wet tons of FPR required per acre:

$$\text{Wet Tons of FPR per acre} = \frac{\text{Dry Tons of FPR per Acre x 100}}{\text{Avg. FPR Solids Content in \%}}$$

c. For liquid application, gallons per acre can be calculated::

$$\text{Gallons of FPR per acre} = \frac{\text{Dry Tons of FPR per Acre} \times 100}{\text{Avg. FPR Solids Content in \%} \times 0.00425}$$

Step 2: Determine the capacity of the application vehicle

a. For a liquid FPR application vehicle, such as an Ag-Gator or Field Gymmy, find the capacity of the tank in gallons. This will normally be on the order of 1500 to 3000 gallons.

b. For solid FPR application equipment, such as a conventional manure spreader pulled by a tractor:

1. Use a pair of field scales to weight the empty spreader. This will require the operator to drive over the scales. Weights will be recorded for all the wheels of the spreader and the rear tires of the tractor if it bears some of the spreader weight. These should be added to find the composite weight.
2. Using a front-end loader, fill the spreader to capacity with solid FPR.
3. Once again, weigh the spreader with the field scales and get a composite weight.
4. Subtract the initial total weight with the spreader empty from the final total weight with the spreader full. The result is the total wet weight capacity of the spreader. Divide this weight by 2000 to express weight in tons.

Step 3: Determine the application width of the vehicle

Apply the FPR for a short distance, approximately 100 feet and measured the width of the application using a tape or measuring wheel.

Step 4: Determine the desired length of field to apply per load

The desired length of field needed to empty the full capacity of the spreader for a given application rate can be found through the following formula:

$$\text{Area Applied per Load in ft}^2 = \frac{(\text{capacity of Application Vehicle}) \times 43{,}560}{\text{Target FPR Application Rate}}$$

$$\text{Length of Application per Load in ft} = \frac{\text{Area Applied per Load in ft}^2}{\text{Width of Application}}$$

Step 5: Calibrate the application vehicle settings

a. With the measuring wheel, roll out the target distance (from Step 4) that the operator of the FPR application vehicle must travel as he uniformly applies his load. Place a marker flag.

b. Depending on the vehicle used, one or more combinations of vehicle speed and spreader settings may meet the target FPR application rate. However, it usually takes several trial runs to find an acceptable combination of engine speed (rpm), gear, and valve opening settings.

c. Over the course of the first year of application, the operator will gain experience in applying at various rates, thereby requiring less time for calibration.

Tables M-1 and M-2 provide useful conversions when calculating weights and volume of FPR.

Table M-1
FPR conversion table for application vehicle capacity

Tank Size	Tons of Wet FPR
500 gallons	2.1 tons
1000 gallons	4.3 tons
2000 gallons	8.5 tons
4000 gallons	17.0 tons
Gallon of FPR=8.5 lbs.	
75 bushels	3.0 tons
100 bushels	4.0 tons
125 bushels	5.0 tons
150 bushels	6.0 tons
1 bushel of FPR-80 lbs	
100 cubic feet	3.2 tons
200 cubic feet	6.4 tons
300 cubic feet	9.6 tons
1 cubic foot of FPR – 64 lbs.	
Other Helpful Conversions: 7.5 gallons per 1 cubic foot of FPR 1.25 cubic feet per of FPR 0.8 bushel per 1 cubic foot of FPR	

Table M-2
Land Application Liquid. FPR Volumes for Varying Solids Content and Loading Rates

FPR solids content %	Loading rate, dry tons						
	1	2	3	4	5	6	7
	FPR gallons (assuming 1 gallon FPR = .5 lb) (a)						
1	23,529	47,059	70,588	94,118	117,647	141,176	164,706
2	11,765	23,529	35,294	47,059	58,824	70,588	82,353
3	7,843	15,686	23,529	31,373	39,216	47,059	54,902
4	5,882	11,765	17,647	23,529	29,412	35,294	41,176
5	4,706	9,412	14,118	18,824	23,529	28,235	32,941
6	3,922	7,843	11,765	15,686	19,608	23,529	27,451
7	3,361	6,723	10,084	13,445	16,807	20,168	23,529
8	2,941	5,882	8,824	11,765	-14,706	17,647	20,588
9	2,614	5,229	7,843	10,458	13,072	15,686	18,301
10	2,353	4,706	7,059	9,412	11,765	14,118	16,471
11	2,139	4,278	6,417	8,556	10,695	12,834	14,973
12	1,961	3,922	5,882	7,843	9,804	11,765	13,725
13	1,810	3,620	5,430	7,240	9,050	10,860	12,670
14	1,681	3,361	5,042	6,723	8,403	10,084	11,765
15	1,569	3,137	4,706	6,275	7,843	9,412	10,980

Table M-2 (cont'd)

FPR solids content %	Loading rate 1	2	3	4	5	6	7
	FPR wet tons (assuming 1 gallon FPR = 1.02) (b)						
10	10.00	20.00	30.00	40.00	50.00	60.00	70.00
11	9.09	18.18	27.27	36.36	45.45	54.55	63.64
12	8.33	16.67	25.00	33.33	41.67	50.00	58.33
13	7.69	15.38	23.08	30.77	38.46	46.15	53.85
14	7.14	14.29	21.43	28.57	35.71	42.86'	50.00
15	6.67	13.33	20.00	26.67	33.33	40.00	46.67
16	6.25	12.50	18.75	25.00	31.25	37.50	43.75
17	5.88	11.76	17.65	23.53	29.41	35.29	41.18
18	5.56	11.11	16.67	22.22	27.78	33.33	38.89
19	5.26	10.53	15.79	21.05	26.32	31.58	36.84
20	5.00	10.00	15.00	20.00	25.00	30.00	35.00
21	4.76	9.52	14.29	19.05	23.81	28.57	33.33
22	4.55	9.09	13.64	18.18	22.73	27.27	31.82
23	4.35	8.70	13.04	17.39	21.74	26.09	30.43
24	4.17	8.33	12.50	16.67	20.83	25.00	29.17
25	4.00	8.00	12.00	16.00	20.00	24.00	28.00
26	3.85	7.69	11.54	15.38	19.23	23.08	26.92
27	3.70	7.41	11.11	14.81	18.52	22.22	25.93
28	3.57	7.14	10.71	14.29	17.B6	21.43	25.00
29	3.45	6.90	10.34	13.79	17.24	20.69	24.14
30	3.33	6.67	10.00	13.33	16.67	20.00	23.33
31	3.23	6.45	9.68	12.90	16.13	19.35	22.58
32	3.13	6.25	9.38	12.50	15.63	18.75	21.88
33	3.03	6.06	9.09	12.12	15.15	18.18	21.21
34	2.94	5.88	8.82	11.76	14.71	17.65	20.59
35	2.86	5.71	8.57	11.43	14.29	17.14	20.00
36	2.78	5.56	8.33	11.11	13.89	16.67	19.44
37	2.70	5.41	8.11	10.81	13.51	16.22	18.92
38	2.63	5.26	7.89	10.53	13.16	15.79	18.42
39	2.56	5.13	7-69	10.26	12.82	15.38	17.95
40	2.50	5.00	7.50	10.00	12.50	15.00	17.50
41	2.44	4.88	7.32	9.76	12.20	14.63	17.07
42	2.38	4.76	7.14	9.52	11.90	14.29	16.67
43	2.33	4.65	6.98	9.30	11.63	13.95	16.28
44	2.27	4.55	6.82	9.09	11.36	13.64	15.91
45	2.22	4.44	6.67	8.89	11.11	13.33	15.56
46	2.17	4.35	6.52	8.70	10.87	13.04	15.22
47	2.13	4.26	6.38	8.51	10.64	12.77	14.89
48	2.08	4.17	6.25	8.33	10.42	12.50	14.58
49	2.04	4.08	6.12	8.16	10.20	12.24	14.29
50	2.00	4.00	6.00	8.00	10.00	12.00	14.00

(a) gallons = (dry tons x 2000) / ((%solids/100) x 8.5)
(b) FPR wet tons = dry tons / (%solids/100)