United States Environmental Protection Agency

Technical Development Document for the Final Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Point Source Category (40 CFR 432)

Volume 1 of 4

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SECTION 1

SUMMARY AND SCOPE OF THE REGULATION

This section provides an overview and summarizes the Meat and Poultry Products (MPP) Point Source Category regulation. Section 1.1 describes the purpose of the rulemaking, and Section 1.2 presents an overview of the MPP Point Source Category. Section 1.3 summarizes the final MPP rulemaking. Finally, Section 1.4 explains how confidential business information used to develop the regulation was protected.

1.1 PURPOSE OF THIS RULEMAKING

Pursuant to the Clean Water Act (CWA), the United States Environmental Protection Agency (EPA) is promulgating effluent limitations guidelines and standards (ELGs) for the MPP Point Source Category (40 CFR Part 432). The ELGs for the final rule apply to existing and new MPP facilities that are direct dischargers. Direct discharging facilities are those that directly release wastewater to surface waters of the United States (e.g., lakes, rivers, oceans). This document and the administrative record for this rulemaking provide the technical basis for these final limitations and standards.

1.2 OVERVIEW OF THE MPP POINT SOURCE CATEGORY

The MPP industry includes facilities that slaughter livestock and/or poultry or that process meat and/or poultry into products for further processing or sale to consumers.[1] The industry is often divided into three categories: (1) meat slaughtering and processing, (2) poultry slaughtering and processing, and (3) rendering. Facilities may perform slaughtering operations, processing operations using carcasses slaughtered at other facilities and/or their own facilities, or both types of operations. Companies that own meat or poultry product facilities may also own the

[1]*Meat products* include all animal products from cattle, calves, hogs, sheep, and lambs and any meat that is not listed under the definition of poultry. *Poultry products* include all poultry products from broilers, other young chickens, hens, fowl, mature chickens, turkeys, capons, geese, ducks, exotic poultry (e.g., ostriches), and small game such as quail, pheasants, and rabbits. This category may include species not classified as poultry by the United States Department of Agriculture's (USDA's) Food Safety and Inspection Service (FSIS) and that may or may not be under the USDA FSIS voluntary inspection.

facilities that raise the animals. These other enterprises (e.g., feedlots) are not covered by the MPP ELGs.

The MPP industry encompasses primarily four North American Industry Classification System (NAICS) codes, which are developed by the Department of Commerce. These NAICS codes are Animal Slaughtering (Except Poultry), NAICS 311611; Meat Processed from Carcasses, NAICS 311612; Poultry Processing, NAICS 311615; and Rendering and Meat By-product Processing, NAICS 311613.

The MPP industry includes almost 6,620 facilities, of which an estimated 4,711 discharge process wastewater (Table 1-1). Of the facilities discharging process wastewater, EPA estimates that 94 percent are indirect dischargers (i.e., dischargers that send their wastewater to a publicly owned treatment plant) and 6 percent are direct dischargers. The Agency estimates that 1,908 facilities either discharge no process wastewater or use contract haulers. See Section 5 for a description of how EPA subcategorized MPP facilities.

Table 1-1. National Estimates of Number of MPP Facilities

		Facility Size							
		Small				Non-small			
40 CFR 432 Subcategory	Description	Direct only	Indirect only	Both Direct/ Indirect	Zero	Direct only	Indirect only	Both Direct/ Indirect	Zero
A, B, C, D	Meat First Processors	63	738	0	929	45	74	2	18
E	Small Meat Further Processors	22	1,755	3	640	--	--	--	--
F, G, H, I	Meat Further Processors	22	765	0	73	4	134	0	12
J	Independent Renderers	0	10	0	5	19	65	0	33
K	Poultry First Processors	17	77	0	51	77	107	2	20
L	Poultry Further Processors	7	532	0	94	5	166	0	31
Total		131	3,877	3	1,793	150	546	4	115

Source: EPA Screener Survey.

EPA estimated engineering compliance costs for each of the technology options for a set of MPP facilities, and then used these facilities to estimate compliance costs for the entire MPP industry. The Agency also estimated the pollutant loadings and removals associated with each technology option. EPA then used the loadings and removals to assess the effectiveness of each technology option. The Agency used the costs to estimate the financial impact on the industry of implementing the various technology options. (See *Economic and Environmental Benefits Analysis of the Final Meat and Poultry Products Rule* [EPA-821-R-04-010]. Details on the cost-effectiveness analysis, water quality impacts, and potential benefits for each technology option can be found in the same document.)

1.3 SUMMARY OF THE FINAL MPP EFFLUENT LIMITATIONS AND GUIDELINES

EPA is establishing regulations for MPP direct dischargers based on the "best practicable control technology currently available" (BPT), the "best conventional pollutant control technology" (BCT), the "best available technology economically achievable" (BAT), and the "best available demonstrated control technology for new source performance standards" (NSPS).

The Agency is establishing revised ELGs for 9 of the 10 existing subcategories of the meat products industry: Simple Slaughterhouse, Complex Slaughterhouse, Low Processing Packinghouse, High-Processing Packinghouse, Meat Cutter, Sausage and Luncheon Meats Processor, Ham Processor, Canned Meats Processor, and Renderer. The Agency is also establishing two new MPP subcategories with effluent guidelines and performance standards for the Poultry First Processing (slaughtering) and Poultry Further Processing categories. EPA is not establishing any new or revised ELGs or pretreatment standards for the small processor subcategory.

Table 1-2 summarizes the regulatory changes that serve as the basis for the final ELGs and standards promulgated for the MPP industry. For descriptions and discussion of the subcategories, see Section 5; for a discussion of treatment technologies in use by MPP facilities, see Section 8; for a discussion of the process wastewater generated by these subcategories, see Section 6; and for a discussion of the promulgated limits, see Section 13.

Table 1-2. Summary of Technology Bases for Promulgated MPP Limitations and Standards

Subcategory	Size Threshold for Final Rule	Facility Type	Final Rule
A- D: Meat First Processors	Non-small (>50 million lbs yr)	Existing	BPT: Option 2 2.5 for ammonia (as nitrogen), no revision for conventionals BAT: Option 2.5 for total nitrogen
		New	NSPS BPT (Option 2) for ammonia (as nitrogen) NSPS BAT (Option 2.5) for total nitrogen No revision for conventionals
	Small (< 50 million lbs yr)	Existing New	No revision
E: Small Meat Further Processors	Small (< 1,560,000 lbs yr)	Existing New	No revision
F-I: Meat Further Processors	Non-small (>50 million lbs yr)	Existing	BPT: no revision BAT: Option 2.5 for total nitrogen, no revision for ammonia (as nitrogen)
		New	NSPS BAT (Option 2.5) for total nitrogen NSPS Option 2 2.5 for ammonia (as nitrogen) NSPS no revision for conventionals
	Small (>1,560,000 but < 50 million lbs yr)	Existing New	No revision
J: Independent Renderers	(>10 million lbs yr)	Existing	BPT: no revision BAT: OPTION 2.5 for total nitrogen, no revision for ammonia (as nitrogen)
		New	NSPS BAT (Option 2 2.5) for total nitrogen NSPS no revision for ammonia (as nitrogen) and conventionals
K: Poultry First Processors	Non-small (>100 million lbs yr)	Existing	BPT: Option 2 2.5 for ammonia (as nitrogen) and conventionals BAT: Option 2.5 for total nitrogen, BAT BPT for ammonia (as nitrogen)
		New	NSPS BPT (Option 2 2.5) for ammonia (as nitrogen) and conventionals NSPS BAT (Option 2.5) for total nitrogen
	Small (< 100 million lbs yr)	Existing	No Regulation
		New	Option 2 2.5 for ammonia (as nitrogen), Option 2 for conventionals

Table 1-2. Summary of Technology Bases for Promulgated MPP Limitations and Standards (Continued)

Subcategory	Size Threshold for Final Rule	Facility Type	Final Rule
L: Poultry Further Processor	Non-Small (>7 million pounds yr)	Existing	BPT: Option 2 2.5 for ammonia (as nitrogen) and Option 2 for conventionals BAT: Option 2.5 for total nitrogen, BAT BPT for ammonia (as nitrogen)
		New	NSPS BPT (Option 2 2.5) for ammonia (as nitrogen) and Option 2 for conventionals NSPS BAT (Option 2.5) for total nitrogen
	Small (7 million pounds yr)	Existing	No Regulation
		New	Option 2 2.5 for ammonia (as nitrogen) and Option 2 for conventionals

BCT Best practicable control technology currently available.
BAT Best available technology economically achievable.
NSPS Best available demonstrated control technology for new source performance standards.
BCT Best conventional pollutant control technology.
PSES Pretreatment standards for existing sources.
PSNS Pretreatment standards for new sources.

1.4 PROTECTION OF CONFIDENTIAL BUSINESS INFORMATION

EPA recognizes that certain data in the rulemaking record have been claimed as confidential business information (CBI). The Agency has withheld CBI from the public record in the MPP docket. In addition, the Agency has withheld from disclosure some data not claimed as CBI because the release of the data could indirectly reveal CBI. EPA has also aggregated certain data in the public record, masked facility identities, or used other strategies to prevent the disclosure of CBI. The Agency's approach to CBI protection ensures that the data in the public record both explain the basis for the final rule and provide the opportunity for public comment, without compromising data confidentiality.

SECTION 2

LEGAL AUTHORITY AND BACKGROUND

This section presents background information supporting the development of effluent limitations guidelines (ELGs) and standards for the Meat and Poultry Products (MPP) Point Source Category. Section 2.1 presents the legal authority to regulate the MPP industry. Section 2.2 discusses the Clean Water Act (CWA), the Pollution Prevention Act, the Regulatory Flexibility Act (as amended by the Small Business Regulatory Enforcement Fairness Act of 1996), and prior regulation of the MPP industry. Section 2.3 discusses the scope and applicability of the MPP final rule.

2.1 LEGAL AUTHORITY

The Agency's promulgating these regulations under the authority of Sections 301, 304, 306, 307, 308, 402, and 501 of the CWA, 33 U.S.C. 1311, 1314, 1316–1318, 1342, and 1361.

2.2 REGULATORY BACKGROUND

2.2.1 Clean Water Act

Congress adopted the CWA to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101(a), 33 U.S.C. 1251(a)). To achieve this goal, the act prohibits the discharge of pollutants into navigable waters except in compliance with the statute. The CWA addresses the problem of water pollution on a number of different fronts. It relies primarily, however, on establishing restrictions on the types and amounts of pollutants discharged from various industrial, commercial, and public sources of wastewater.

Direct dischargers (those which discharge effluent directly into navigable waters) must comply with the ELGs and new source performance standards in their National Pollutant Discharge Elimination System (NPDES) permits. Indirect dischargers (those which discharge to publicly owned treatment works) must comply with pretreatment standards. These limitations and standards are established by regulation for categories of industrial dischargers based on the degree of control that can be achieved using various levels of pollution control technology. The limitations and standards are summarized below.

2.2.1.1 Best Practicable Control Technology Currently Available (BPT)—Section 304(b)(1) of the CWA

EPA defines BPT limitations for discharges of conventional, toxic, and nonconventional pollutants[2] from existing sources. In specifying BPT, EPA considers the cost of achieving effluent reductions in relation to the effluent reduction benefits, age of equipment and facilities, processes employed, process changes required, engineering aspects of the control technologies, non-water quality environmental impacts (including energy requirements), and other factors the EPA Administrator deems appropriate (CWA § 304(b)(1)(B)). Traditionally, EPA establishes BPT effluent limitations based on the average of the best performances of facilities within the industry, grouped to reflect various ages, sizes, processes, or other common characteristics. Where existing performance is uniformly inadequate, however, EPA may establish BPT limitations based on higher levels of control than those currently in place in an industrial category if the Agency determines that the technology is available in another category or subcategory and can be practically applied.

2.2.1.2 Best Conventional Pollutant Control Technology (BCT)—Section 304(b)(4) of the CWA

The 1977 amendments to the CWA established BCT as an additional level of control for discharges of conventional pollutants from existing industrial point sources. In addition to other factors specified in section 304(b)(4)(B), the CWA requires that BCT limitations be established in light of a two-part "cost-reasonableness" test. EPA published a methodology for the development of BCT limitations in July 1986 (51 FR 24974, July 9, 1986).

Section 304(a)(4) designates the following as conventional pollutants: biochemical oxygen-demanding pollutants (measured as BOD_5), total suspended solids (TSS), fecal coliform bacteria, pH, and any additional pollutants defined by the Administrator as conventional. The

[2] *Conventional pollutants* are biochemical oxygen demand (BOD_5), total suspended solids (TSS), fecal coliform, pH, and oil and grease; *toxic pollutants* are those pollutants listed by the Administrator under CWA Section 307(a); and *nonconventional pollutants* are those which are neither listed as toxic nor conventional.

Administrator designated oil and grease as an additional conventional pollutant on July 30, 1979 (44 FR 44501).

2.2.1.3 Best Available Technology Economically Achievable (BAT)—Section 304(b)(2)(B) of the CWA

In general, BAT ELGs represent the best existing economically achievable performance of direct discharging facilities in the industrial subcategory or category. The factors considered in assessing BAT are the cost of achieving BAT effluent reductions, age of equipment and facilities involved, processes employed, engineering aspects of the control technology, potential process changes, non-water quality environmental impacts (including energy requirements), and other factors that the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded to these factors. An additional statutory factor considered in setting BAT is economic achievability. Generally, the achievability is determined based on the total cost to the industry and the effect of compliance with the BAT limitations on overall industry and subcategory financial conditions. Unlike BPT, BAT limitations may be based on effluent reductions attainable through changes in a facility's processes and operations. Like BPT, where existing performance is uniformly inadequate, BAT limitations may be based on technology transferred from a different subcategory within an industry or from another industrial category. BAT may also be based on process changes or internal controls, even when these technologies are not common industry practice.

2.2.1.4 New Source Performance Standards (NSPS)—Section 306 of the CWA

NSPS reflect effluent reductions that are achievable based on the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the greatest degree of effluent reduction attainable through the application of the best available demonstrated control technology for all pollutants (conventional, nonconventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements.

2.2.1.5 Pretreatment Standards for Existing Sources (PSES)—Section 307(b) of the CWA

PSES are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of a publicly owned treatment works (POTW). The CWA authorizes EPA to establish pretreatment standards for pollutants that pass though POTWs or interfere with treatment processes or sludge disposal methods. The pretreatment standards are to be technology-based and analogous to the BAT ELGs.

The General Pretreatment Regulations, which establish the framework for implementing categorical pretreatment standards, are at 40 CFR Part 403. These regulations provide a definition of pass-through that addresses local rather than national instances of pass-through, and they establish pretreatment standards that apply to all nondomestic dischargers (52 FR 1586, January 14, 1987).

2.2.1.6 Pretreatment Standards for New Sources (PSNS)—Section 307(b) of the CWA

Like PSES, PSNS are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. PSNS are to be issued at the same time as NSPS. New indirect dischargers have the opportunity to incorporate into their facilities the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS as those considered in promulgating NSPS.

2.2.1.7 Best Management Practices (BMPs)

Sections 304(e), 308(a), 402(a), and 501(a) of the CWA authorize the Administrator to prescribe BMPs as part of ELGs and standards or as part of a permit. Section 304(e) of the CWA authorizes EPA to include BMPs in ELGs for certain toxic or hazardous pollutants for the purpose of controlling "plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage." Section 402(a)(1) and the NPDES regulations at 40 CFR 122.44(k) also provide for BMPs to control or abate the discharge of pollutants when numeric limitations and standards are infeasible. In addition, Section 402(a)(2), read in concert with Section 501(a), authorizes EPA to prescribe as wide a range of permit conditions as the Administrator deems appropriate to ensure compliance with applicable ELGs and standards and such other requirements as the Administrator deems appropriate. Table 2-1 summarizes these regulatory levels of control and the pollutants controlled.

Table 2-1. Summary of Regulatory Levels of Control

Type of Site Regulated	BPT	BAT	BCT	NSPS	PSES	PSNS
Existing Direct Dischargers	X	X	X			
New Direct Dischargers				X		
Existing Indirect Dischargers					X	
New Indirect Dischargers						X
Type of Pollutant Regulated	**BPT**	**BAT**	**BCT**	**NSPS**	**PSES**	**PSNS**
Priority Toxic Pollutants	X	X		X	X	X
Nonconventional Pollutants	X	X		X	X	X
Conventional Pollutants	X		X	X	X	X

Source: Clean Water Act.

2.2.2 Section 304(m) Requirements

Section 304(m) requires EPA to establish schedules for reviewing and revising existing ELGs and standards, as well as promulgating new ELGs and standards. Section 304(m) does not apply to pretreatment standards for indirect dischargers, which EPA promulgates pursuant to Sections 307(b) and 307(c) of the CWA.

On October 30, 1989, Natural Resources Defense Council, Inc., and Public Citizen, Inc., filed an action against EPA in which they alleged, among other things, that EPA had failed to comply with CWA Section 304(m) (see *NRDC* v. *Browner*, civ. no. 89-2980 (D.DC.)). The plaintiffs and EPA agreed to a settlement of that action in a consent decree entered on January 31, 1992. The consent decree, which has been modified several times, established a schedule on which EPA is to propose and take final action for 11 point source categories identified by name in the decree and for 8 other point source categories identified only as "new or revised rules", numbered 5 through 12. EPA selected the MPP industry as the subject for New or Revised Rule 11. Under the decree, as modified, the Administrator was required to sign a proposed rule for the MPP industry by no later than January 30, 2002, and was required to take final action on that proposal by no later than December 31, 2003. The December deadline was later modified by the court, in an unopposed motion, to February 26, 2004.

2.2.3 Total Maximum Daily Load (TMDL) Program

The CWA requires states to identify waters not meeting water quality standards and to develop Total Maximum Daily Loads (TMDLs) for those waters (Section 303(d) of the CWA). A TMDL is essentially a prescription designed to restore the health of the polluted body of water by indicating the amount of pollutants that may be present in the water and still meet water quality standards. More than 25,000 bodies of water across America have been identified as impaired. These waters include more than 300,000 river and shoreline miles and 5 million acres of lakes. EPA estimates that more than 40,000 TMDLs must be established.

A TMDL must be developed for waters that do not attain water quality standards. A TMDL identifies the loading capacity of a waterbody for the applicable pollutant, which is the greatest amount of a pollutant that a water can receive without exceeding water quality standards. The TMDL also identifies the load reduction needed to attain standards and allocates such reductions to point source dischargers (wasteload allocation(s)) and nonpoint sources (load allocation(s)). Thus, the TMDL is actually a "pollution budget" or water quality-based approach that allows the waterbody to achieve water quality standards. Wasteload allocations are reflected in the NPDES permits written for point sources that discharge into the waterbody.

EPA promulgated a final rule in July 2000 to amend and clarify the existing regulations at 40 CFR 130.7 implementing Section 303(d) of the CWA. Those regulations require states to identify waters that are not meeting state water quality standards and to establish TMDLs to restore the quality of those waters. The July 2000 revisions of the rule established specific time frames under which EPA will ensure that TMDLs are completed, and that necessary point and nonpoint source controls are implemented to meet the TMDLs.

The July 2000 rule amended and clarified existing regulations implementing the section of the CWA, that requires states to identify waters that are not meeting applicable water quality standards and to establish TMDLs, to restore the quality of those waters. The July 2000 rule also amended EPA's NPDES regulations to include provisions addressing the implementation of TMDLs through NPDES permits. Although the July 2000 rule was scheduled to take effect on April 30, 2003, it has never become effective. On March 19, 2003, EPA announced that it was withdrawing the July 2000 final rule. The 2000 rule was determined to be unworkable based on reasons described by thousands of comments and was challenged in court by some two dozen parties. Regulations that EPA promulgated in 1985 and amended in 1992 remain the regulations in effect for implementing the TMDL Program.

EPA believes that significant changes would need to be made to the July 2000 rule before it could serve as the blueprint for an efficient and effective TMDL Program. Furthermore, EPA needs additional time beyond April 2003 to decide whether and how to revise the currently effective regulations implementing the TMDL Program in a way that will best achieve the goals of the CWA. In the meantime, EPA continues to work steadily on improvements to the TMDL Program to further enhance the quality of the Nation's waters. EPA has been identifying options to improve the TMDL Program, including addressing problems reported by the National Academy of Sciences' National Research Council. The Agency has conducted several public meetings and is reviewing its ongoing implementation of the existing program with a view toward continual improvement and regulatory changes in light of stakeholder input and recommendations from the National Academy of Science's National Research Council. The NRC issued a report with numerous recommendations for improving the rule and program that were not reflected in the July 2000 rule. Ultimately, Congress passed a law prohibiting EPA from implementing the July 2000 rule.

Effluent guidelines are technology-based controls for point source dischargers and are implemented NPDES permits that point sources must obtain prior to discharging pollutants to waters of the United States. EPA is not required to demonstrate the environmental benefits of its technology-based effluent guidelines. It is well established that EPA is not required to consider receiving water quality in setting technology-based ELGs and standards. *Weyerhaeuser* v. *Costle*, 590 F. 2nd 1011, 1043 (D.C. Cir. 1978), the Senate Committee declared that '[t]he use of any river, lake, stream or ocean as a waste treatment system is unacceptable'– regardless of the measurable impact of the waste on the body of water in question. (Legislative History at 1425 (Senate Report)). The Conference Report states that the Act 'specifically bans pollution dilution as an alternative to treatment (Id. at 284). The purpose of such technology-based limits is to "result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants." See NRDC, 863 F.2d at 1433 (9th Cir. 1988). In short, the CWA set up both TMDLs and effluent guidelines as complementary regulatory programs because both are necessary for restoring the quality of the Nation's waters.

2.2.4 Pollution Prevention Act

The Pollution Prevention Act of 1990 (42 U.S.C. 13101 et seq., Pub.L. 101-508, November 5, 1990), makes pollution prevention the national policy of the United States. This act identifies an environmental management hierarchy in which pollution "should be prevented or reduced whenever feasible; pollution that cannot be prevented or recycled should be reused in an environmentally safe manner whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or release into the environment should be employed only as a last resort..." (Sec. 6602; 42 U.S.C. 13103).

According to the Pollution Prevention Act, source reduction reduces the generation and release of hazardous substances, pollutants, wastes, contaminants, or residuals at the source, usually within a process. The term *source reduction* "includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. The term source reduction does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to or necessary for the production of a product or the providing of a service." In effect, source reduction means reducing the amount of a pollutant that enters a waste stream or that is otherwise released into the environment prior to out-of-process recycling, treatment, or disposal. The Pollution Prevention Act directs the Agency to, among other things, "review regulations of the Agency prior and subsequent to their proposal to determine their effect on source reduction" (Sec. 6604; 42 U.S.C. 13103). This final regulation for the MPP industry was reviewed for its incorporation of pollution prevention as part of the Agency effort. Section 8 outlines pollution prevention practices applicable to the MPP industry.

2.2.5 Regulatory Flexibility Act (RFA) as Amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA)

The RFA generally requires an agency to prepare a regulatory flexibility analysis for any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For the purpose of assessing the impact of this rulemaking on small entities, a *small entity* is defined as (1) a small business based on full-time equivalents (FTEs) or annual revenues established by the Small Business Administration (SBA), (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of fewer than 50,000, and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

The definitions of small business for the MPP industry are in the SBA's regulations at 13 CFR 121.201. These size standards were updated effective October 1, 2000. The SBA size standards for the MPP industry (that is, for NAICS codes 311611, 311612, 311613, and 311615) define a "small business" as one with 500 or fewer employees.

EPA estimated that the final rule would regulate up to 51 small businesses that own MPP facilities (i.e., 18 small businesses for which we have detailed surveys and 33 businesses that may potentially be small based on their screener survey response). The scope of the final rule does not include any small governmental jurisdictions or not-for-profit organizations.

Only facilities that exceed the subcategory-specific production thresholds, described further in Section 2.3, are subject to the final rule. Of the small businesses for which EPA had facility-level financial data, EPA projected no facility closures for the final rule. In addition, of the other 33 potentially small entities, two entities are estimated to incur annualized post-tax compliance costs of greater than three percent of revenues; seven are estimated to incur compliance costs of between 1 and 3 percent of revenues; 24 small entities are estimated to incur compliance costs of less than 1 percent of revenues.

Although the final rule did not have a significant economic impact on a substantial number of small entities, EPA nonetheless tried to reduce the impact of the final rule on small entities. The final rule includes subcategory-specific production thresholds that will allow smaller production facilities to retain their existing limitations or to remain without national effluent limitations. In addition, EPA did not promulgate pretreatment standards; indirect dischargers will remain subject to local limits. Indirect dischargers represent almost 95 percent of the overall MPP industry.

2.2.6 Regulatory History of the MPP Industry

In 1974 EPA promulgated effluent guidelines for meat slaughterhouses and packinghouse facilities (40 CFR 432, Subcategories A through D), and in 1975 EPA promulgated effluent guidelines for meat further processing facilities (40 CFR 432, Subcategories E through I) and independent rendering facilities (40 CFR 432 Subcategory J). The Agency proposed regulations for the poultry industry in 1974, but the rule was never finalized. The following sections describe the current regulatory framework for the MPP industry.

2.2.6.1 Meat Facilities

The ELGs and standards for the meat products industry were developed and promulgated in the 1970s. As described above, there are existing regulations for the meat slaughtering and processing subcategories and for independent rendering. These regulations were issued in phases and are grouped under 40 CFR Part 432. Although there is no definition of *red meat* or *meat* in the existing MPP effluent guidelines, EPA defined these terms in the technical development documents associated with the prior rules as all animal products from cattle, calves, hogs, sheep and lambs, and from any animal that is not listed under the definition of poultry. EPA is using "meat" as synonymous with the "red meat." EPA included the same definition in the final regulations. The current regulations for meat processing cover all aspects of producing meat products from the slaughter of the animal to the production of final consumer products (e.g., cooked, seasoned, or smoked products, such as luncheon meats or hams.)

EPA promulgated BPT, BAT, and NSPS effluent limitations and standards for existing and new meat slaughterhouses and packinghouses on February 28, 1974 (39 FR 7894). EPA established separate limitations and standards for existing and new sources for various types of meat slaughterhouses and packinghouses: Simple Slaughterhouse, Complex Slaughterhouse, Low-Processing Packinghouse, and High-Processing Packinghouse (40 CFR 432, Subcategories A through D).

The Agency promulgated BPT, BAT, and NSPS limitations and standards for existing and new meat further processing subcategories and the independent rendering subcategory on January 3, 1975 (40 FR 902). EPA promulgated no PSNS for this segment of the industry in the January 3, 1975, notice. EPA established separate effluent limitations and standards for existing and new sources for various types of meat further processors and independent renderers: Small Processor, Meat Cutter, Sausage and Luncheon Meats Processor, Ham Processor, Canned Meats Processor, and Independent Renderer (40 CFR 432, Subcategories E through J).

EPA did not establish any pretreatment standards in the 1974 or 1975 regulations.

The BPT and BAT limitations established in the February 28, 1974 notice were the subject of litigation in *American Meat Institute* v. *EPA*, 526 F.2d 442 (7th Cir. 1975). The Seventh Circuit Court of Appeals reviewed the effluent limitations and remanded selected portions of those regulations. The BPT and BAT regulations remanded by the court were subsequently revised or withdrawn. (See 44 FR 50732, August 29, 1979, and 45 FR 82253, December 15, 1980.)

The regulations for the Independent Renderer subcategory were also the subject of litigation in *National Renderers Association et al.*, v. *EPA et al.*, 541 F. 2d 1281 (8th Cir. 1976). The Court remanded the regulations to the Agency to reconsider the economic impact of the costs associated with these requirements. The BAT limitations for independent renderers were not remanded, but EPA reevaluated those limitations nonetheless. On October 6, 1977 (42 FR

54417), EPA promulgated a final rule that revised the BAT limitations and NSPS limitations for this subcategory. In that final rule, the BAT limitations for ammonia, BOD_5, and TSS are less stringent than the original BAT limitations; however, the October 6, 1977, NSPS are more stringent than the original NSPS limitations. In the final rule, EPA retained an exclusion for small facilities (less than 75,000 pounds of raw material per day) from BPT, BAT, and NSPS.

2.2.6.2 Poultry Facilities

EPA proposed BPT, BAT, NSPS, and PSNS limitations and standards for existing and new poultry slaughterers and processors on April 24, 1975 (40 FR 18150). EPA proposed to subcategorize the poultry processing sector into five subcategories—four distinguished by the type of animal or bird being processed and a fifth that applied to further processing. These regulations were never finalized because the 1977 amendments to the Clean Water Act refocused the Agency's attention on establishing ELGs for industry sectors with effluents that contain toxic metals and organics.

2.3 SCOPE AND APPLICABILITY OF FINAL REGULATION

EPA is establishing new or revised ELGs and standards for 9 of the 10 subcategories of the MPP point source category (40 CFR Part 432): Simple Slaughterhouse, Complex Slaughterhouse, Low-Processing Packinghouse, High-Processing Packinghouse, Meat Cutter, Sausage and Luncheon Meats Processor, Ham Processor, Canned Meats Processor, and Renderer. The Agency is establishing no new or revised ELGs or pretreatment standards for the Small Processor category. EPA is also establishing two new MPP subcategories with ELGs and NSPS for the Poultry First Processing (slaughtering) and Further Processing subcategories.

2.3.1 Meat Facilities

2.3.1.1 Meat Slaughtering and Further Processing Facilities

In 1974 EPA established regulations that apply to meat slaughterhouses and packinghouses (40 CFR 432, Subcategories A through D). In 1975 EPA established regulations that apply to meat further processing facilities (40 CFR 432, Subcategories E through I). The current regulations for meat cover all aspects of producing meat products from slaughtering the animal to producing final consumer products (e.g., cooked, seasoned, or smoked products, such as luncheon meats or hams). For Subcategories F, G, H, and I of the existing regulations, EPA established a production rate threshold of greater than 6,000 pounds of finished product per day, below which the regulations do not apply. Subcategory E of the existing regulations applies to small meat further processors that produce less than or equal to 6,000 pounds of finished product per day.

EPA is not changing the existing production rate thresholds in Subcategory E through I of this rule for existing limitations and standards. EPA is establishing new production rate thresholds in Subcategories A through D and F through I for the limitations and standards based on current data collected for this rulemaking (see Section 3). These new production rate thresholds do not affect Subpart E (Small Processors) meat facilities because the new production rate thresholds are all higher than the Subpart E production rate threshold (6,000 pounds of finished product per day).

Based on current MPP survey data, EPA defines small facilities based on their annual production. EPA defines the following facilities, which are currently covered under 40 CFR Part 432, as small:

- Facilities in Subcategories A, B, C, and D that slaughter less than or equal to 50 million pounds (as live weight killed (LWK)) per year.
- All facilities in Subcategory E.
- Facilities in Subcategories F, G, H, and I that produce greater than 6,000 pounds per day but less than or equal to 50 million pounds of finished product per year.
- Facilities in Subcategory J that render less than 10 million pounds per year of raw material.

Most smaller MPP facilities are excluded from the scope of today's proposal for a number of reasons: (1) small MPP facilities as a group discharge less than 3 percent of the conventional pollutants (or 35 million pounds per year), 1 percent of the toxic pollutants (or 1.3

million pounds per year), 4 percent of the nutrients (or 7.5 million pounds per year), and less than 1.5 percent of the pathogens (or 47 x 10^9 colony-forming units per year) as compared to all discharges from the entire MPP industry; (2) EPA determined that only a limited amount of loadings removal would be accomplished by improved treatment at small facilities; and (3) EPA determined that small MPP facilities would discharge a very small portion of the total industry discharge. Therefore, EPA is not revising the current ELGs and standards for small meat facilities. The existing regulations, however, will continue to apply to those facilities.

The existing regulations apply to all sizes of meat direct dischargers (except for renderers processing less than 75,000 pounds of raw material per day). The final revisions to 40 CFR Part 432 apply to meat facilities above the new production-based thresholds and to all poultry facilities that discharge directly to a receiving stream or other waters of the United States.

2.3.1.2 Independent Rendering Facilities

In 1975 EPA established regulations (40 CFR Part 432, Subcategory J) that apply to independent renderers, defined as independent or off-site operations that manufacture meat meal, dried animal by-product residues (tankage), animal fats or oils, grease, and tallow, including hide curing by a renderer. The existing regulations establish a size threshold of 75,000 pounds of raw material per day processed. Facilities that process less than this amount are not subject to the existing regulations.

EPA is lowering this production threshold in this rulemaking to include all facilities that render more than 10 million pounds per year of raw material (or approximately 27,000 pounds per day for a facility that operates 365 days a year). EPA is lowering this production threshold based on data collected for this rulemaking. See *Economic and Environmental Benefits Analysis of the Final Meat and Poultry Products Rule* (EPA-821-R-04-010) for a description of EPA's reasons for setting production thresholds and exempting most small MPP facilities (including all small rendering facilities that render less than 10 million pounds per year of raw material) from the revisions to 40 CFR Part 432. Subpart J applies to the rendering of any meat or poultry raw material. When rendering is done in conjunction with a meat slaughterhouse or packinghouse, the rendering wastewater generated is regulated under the limitations for the appropriate meat slaughtering or packinghouse subcategory (the limitations under Subparts A, B, C, or D).

2.3.2 Poultry Slaughtering and Further Processing Facilities

EPA is establishing ELGs and NSPS for the new Poultry First Processing (slaughtering) and Further Processing subcategories. Poultry includes broilers, other young chickens, hens, fowl, mature chickens, turkeys, capons, geese, ducks, and small game such as quail, pheasants, and rabbits.

EPA proposed regulations for this segment of the MPP industry in 1975 but did not finalize them. EPA has reanalyzed this segment of the MPP industry and is establishing BPT, BCT, and BAT limitations and standards for existing facilities and NSPS limitations for new direct dischargers.

As noted above, EPA is creating two new subcategories that would apply to poultry processing facilities. The first is the Poultry First Processing subcategory, which includes the slaughtering and evisceration of the bird or animal and dressing the carcass for shipment either whole or in parts, such as legs, quarters, breasts, and boneless pieces. These facilities are commonly known as "ice pack facilities." The second new poultry subcategory is the Poultry Further Processing subcategory. It covers additional preparation of the meat, including further cutting, cooking, seasoning, and smoking to produce ready-to-be-eaten or reheated servings. The additions to 40 CFR Part 432 for poultry being proposed apply to facilities that discharge directly to waters of the United States.

EPA is setting less stringent ELGs for direct dischargers slaughtering up to 100 million pounds of poultry per year and for further processors producing up to 7 million pounds of poultry per year. See *Economic and Environmental Benefits Analysis of the Final Meat and Poultry Products Rule* (EPA-821-R-04-010) for a description of EPA's reasons for setting production thresholds. The treatment options promulgated for larger poultry slaughtering and further processing facilities are economically unachievable for small poultry slaughtering and further processing facilities. Rendering performed in conjunction with a poultry first processing facility would be subject to the appropriate regulations for the Poultry First Processing subcategory (Subpart K).

SECTION 3

DATA COLLECTION ACTIVITIES

EPA conducted a number of data collection activities in support of developing the final rule. Section 3.1 describes EPA's site visit and sampling program and Section 3.2 describes EPA's industry surveys. Section 3.3 discusses other information collection activities, including literature searches, National Pollutant Discharge Elimination System (NPDES) permits, and NPDES Discharge Monitoring Reports (DMRs). Section 3.4 describes EPA's outreach activities.

3.1 SUMMARY OF EPA'S SITE VISIT AND SAMPLING PROGRAM

3.1.1 EPA Site Visits

From 2000 to 2002 EPA conducted site visits at 17 meat and poultry products (MPP) processing facilities. Six of these site visits were conducted at meat facilities, eight at poultry facilities, two at rendering-only facilities, and one at a further processing-only facility. The purposes of these site visits were (1) to collect information on meat and poultry processing operations, (2) to collect information on wastewater generation and waste management practices used by MPP facilities, and (3) to evaluate each facility as a candidate for multiday sampling. In addition, EPA conducted limited sampling during several of the site visits to screen for potential contaminants that might be found in wastewaters from the different types of meat and poultry processing operations.

In selecting candidates for site visits, EPA attempted to identify facilities representative of various MPP processing operations, as well as both direct and indirect dischargers. EPA specifically considered the type of meat and/or poultry processing operation, age of the facility, size of the facility (in terms of production), wastewater treatment processes employed, and best management practices and pollution prevention techniques used. EPA also solicited recommendations for well-performing facilities (e.g., facilities with advanced wastewater treatment technologies) from EPA regional offices and state agencies. The site-specific selection criteria are discussed in site visit reports prepared for each site visited by EPA. (They can be found in Sections 6.1.4.2 and 19.1.2.2 of the Administrative Record.)

During each site visit, EPA collected information on the facility and its operations, including (1) general production data and information; (2) the types of meat and poultry processing wastewaters generated and treated on-site; (3) water source and use; (4) wastewater treatment and disposal operations; (5) potential sampling locations for wastewater (raw influent, within the treatment system, and final effluent); and (6) other information necessary for developing a sampling plan for possible multiday sampling episodes. EPA also collected wastewater samples of influent and effluent at 7 of the 17 facilities for screening purposes only.

3.1.2 EPA Sampling

3.1.2.1 Overview

Based on data collected from the site visits, EPA selected 12 facilities for multiday sampling. The purpose of the multiday sampling was to characterize pollutants in raw wastewaters prior to treatment, as well as to document wastewater treatment plant performance (including selected unit processes). Selection of facilities for multiday sampling was based on an analysis of information collected during the site visits, as well as the following criteria:

- The facility performed meat and/or poultry slaughtering and/or further processing operations representative of MPP facilities.
- The facility used in-process treatment and/or end-of-pipe treatment technologies that EPA was considering for technology option selection.
- Compliance monitoring data for the facility indicated that it was among the better-performing treatment systems or that it employed a wastewater treatment process for which EPA sought data for option selection.

Multiday sampling occurred at six meat facilities and six poultry facilities. EPA performed multi-day sampling at four facilities, and nine facilities performed the multiday sampling on behalf of EPA. It should be noted that due to concerns related to the sampling results, EPA re-sampled two facilities that were sampled prior to the proposal. After the proposed rule was published, EPA conducted two public outreach meetings on the proposed regulations and continued to meet with representatives of stakeholder groups, including representatives of various industry trade associations. EPA used several additional means to provide outreach to stakeholders, such as managing websites that post information related to these regulations. EPA provided supporting documents for the proposed rule on these sites. These documents included the "Technical Development Document," "Economic Analysis," and "Environmental Assessment" of the proposed regulations. These are available at www.epa.gov/guide/mpp/. For the nine facilities that performed the sampling, EPA developed sampling plans that detailed the procedures for sample collection, including the pollutants to be sampled; location of sampling points; and sample collection, preservation, and shipment techniques. EPA assisted the nine facilities as necessary (e.g., by providing sample bottle labels, assistance in shipping, and in one instance on-site contractor support during the sampling event).

3.1.2.2 Description of Sampling Episodes

During each multiday sampling episode, EPA sampled facility influent and effluent waste streams. EPA did not collect source water information but did collect source water data from three facilities after proposal. At some facilities, the Agency also collected samples at intermediate points throughout the wastewater treatment system to assess the performance of individual treatment units. Some of the facilities chosen for sampling perform rendering and/or further processing operations in addition to meat and/or poultry processing. For facilities that also perform rendering operations or further processing, EPA sampled wastewater from the rendering and/or further processing operations separately, when possible.

Sampling episodes were conducted over a 3-day or 5-day period. EPA obtained samples using a combination of 24-hour composite and grab samples, depending on the pollutant parameter to be analyzed. Depending on the type of wastewater processed and the treatment technology being evaluated, EPA analyzed wastewater for up to 53 parameters, including conventional pollutants (biochemical oxygen demand (BOD_5), total suspended solids, oil and grease, fecal coliform bacteria, and pH); toxic pollutants (selected metals and pesticides); and nonconventional pollutants (e.g., nutrients, microbiologicals). When possible for a given parameter, EPA collected 24-hour composite samples to capture the variability in the waste streams generated throughout the day (e.g., production wastewater versus cleanup wastewater).

Data collected from the influent samples contributed to characterizing of the industry, developing the list of pollutants of concern to be evaluated for regulation, and determining the raw wastewater pollutant concentrations. EPA used the data collected from the influent, intermediate, and effluent points to analyze the efficacy of treatment at the facilities and to develop current discharge concentrations and loadings, as well as the treatment technology options for the MPP industry. EPA used selected effluent data to estimate the potential long-term averages and numerical limits for each of the regulatory options considered for the final rule (see Chapter 13 for a description of the data EPA used for effluent limit development). During each sampling episode, EPA also collected flow rate data corresponding to each sample, when possible, and production information from each associated manufacturing operation for use in calculating pollutant loadings and production-normalized flow rates. EPA has included in the Administrative Record all information collected for which each facility has not asserted a claim of confidential business information (CBI) or which would indirectly reveal information claimed to be CBI.

3.1.2.3 Sampling Episode Reports

EPA used the site visit reports to prepare multiday sampling and analysis plans (SAPs) for each facility that would undergo multiday sampling. The Agency collected the following types of information during each sampling episode:

- Dates and times of sample collection.
- Flow data corresponding to each sample.
- Production data corresponding to each sample.
- Design and operating parameters for source reduction, recycling, and treatment technologies characterized during sampling.

- Information about site operations that had changed since the site visit or that were not included in the site visit report.

- In-situ readings for Temperature, pH, and dissolved oxygen of the sampled waste streams.

After the sampling episodes ended, EPA prepared a sampling episode report for each facility. The reports included descriptions of the wastewater treatment processes, sampling procedures, and analytical results. EPA documented all data collected during the sampling episodes in the sampling episode report for each sampled site and has included them in the MPP Administrative Record. For detailed information on sampling and preservation procedures, analytical methods, and quality assurance/quality control procedures, see the various sampling episode reports in the rulemaking record (see Sections 6 and 19 of the Administrative Record).

3.1.2.4 Pollutants Sampled

The Agency (or facilities, as directed by the Agency) collected, preserved, and transported all samples according to EPA protocols, as specified in EPA's *Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants* and in the MPP Quality Assurance Project Plan (QAPP).

EPA collected composite samples for most parameters because the Agency expected the wastewater composition to vary over the course of a day. The Agency took grab samples from unit operations for oil and grease and microbiologicals. EPA collected composite samples manually or by using an automated sampler. The Agency collected individual aliquots for the composite samples at least once every 4 hours over each 24-hour period. Oil and grease samples were collected every 4 hours, and microbiologicals were collected once a day.

Table 3-1 lists the parameters sampled at most of the facilities. Some of the parameters have not been identified as pollutants of concern (see Chapter 7 for an evaluation of the pollutants of concern in the MPP industry).

Table 3-1. MPP Sampled Parameters

Biochemical oxygen demand (BOD_5)	Oil and grease
Carbonaceous biochemical oxygen demand ($CBOD_5$)	Metals (e.g., arsenic, chromium, copper, mercury, zinc)
Dissolved biochemical oxygen demand ($DBOD_5$)	Carbamate pesticide (carbaryl)
Chemical oxygen demand (COD)	Permethrin (cis- and trans-)
Total organic carbon (TOC)	Malathion
Total suspended solids (TSS)	Stirofos
Total dissolved solids (TDS)	Dichlorvos
Total volatile solids (TVS)	Total coliform bacteria
Chloride	Fecal coliform bacteria
Total residual chlorine (TRC)	*Escherichia coli*
Ammonia as nitrogen	Fecal streptococci
Nitrate/nitrite	*Salmonella*
Total Kjeldahl nitrogen (TKN)	*Aeromonas*
Total phosphorus (TP)	*Cryptosporidium* (meat facilities only)
Total dissolved phosphorus (TDP)	
Orthophosphate	

EPA contract laboratories completed all wastewater sample analyses except the field measurements of temperature, DO, and pH. EPA or facility staff collected field measurements of temperature, DO, and pH at the sampling site. The analytical chemistry methods used, as well as the sample volume requirements, detection limits, and holding times, were consistent with the individual laboratory's quality assurance and quality control plan. Laboratories contracted for MPP sample analysis followed EPA-approved analysis methods for all parameters.

The EPA contract laboratories reported data on their standard report sheets and submitted the sheets to EPA's sample control center (SCC). The SCC reviewed the report sheets for completeness and reasonableness. EPA reviewed all reports from the laboratories to verify that the data were consistent with requirements, reported in the proper units, and in compliance with the applicable protocol. Appendix A provides brief descriptions of each of the analytical methods.

Quality control measures used in performing all analyses complied with the guidelines specified in the analytical methods and in the MPP QAPP. EPA reviewed all analytical data to ensure that these measures had been followed and that the resulting data were within the QAPP-specified acceptance criteria for accuracy and precision. The SCC's review is summarized in the Data Review Narratives available in Sections 6.1.4.2 and 22.6 of the Administrative Record.

3.2 EPA MPP INDUSTRY SURVEYS

3.2.1 Overview of Industry Surveys

EPA did not have the site-specific technical and economic information required for the development of technologically achievable regulatory options for the MPP industry. Therefore, EPA used two survey questionnaires to collect that information.

EPA published a notice in the *Federal Register* on May 1, 2000 (65 FR 25325) announcing its intent to submit the MPP industry survey Information Collection Request (ICR) to the Office of Management and Budget (OMB). The May 1, 2000, notice requested comment on the draft ICR and the survey questionnaires. EPA received five sets of comments during the 60-day public comment period. Commentors on the ICR included the National Chicken Council, National Renderers Association, American Meat Institute, U.S. Poultry and Egg Association, and BCR Foods. EPA made minor clarifying revisions to the survey methodology and questionnaires as a result of the public comments received.

EPA made every reasonable attempt to ensure that data and information to be collected in the survey questionnaires were not currently available through less burdensome mechanisms. Before publishing the May 1, 2000, notice, EPA met with and distributed draft copies of the survey questionnaires to three trade associations representing the MPP industry: American Meat Institute, National Chicken Council, and National Renderers Association. EPA subsequently obtained approval from OMB for the use and distribution of two survey questionnaires—a short screener survey and a more detailed survey.

3.2.2 Description of Survey Instruments

In February 2001 EPA mailed a short screener survey entitled "2001 Meat Products Industry Screener Survey" to 1,650 MPP facilities. The screener survey consisted of seven questions that elicited site-specific information such as the type of animal processed and processing operation, wastewater disposal method, and number of full-time employees at the site and in the company. EPA used the information collected from the screener survey to describe industry operations, wastewater generation rates, and wastewater disposal practices. EPA also used the responses to the site employment question to classify each facility as small or not-small according to the Small Business Administration regulations at 13 CFR Part 121.

EPA designed the second survey to collect detailed, site-specific technical and financial information. In March 2001 the second survey, "2001 Meat Products Industry Survey," was mailed to 350 MPP facilities. The detailed survey was divided into five parts. The first four parts collected general facility and technical data. The first set of questions requested general facility site information. The general facility information questions asked the site to identify itself; characterize itself by certain parameters (including MPP operations, age, and location); and confirm that it was engaged in meat and/or poultry processing operations. Respondents also indicated whether they use trisodium phosphate (TSP) as a biocide. (Substituting other non-phosphorus-based biocides with TSP has the potential to lower overall phosphorus concentrations in the raw wastewater and treated effluent.) The second set of questions requested analytical and production data, including detailed daily analytical and flow rate data for selected sampling points, monthly production data, and operating hours for selected manufacturing operations. Survey respondents were also required to provide existing sampling data and information. The Agency used the analytical data to estimate baseline pollutant loadings and pollutant removals from facilities with treatment in place resembling projected regulatory options and to evaluate the variability associated with MPP industry discharges. The Agency used the production data collected to evaluate possible relationships between production and wastewater quantity and characteristies.

The next two sections of the survey focused on wastewater characteristics and current treatment practices, respectively. Questions regarding wastewater and treatment were designed to gather the following: information on the wastewater treatment systems (including flow diagrams) and discharge flow rates, analytical monitoring data, and operating and maintenance cost data (including treatment chemical usage). The outfall information questions covered permit information such as discharge location, wastewater sources to the outfall, flow rates, regulated parameters and limits, and permit monitoring data. EPA used this information to calculate the effluent limitations guidelines (ELGs) and standards and the pollutant loadings associated with the regulatory options that the Agency considered for the final rule. The Agency also used data received in response to these questions to identify treatment technologies in place; to determine the feasibility of regulatory options and potential revision of the subcategorization scheme for the MPP industry; and to estimate compliance costs, the pollutant reductions associated with the likely technology-based options, and potential environmental impacts associated with the regulatory options EPA considered for the final rule.

The fifth part of the detailed survey elicited site-specific financial and economic data. EPA used this information to characterize the economic status of the industry and to estimate the potential economic impacts of the final rule. The financial and economic information collected in the survey was necessary to complete the economic analysis of the ELGs and standards for the MPP industry. EPA requested financial and economic information for the fiscal years ending 1997, 1998, and 1999, the most recent years for which data are available.

3.2.3 Development of Survey Mailing List

EPA sent the two MPP industry survey questionnaires to a random sample of facilities included in the United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) Hazard Analysis and Critical Control Points (HACCP) database and to a list of renderers provided by the National Renderers Association. The HACCP database provided a list of 7,891 federally and state-inspected meat and poultry processing facilities. The HACCP database used by EPA was dated March 9, 2000, for the federally inspected facilities and May 10, 2000, for the state-inspected facilities. The entire database is classified into large, small, and very small facilities, corresponding to more than 500 employees, 10 to 500 employees, and fewer than 10 employees at the facility (site) level. The 231 renderers from the Association's list were not classified by size. The *Urner Barry Meat and Poultry Directory 2000* included production information (that is, whether a facility was a slaughterer or further processor) for at least 242 of the 292 large facilities (82 percent) and 1,236 of the 2,381 small facilities (52 percent). No such information was available for the remaining large and small facilities or for any of the 5,308 very small facilities.

3.2.4 Sample Selection

EPA grouped the facilities into seven strata by size and the type of meat and poultry processing operation that takes place at each facility, so that each stratum would encompass facilities with similar operations. Such grouping (also known as stratification) increases precision (reducing one source of uncertainty) for estimates of costs, benefits, and other quantities. Table 3-2 shows the stratification of the MPP industry based on employment and other information from the HACCP database, the *Urner Barry Meat and Poultry Directory 2000*, and the National Renderers Association.

Various meat and poultry processors were randomly selected within each grouping. EPA weighted each survey response to account for facilities not surveyed and to develop national estimates from the survey responses. EPA deliberately selected the 65 "certainty" facilities to obtain site-specific information on the top producers for all types of MPPs, as well as facilities identified as good performers by state and EPA Regional personnel.

Table 3-2. Meat and Poultry Products Industry Strata

Stratum (No. of Employees)	Number of Facilities in Stratum	Screener Survey Sample Size	Detailed Survey Sample Size
Certainty	65	0	65
Large further processor (> 500)	43	31	3
Large first processor (> 500)	190	100	52
Small further processor (10–499)	1,878	688	62
Small first processor (10–499)	498	130	69
Very small further processor (< 10)	5,308	649	57
Renderer	235	52	42
Total	8,217	1,650	350

EPA focused much of its analysis on the characteristics of larger facilities because small facilities as a group are estimated to discharge fewer than 3 percent of the conventional pollutants, 1 percent of the toxic pollutants, 4 percent of the nutrients, and less than 1.5 percent of the pathogens as compared to all discharges from the entire MPP industry. Moreover, most of these small facilities discharge small volumes of wastewater into large urban publicly owned treatment works (POTWs) and therefore the impact on POTW operations and the passing of MPP pollutants of concern through POTWs into waters of the United States are minimal. Consequently, larger facilities were oversampled in the sample design. The oversampling rate is approximately 6:3:1, meaning that the large facilities were sampled at six times the rate of the very small facilities, and the small facilities at three times the rate of the very small. In addition, many of the very small facilities were not eligible for the survey because they were no longer in operation. Appendix B provides additional information on how the Agency designed the survey, developed the sample size, and extrapolated the survey results.

3.2.5 Survey Response

Among the 2,000 mailed surveys, 350 facilities were mailed detailed surveys and 1,650 facilities were mailed screener surveys. Of the detailed surveys, 65 were certainty facilities. EPA received 1,498 out of the 1,650 screener surveys, and 328 out of the 350 detailed surveys. Out of the 328 returned detailed surveys, 249 were considered complete based on meeting the requirements of a survey completeness checklist. Out of the 1,498 returned screener surveys, 1,191 screener surveys were considered complete. Only 64 out of the 65 certainties were returned, and one of these was a duplicate. Thus, only 63 certainty surveys were considered complete. EPA used all surveys in analyses for the NODA (68 FR 48472; August 13, 2003) and final rule.

3.2.6 Survey Review and Follow-up

EPA conducted several follow-up efforts to ensure that the detailed survey data collected from MPP facilities were as complete and accurate as possible, including follow-up phone calls to facilities if survey responses were incomplete or if there were discrepancies in the data reported. EPA then made an effort to systematically confirm information for all direct discharge detailed survey recipients. Specifically, EPA mailed a summary of facility-specific responses (referred to as a "fact sheet") to the 58 detailed survey respondents that had indicated in their survey response that they were direct dischargers. The fact sheet requested confirmation of the following information for 1999 by product type (meat or poultry): the type of processing (first processing, further processing, rendering); the related production volume; and the wastewater flows from various production operations. In addition, the Agency requested information on each site's wastewater treatment system. This included confirmation of EPA's classification of the treatment level of the facility's wastewater treatment system according to the Agency's treatment option designations, as identified in the cover letter to the facility; average effluent flow rate; targeted pollutant parameters (e.g., BOD removal, nitrification, phosphorus removal); and confirmation of the summary of the effluent parameters and concentrations from the survey that EPA intends to use in developing pollutant loading estimates. Facilities were contacted when clarification was needed on any responses provided. Based on the revised fact sheets, EPA incorporated changes to its database to the extent possible (e.g., EPA did not incorporate revisions to microbial concentrations that had been calculated using the geometric mean).

In addition to incorporating the survey data described above, EPA sought to clarify screener survey information and collected additional information from screener survey sites in response to comments regarding the validity of the Agency's database and the Agency's characterization of the baseline pollutant loadings from the MPP industry. EPA contacted 34 screener survey facilities that appeared to be direct dischargers based on their survey responses. These 34 facilities represent direct dischargers that were not engaged in slaughtering operations; that is, performed only further processing or rendering. Most of these sites were identified as further processors, but five sites were renderers. EPA contacted these facilities to discuss the wastewater treatment systems in place at the sites in 1999 (the base year of the survey), as well as to verify the following information: manufacturing type (e.g., meat further processor vs. poultry further processor); wastewater flows; production classification (small vs. non-small); discharge mode/wastewater management type (e.g., indirect discharge to POTW, direct discharge to receiving water, land application); monitored pollutant parameters; current wastewater treatment system and target concentrations; and receiving waterbody. EPA obtained responses from 30 sites. Of these, 18 were in fact direct dischargers, 11 turned out to be indirect dischargers, and 1 was not operating. EPA also received discharge monitoring report DMR data from three further processing sites in response to these follow-up discussions. EPA has incorporated the information described above into the analyses of further processors and renderers.

3.3 OTHER INFORMATION COLLECTION ACTIVITIES

EPA conducted a number of other data collection efforts to supplement information gathered through the survey process, facility sampling activities, site visits, and meetings with industry experts and the public. The main purpose of these other data collection efforts was to obtain information on the documented environmental impacts of MPP industry facilities, as well as additional data on animal processing waste characteristics, pollution prevention practices, wastewater treatment technology innovation, and facility management practices. These other data collection activities included a literature search, a review of current NPDES permits, and a review of NPDES DMRs.

3.3.1 Literature Search

EPA conducted a literature search to obtain information on various aspects of the animal processing industry, including documented environmental impacts, wastewater treatment technologies, waste generation and facility management, and pollution prevention. EPA performed extensive Internet and library searches for applicable information. The Agency used the resources of its own environmental library and of the USDA's National Research Library to obtain technical articles on environmental issues related to the MPP industry. Researchers also consulted several university libraries and industry experts during the literature search. As a result, EPA was able to compile a list of environmental impacts associated with the MPP industry. The scope of the literature search included government reports of permit violations and any associated environmental impacts. EPA has included a summary of the case studies in the Administrative Record associated with the MPP rule. The primary sources for the case studies are newspaper and technical journal articles, government reports, and papers included in industry and academic conference proceedings.

3.3.2 Current NPDES Permits

EPA extracted information from the Agency's Permit Compliance System (PCS) to identify meat and poultry processing industry point source dischargers with NPDES permits. PCS is a database that contains monitoring and NPDES permit data from major and some minor point sources that discharge wastewater directly to surface waters. This initial extraction was performed by searching PCS using reported Standard Industrial Classification (SIC) codes used to describe the primary activities that occur at the site. Specifically, the following SIC codes were used:

- 2011—Meat Packing Facilities
- 2013—Sausages and Other Prepared Meats
- 2015—Poultry Slaughtering and Processing
- 2077—Animal and Marine Fats and Oils

EPA identified 359 active meat and poultry product facilities with NPDES permits in PCS. The PCS estimate of MPP direct dischargers is approximately equivalent to the screener survey estimate of direct dischargers.

EPA selected a sample from the universe of direct dischargers in PCS. The Agency then reviewed NPDES permits and permit applications to obtain information on treatment technologies and wastewater characteristics for each of the respective animal processing and rendering sectors. EPA used this information as part of its initial screening process to identify the universe of processing facilities that would be covered under the proposal. In addition, the Agency used this information to better define the scope of the ICRS and to supplement other information collected on meat and poultry processing waste management practices.

In an effort to obtain additional information without burdening the facilities directly, EPA gathered permits, permit applications, and permit fact sheets from EPA regional offices and states for some facilities from which EPA did not receive a detailed survey and which were identified as meat or poultry processors either in PCS or in the screener survey database.

EPA was interested in obtaining information on the permit requirements and treatment in place at facilities that had specific production processes about which the Agency had limited information for the proposal (e.g., stand-alone further processors and renderers). EPA identified over 980 facilities in PCS classified under SIC codes 2011, 2013, 2015, and 2077 (the codes that identify meat or poultry processing and rendering), plus some related sic codes referring to different aspects of food processing such as 2091 (Canned and Cured Fish and Seafoods) and 2099 (Food Preparations, Not Elsewhere Classified). EPA then refined the list by selecting those facilities that had data in PCS for at least one of the pollutants (POCs) of concern, for which EPA had limited data. EPA identified facilities with the following POCs: total Kjeldahl, nitrogen (TKN), nitrate + nitrite, total phosphorus, chemical oxygen demand, carbonaceous biochemical oxygen demand, total nitrogen, fecal streptococci, total dissolved solids, chloride, Eschenchia. coli, oil and grease as hexane-extractable material, copper, chromium, nickel, and zinc. EPA then added to the list all further processors and independent renderers that were in the screener survey database but were not currently on the list generated through PCS. Detailed survey recipients were then excluded because they had provided sufficient information in their survey responses. EPA then sought permits for all the facilities identified on this refined list (104 facilities), which is included in the Administrative Record (see Section 18.1.1, DCN 100769).

EPA obtained a copy of the NPDES permit, permit application, and/or fact sheet for 61 facilities (in 20 states) of 104 total facilities (in 27 states) on the refined list and obtained notice of closure on an additional 14 of the 104 facilities.

3.3.3 Discharge Monitoring Reports

In addition, the Agency collected long-term effluent data from facility DMRs through PCS in an effort to perform a "real world" check on the achievability of the MPP limits. DMRs summarize the quality and volume of wastewater discharged from a facility under an NPDES permit. They are critical for monitoring compliance with NPDES permit provisions and for generating national trends in Clean Water Act compliance. DMRs may be submitted monthly, quarterly, or annually depending on the requirements of the NPDES permit.

EPA extracted discharge data and permit limits from the DMRs (through PCS) to help identify pollutants of concern (pollutants currently being regulated) and to identify better-performing facilities. EPA conducted this analysis in part to identify potential facilities for sampling, as well as to assist in identifying a selection of facilities for the certainty component of the detailed survey exercise.

EPA was able to collect DMR information on a total of 176 facilities from four MPP sectors: 77 meat packing facilities, 17 facilities producing sausages and other prepared meat products; 65 poultry slaughtering and processing facilities, and 17 animal and marine fat and oils facilities. EPA collected 31,311 data points on 83 separate pollutant parameters.

Indirect dischargers file compliance monitoring reports with their control authority (e.g., POTW) at least twice a year as required under the General Pretreatment Standards (40 CFR 403), while direct dischargers file DMRs with their permitting authority at least once a year. EPA did not collect compliance monitoring reports for MPP facilities that are indirect dischargers for two reasons: (1) a vast majority of MPP indirect dischargers are small facilities (in terms of volume of wastewater), and (2) this information is less centralized and therefore harder to collect than information on direct dischargers.

Because DMRs and indirect dischargers' compliance monitoring reports do not provide information about processes and production, EPA was not able to use these data directly in calculating the limitations and standards. Instead, in the detailed survey EPA requested that facilities provide the individual daily measurements from their monitoring (for DMRs or the control authority) along with detailed information about their treatment systems and processes. After further evaluation of the detailed surveys, EPA used the self-monitoring data corresponding to the treatment options to calculate the final limits and to reassess the achievability of the limits by well-operated best available technology economically achievable (BAT) systems. In cases where EPA determined that improved system operation will allow the limits to be achieved consistently, it included additional treatment costs for the facility in its cost estimations for the final rule where it had not already done so. In following the approach described above, EPA addressed issues related to the achievability of the numerical limits by well-operated and economically achievable treatment systems.

Following proposal, based on the DMR summary data provided in the detailed surveys or PCS, EPA requested individual data points (e.g., daily or weekly measurements) from 24 detailed survey sites in the slaughtering subcategories (Subcategories A through D and K) for use in evaluating and revising the ELGs and standards and supporting analyses. EPA also has received complete data from 16 facilities, partial data from 5 facilities, and no data from 3 facilities (see Section 19.3.3 of the Administrative Public Record). EPA has incorporated the daily/weekly data sets into its development of facility-level (episode-level) long-term averages and variability factors.

3.3.4 Data Submitted by Industry

EPA received some estimated summary-level cost data in the industry comments on what it might cost for a meat or rendering facility to upgrade its existing technologies. EPA also obtained upgrade/retrofit cost information from one meat site and one poultry products site as a follow-up to earlier, pre-proposal sampling and from one poultry site that was sampled after proposal. EPA has used this information in the development of the cost estimates.

In response to its request in the proposed rule, EPA received data submitted for several facilities, two companies (one provided site-specific data for four facilities, and one provided generalized data for its facilities), an industry coalition, and an industry trade association. The data submitted by the industry coalition and the industry trade association were the same and represented data for four pollutants for one of the poultry facilities sampled by EPA for the proposal. Of the facilities for which data were submitted, data for two of the facilities were the same as the data provided in the facilities' detailed surveys (the data were provided only for TKN.) EPA included the TKN data in the loadings and cost analyses but did not use data from some facilities for its analyses because the Agency requires supporting information about the facilities (e.g., treatment system type, production type) before the data can be used to classify the data properly. EPA did not incorporate some TKN data because it supplied only a typical range of TKN values for a number of poultry facilities, not data for any specific facility.

3.4 STAKEHOLDER MEETINGS

EPA encouraged the participation of all interested parties throughout the development of the MPP rule. The Agency conducted outreach to the following trade associations (which represent the vast majority of the facilities that will be affected by the ELGs and standards): American Meat Institute, American Association of Meat Processors, National Renderers Association, U.S. Poultry and Egg Association, and National Chicken Council. EPA met on numerous occasions with various industry representatives to discuss aspects of the regulation development. EPA also participated in industry meetings and gave presentations on the status of the regulation development. Summaries of these meetings are in the Administrative Record for the rulemaking.

In the development of the surveys used to gather facility-specific information on the MPP industry, EPA consulted with the industry groups and several of their members to ensure that the information was being requested in an intelligible manner and that they would provide it in the form requested.

EPA also met with representatives from USDA to discuss this regulation and how it might be affected by or affect requirements on the meat and poultry processing industry implemented by USDA FSIS. EPA met with representatives from state and local governments to discuss about concerns about meat and poultry processing facilities and how EPA should approach these facilities in regulation. Summaries of these meetings are in the Administrative Record. In addition, EPA regional and state pretreatment coordinators were contacted to identify MPP indirect dischargers that were causing POTW interference or pass-through. The results of that search are summarized in the Administrative Record. After proposal, EPA conducted a more systematic and thorough study of POTWs accepting MPP indirect discharges to better characterize interference and pass-through issues. EPA presented the results of the findings in the NODA (see 68 FR 48477; August 13, 2003)

SECTION 4

MEAT AND POULTRY PRODUCTS INDUSTRY OVERVIEW

This section provides an overview of the meat and poultry products (MPP) industry. Section 4.2 provides a general overview of the industry. Sections 4.3, 4.4, and 4.5 provide more detailed information related to meat, poultry, and rendering operations, respectively.

4.1 INTRODUCTION

The MPP industry includes facilities that slaughter livestock (e.g., cattle, calves, hogs, sheep, and lambs), poultry, or both or process meat, poultry, or both into products for further processing or sale to consumers. In some facilities, slaughtering and further processing activities are combined. The industry is often described in terms of three categories: (1) meat slaughtering and processing, (2) poultry slaughtering and processing, and (3) rendering. A facility might perform slaughtering operations, processing operations from carcasses slaughtered at the facility or at other facilities, or both. Companies that own MPP facilities might also own the facilities that raise the animals or further process the meat or poultry products into final consumer goods. Wastewater generated by the raising of animals, however, is not covered by the MPP industry effluent limitations guidelines (ELGs).

Since the 1970s when EPA issued the existing regulations for the meat and rendering industry sectors, the MPP industry has become increasingly concentrated and vertically integrated through alliances, acquisitions, mergers, and other relationships. This vertical integration is particularly pronounced in the broiler sector of the poultry industry. Most of the broiler and other chicken products that reach the consumer have been under the control of the same company from the hatching through the processing of the birds. Vertical integration has not occurred to the same extent in the meat sector, although there is increasing vertical integration, particularly in the hog sector.

The MPP industry encompasses four North American Industry Classification System (NAICS) codes developed by the Department of Commerce. These codes are Animal

Slaughtering (Except Poultry), NAICS 311611; Meat Processed from Carcasses, NAICS 311612; Poultry Processing, NAICS 311615; and Rendering and Meat Byproduct Processing, NAICS 311613.

4.2 MEAT PRODUCTS INDUSTRY DESCRIPTION

4.2.1 Animal Slaughtering (Except Poultry)

Meat first processors (NAICS 311611: Animal Slaughtering (Except Poultry)) include meat first processing facilities that slaughter cattle, hogs, sheep, lambs, calves, horses, goats, and exotic livestock (e.g., elk, deer, buffalo) for human consumption. Slaughtering (first processing) is the first step in the processing of meat animals into consumer products. Slaughterhouse operations typically encompass the following steps: (1) receiving and holding of live animals for slaughterm, (2) stunning prior to slaughter, (3) slaughter (bleeding), and (4) initial processing of animals. Slaughterhouse facilities are designed to accommodate this multistep process. In most slaughterhouses, the major steps are carried out in separate rooms.

Many first processing facilities also further process carcasses on-site to produce products such as hams, sausages, and canned meat. Otherwise, carcasses might be shipped to other facilities for further processing. In addition, many first processing facilities include rendering operations that produce edible products, such as lard, and inedible products, including ingredients for animal feeds and products for industrial use.

Based on the 1997 U.S. Census of Manufacturers, the animal first processing industry sector includes 1,300 companies, which operate approximately 1,400 facilities. The industry sector employs 142,000 people and generates a total value of shipments of $54 billion. Twelve states reported shipments in excess of $1 billion; Texas, California, Illinois, Iowa, and Wisconsin contain the largest number of first processing establishments (at least 60 establishments in each state). Nebraska ranks seventh in the number of facilities in the state, but it has the highest number of employees engaged in animal first processing of any state. Nebraska accounts for almost 17 percent of the value added and 16 percent of total shipments in this industry sector. Industry activity is most heavily concentrated in Nebraska, Kansas, Iowa, and Texas.

The Animal First Processing sector comprises a large number of facilities (72 percent of the sector) that have fewer than 20 employees. These facilities employ less than 5 percent of the sector workforce and contribute an even smaller percentage of value added and value of shipments to this sector. Thirty-nine facilities employ between 1,000 and 2,500 employees. Although the 39 facilities constitute only 3 percent of the total number of establishments, they provide 43 percent of the industry employment and 46 percent of the value of shipments.

Revised production rate thresholds exclude most smaller meat product processing facilities from the final revisions to 40 CFR Part 432. Small facilities will remain subject to the existing regulations in 40 CFR Part 432. Based on the current screener survey data, EPA is defining small meat first processing facilities as those which produce 50 million pounds or less live weight kill (LWK) per year.

4.2.2 Meat Processed from Carcasses

Meat further processors (NAICS 311612: Meat Processed from Carcasses) include facilities engaged in processing or preserving meat and meat by-products (but not poultry or small game) from purchased meats. These facilities do not slaughter animals or perform any initial processing (e.g., defleshing, defeathering).

The Meat Further Processing sector includes 1,164 companies, which own and operate about 1,300 facilities. This sector employs about 88,000 people, and the value of shipments is more than $25 billion, of which $9 billion is value added by manufacture.

California, Illinois, New York, and Texas have the highest concentration of meat further processing facilities, each with more than 90 such facilities. The highest levels of employment, however, are in Illinois, Pennsylvania, Texas, and Wisconsin, which together generate one-third of the meat further processing employment. In Wisconsin more than half of the meat further processing facilities employ more than 20 workers, and the state also accounts for the largest share of both total shipments and value added in the industry.

As with the Animal First Processing sector, more than half of the meat further processing facilities employ fewer than 20 workers. The bulk of the employment (54 percent), value added (55 percent), and total shipments (57 percent) is accounted for by meat further processing facilities that employ between 100 and 500 workers. The difference between the Animal First Processing sector and the Meat Further Processing sector is that although the value of shipments in the Animal First Processing sector is heavily concentrated in the largest facilities, the value of shipments in the Meat Further Processing sector is more evenly distributed across meat further processing facilities of all different sizes.

4.3 DESCRIPTION OF MEAT FIRST AND FURTHER PROCESSING OPERATIONS

The meat processing industry produces meat products and by-products from cattle, calves, hogs, sheep, lambs, horses, and all other animal species except poultry, other birds, rabbits, and small game. Equine meat production has declined in the United States in the past 5 years. The total annual production of equine meat was 47,134 head in the year 2000 (USDA, 2001). Most horse meat is exported to Europe for consumption because of the cultural aversion to horse meat consumption in the United States. It is not known whether European demand for horse meat will increase in the future, given concerns about transmissible bovine spongiform encephalopathy (mad cow disease) in cattle.

The processing of animal species other than cattle and hogs accounts for only a small fraction of total production. The live weight of cattle and hogs slaughtered annually is consistently more than 90 percent of the total live weight of meat animals slaughtered for the production of meat products and by-products. Given that there is little difference in the processing of cattle, calves, sheep, lambs, and horses, only the processing of cattle is described in the sections that follow; parallel discussions are provided where cattle and hog processing procedures differ.

Meat processing begins with the assembly and slaughter of live animals and can end with the shipping of dressed carcasses or continue with a variety of additional activities. Meat processing operations are classified as slaughter (first processing) or further processing operations or an integrated combination of both. First processing operations include those operations which receive live meat animals and produce a raw or dressed meat product, either whole or in parts. In this classification system, first processing operations simply produce dressed whole or split carcasses or smaller segments for sale to wholesale meat distributors or directly to retailers. These operations are often prerequisites to further processing activities. Further processing refers to operations that use whole carcasses or cut-up meat or poultry products to produce fresh or frozen products. It can include the following types of processing: cutting and deboning, cooking, seasoning, smoking, canning, grinding, chopping, dicing, forming, breading, breaking, trimming, skinning, tenderizing, marinating, curing, pickling, extruding, and linking. Demand for whole or split carcasses has gradually declined since the mid-1970s with a concurrent increase in demand for a greater degree of carcass cut-up ranging from separation of whole or split carcasses into front and hind quarters or smaller sections (e.g., "boxed beef") to the preparation of packaged, case-ready, fresh cuts of meat. Most first processing operations today perform some cutting, deboning, and grinding operations. Further processing operations such as sausage production, curing, pickling, smoking, cooking, and canning can occur on-site or at off-site facilities.

Therefore, EPA considers the reduction of whole or split carcasses into quarters or smaller segments (including case-ready cuts, which might be with or without bone and might be ground) to be part of first processing operations when performed at first processing facilities. Conversely, EPA considers the cutting, boning, and grinding operations to be further processing operations when performed at facilities not also engaged in first processing activities. The reduction of whole or split carcasses or smaller carcass segments (e.g., boxed beef) into case-ready cuts at the retail level is an example of a case in which cutting, boning, or grinding would be further processing.

4.3.1 Meat Slaughter and Packing Operations

Common to all meat first processing operations are the steps necessary to transform live animals into whole or split carcasses. These steps include the assembly and holding of animals for slaughter; killing, which involves stunning before and bleeding after killing; hide or hair removal in the case of hogs, evisceration, and variety meat (organ) harvest; carcass washing; trimming; and carcass cooling. Depending on the market served, cutting, deboning, and grinding and other further processing operations might occur at the same location.

Most meat facilities for which site visits were conducted slaughtered animals 5 days per week, Monday through Friday. Slaughtering might also be performed on Saturdays during peak production periods. Employees of meat facilities typically work 8 to 9.5 hours per day, Monday through Friday, and when necessary 4 to 5 hours on Saturday. Meat facilities usually have two slaughter shifts per day—one starting at approximately 6 a.m. and the other starting at approximately 3 p.m.

In general, larger meat first processing operations specialize in the processing of one type of animal (e.g., cattle, calves, sheep, lambs, hogs, or horses). Differences in animal size and some processing steps preclude the design of processing equipment for multiple animal types. If a single facility does slaughter different types of meat animals, separate lines, if not buildings, are used (Warriss, 2000); however, very small meat first processing operations might process several types of meat animals in a single building. Figure 4-1 shows the general sequence of steps in the process of transforming live meat animals into carcasses. Detailed descriptions of these steps are given in the following sections.

4.3.1.1 Live Animal Receiving and Holding

Meat processors schedule receipt of live animals for slaughter from producers not only to provide a continuous supply of animals for processing but also to minimize holding time to no more than 1 day. This practice eliminates the need for feeding and reduces manure accumulation in holding pens. Processors do, however, provide water to minimize weight loss. With the relocation of first processing operations to areas of animal production, movement by truck has replaced rail transportation of live animals.

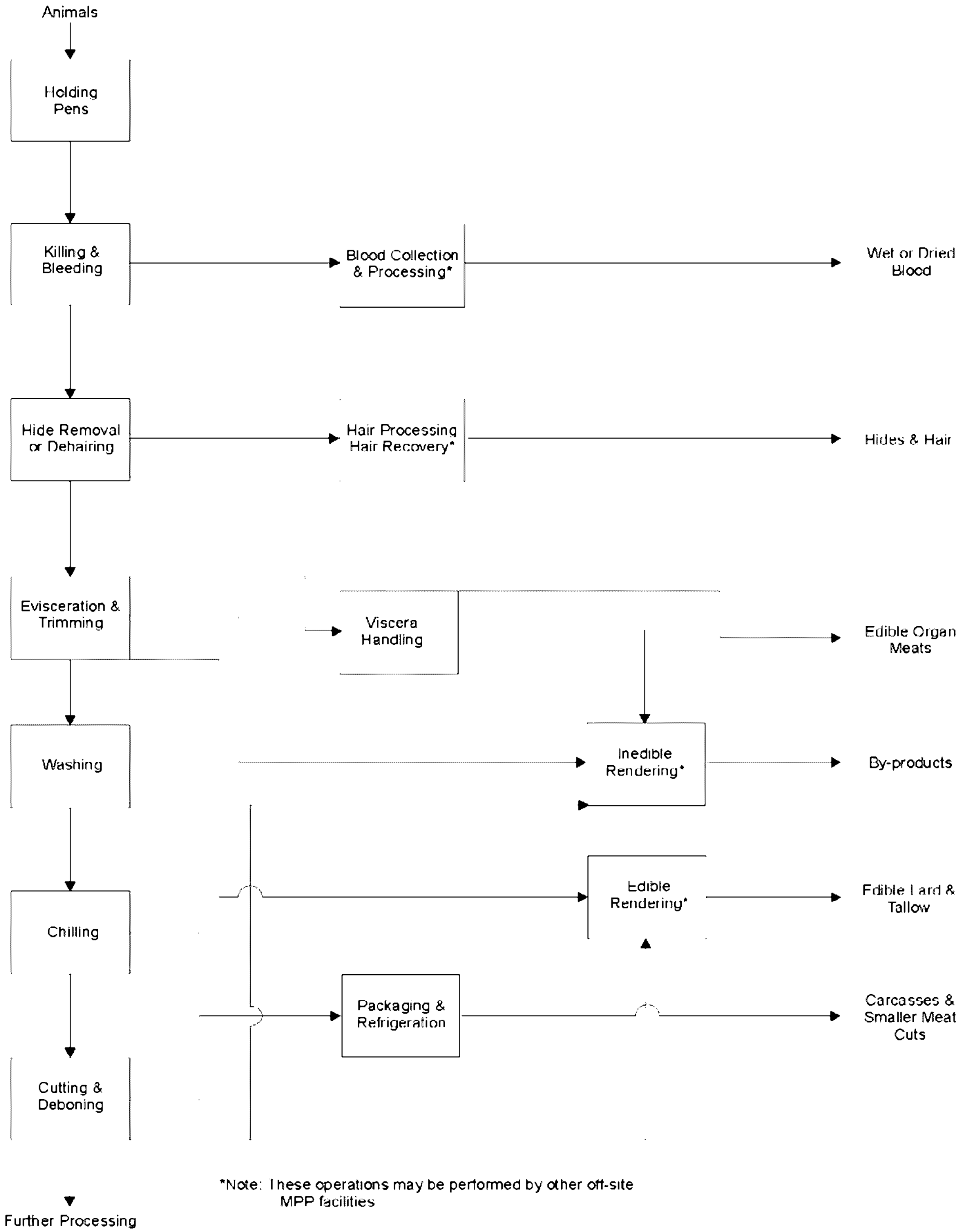

Figure 4-1. General Process for Meat Processing

Holding pens, which allow recovery from shipping-related stress, can be covered or totally enclosed, especially in cold climates, to provide some protection from extreme weather conditions but primarily to reduce contaminated runoff from precipitation events. Holding pens are, however, sources of wastewater resulting from pen washing and drinking water spillage. Water pollutant concentrations depend on whether pens are scraped (dry cleaned) prior to wash-down to remove accumulated manure. Animals are herded from the holding pens to the killing area of the processing plant through connecting alleys. These alleys are also sources of wastewater generated during precipitation events (if uncovered), as well as from cleaning.

4.3.1.2 Methods Used to Stun Animals

Humane slaughter legislation requires that animals be stunned to produce an unconscious state before killing to reduce their pain and suffering. Some exemptions are made for religious meat processing (e.g., kosher, halal). Cattle are typically stunned by mechanical means using a captive bolt pistol, percussion stunner, or free bullet to inflict brain trauma and the immediate loss of consciousness. Electric shock is most commonly used to stun hogs because mechanical stunning can result in convulsions, making subsequent shackling difficult. Electric shock is also commonly used to stun sheep, lambs, and calves before killing.

A less commonly used alternative to electric shock for stunning hogs is exposure to a 70 to 90 percent carbon dioxide environment in a pit or tunnel. Inhalation of a high concentration of carbon dioxide causes a drop in brain fluid pH and loss of consciousness. Current research is being performed to evaluate argon as a substitute for carbon dioxide. Although stunning with argon is believed to be less stressful to the animal than using carbon dioxide, use of argon requires longer exposure periods to achieve unconsciousness (Warriss, 2000).

4.3.1.3 Killing and Bleeding

Immediately after stunning, shackles are attached to the animal's rear legs for suspension from an overhead rail conveyor used to move the carcass through the processing plant. After hanging the animals, processors kill them within seconds by severing main arteries and veins in the neck region to cause death by massive and rapid blood loss (exsanguination). This process is generally known as "sticking," and somewhat different techniques are used for cattle, hogs, sheep, and horses.

Troughs or gutters collect blood lost following sticking for recovery in the form of various by-products. If blood is collected for subsequent human consumption in products such as blood sausage, a hollow knife connected to a special tank under partial vacuum is used. While approximately 40 to 60 percent of the blood exits the body during bleeding, about 3 to 5 percent remains in the muscles and the remainder is in held in the viscera (Wilson, 1998).

Certain religious practices require an alternative slaughter process for cattle. In these cases, the animal is not stunned before slaughter. Instead, the animal is restrained while the slaughterer makes a transverse cut that severs the major vessels in the throat (Warriss, 2000). The Jewish slaughter practice, called Shechita, requires a single cut without pause, pressure, stabbing, slanting, or tearing. The cut severs the skin, muscles, trachea, esophagus, jugular veins, and carotid arteries. After bleeding ceases, the slaughterer searches for lung adhesions. The meat is unfit for consumption if the sores are believed to have been detrimental to the animal while alive. Next, the removal of blood vessels and sinews, called porging, completes the slaughter ritual. Halal, the Muslim slaughter practice, is similar to Shechita; the main difference is that searching and porging do not take place (Wilson, 1998).

Although not common, the slaughtering process might include electric stimulation of the carcasses to improve meat quality and to facilitate removal of the hide. Typically, this process calls for a skull probe, which is inserted into the skull of the carcass through the hole from the captive bolt for 30 seconds (Wilson, 1998). One of the primary goals of electric stimulation is to prevent cold shortening, which makes the meat less tender. Plants use both high-voltage (more than 500 volts) and low-voltage (30 to 90 volts) electric stimulation systems (USEPA, 1997).

4.3.1.4 Hide Removal from Cattle and Sheep and Hair Removal from Hogs

Before evisceration, slaughterers remove hides from cattle and sheep and hair from hog carcasses to reduce the potential for contamination of the carcasses after evisceration from hair, dirt, and manure. Hides are usually removed from cattle and sheep mechanically after the head, tail, and hoove have been removed. The process of hide removal begins with some initial separation from the carcass manually, using conventional or air-driven knives, to enable attachment of mechanical pullers. The pullers then remove the hide by pulling up from the neck to the tail or pulling in the reverse direction, which is less common.

On-site hide processing can consist of salting for preservation before shipment to leather tanning operations, or it can involve washing, defleshing, and salting before shipment. However, on-site hide processing options also include curing before shipment for off-site tanning or complete processing followed by the marketing of tanned hides.

Hogs typically are not skinned. Rather, they are scalded by immersion for about 4 to 5 minutes in hot water having a temperature of about 54 to 60 °C (130 to 140 °F). The objective of scalding to relax hair follicles is to facilitate subsequent mechanical hair removal by passing the carcass between rotating drums with rubber fins or fingers. A constant flow of water washes away the hair removed from the carcass. Any remaining hair is removed by singeing by passing the carcass through a gas flame followed by passing the carcass through a water spray for cooling and washing, and then by manual shaving.

Meat processing facilities usually collect hog hair and other particulate matter from processing wastewater by screening for rendering before any subsequent on-site or off-site wastewater treatment. Hog hair can also be recovered, washed, and baled for sale for various uses, but demand for this material has become quite limited. Also limited is the demand for pigskin leather, which is why most hogs are not skinned.

4.3.1.5 Evisceration

After hide or hair removal from hogs, the carcasses are washed with water sprays to remove any manure, soil, and hair present to retard microbial growth and spoilage. This step is followed by evisceration to remove internal organs. Evisceration begins with a manually made ventral incision that spans the length of the carcass, followed by removal of the gastrointestinal tract (stomach, intestines, and rectum). Then, an incision is made through the diaphragm to allow removal of the remaining organs (trachea, lungs, heart, kidneys, liver, and spleen).

After evisceration, state or federal inspectors inspect the carcasses for indicators of disease and suitability for human consumption. Condemned carcasses are segregated; when possible, usable parts are salvaged. Following evisceration and inspection, with the possible exception of calf and lamb carcasses, carcasses are usually split into two halves by sawing them down the middle of the spinal column.

After evisceration, different organs might be separated for sale as variety meats or pet food ingredients prior to the removal of viscera from the processing plant; otherwise, viscera are generally disposed of through rendering. Liver and kidneys are the organs most commonly harvested from cattle, calf, and lamb viscera; some stomach tissue is harvested from cattle for sale as tripe. Less common is the harvesting of the thymus from calves for sale as sweet breads. Lung tissue might also be harvested for sale as food for mink.

Variety meat harvesting from hogs is more extensive than that from cattle and sheep and includes not only liver and kidneys but also the small and large intestines. The small intestines are sold as chitterlings, while the large intestines are sold as natural casing for sausage. In addition, hog ears and feet, jowls, and the sphincter muscle might be harvested for sale.

4.3.1.6 Washing

After carcass inspection and splitting, a second washing removes blood released during evisceration, bone dust from carcass splitting, and any other foreign matter present. Processors may add bactericide such as an organic acid, chlorine, or potassium chloride to the wash water to reduce microbial populations and the potential for microbe growth and spoilage. Acetic and lactic acids in very dilute concentrations (2 to 3 percent) are the organic acids used as bactericides. Large operations often use automated carcass-washing equipment to maintain appropriate pressure to maximize the efficiency of water use (USEPA, 1997). The time from stunning to the second and final carcass wash varies to some degree, but it is less than 1 hour.

Before refrigeration or freezing, all variety meats are washed to remove blood and any other contaminants. The washing of the small and large intestines of hogs is a very labor-intensive process that requires substantial amounts of water to completely remove fecal material.

4.3.1.7 Chilling

The next step in the meat slaughtering process is carcass chilling to remove residual body heat to inhibit microbial growth and reduce evaporative weight loss. Carcasses are chilled for at least 24 hours but are chilled for 48 hours over weekends and during weeks with holidays. Typically, carcass chilling is a two-step process that begins with snap (flash) chilling at temperatures substantially below freezing to effect a rapid initial rate of reduction in carcass temperature (USEPA, 1997). After snap chilling, carcasses are moved into chill rooms for the remainder of the chilling process. Chill room temperatures are maintained at 1 °C (34 °F) to reduce carcass temperature to no higher than 7 °C (45 °F) before further handling (Warriss, 2000). Chilling facilities separate the "dirty" and "clean" sides of meat processing plants.

4.3.1.8 Packaging and Refrigeration or Freezing

Larger carcass sections are usually packaged in heavy plastic bags, which can then be placed in cardboard boxes for shipping. Large quantities of ground meat are also packaged in heavy plastic bags. Smaller cuts sold as case-ready are placed on Styrofoam trays, wrapped with thin plastic film, and boxed for shipment. Case-ready cuts might also be weighed and labeled showing weight and price. The packaging of case-ready cuts is usually a completely automated process.

Packaged meats are then refrigerated until and during shipment. Meats that have not been further processed are rarely frozen given consumer food safety concerns about refreezing previously frozen meats. Some meat, however, is frozen before shipment, especially meat for commercial use and export markets.

4.3.1.9 Cleaning Operations

Federal and state regulations require that equipment and facilities used for the first processing of all animals for human consumption be completely cleaned after every 8 hours of operation, at the least, to maintain sanitary conditions. Therefore, the daily schedule for meat processing facilities consists of one or two 8-hour production shifts followed by a 6- to 8-hour cleanup shift. During cleanup, all equipment, walls, and floors are first rinsed to remove easily detachable particulate matter. Then they are scrubbed and rinsed again to remove detached particulate matter, detergents, and sanitizing agents used during the scrubbing phase of cleanup activities. In states where phosphorus-based detergents are banned, phosphorus-based detergent use in food processing plants is generally exempted, so phosphorus-based detergents are commonly used. Chlorine solutions and other bactericidal compounds are also commonly used.

4.3.2 Meat Further Processing

As previously discussed, EPA considers the reduction of whole or split carcasses into quarter or smaller segments as further processing operations when they do not occur in conjunction with first processing operations. The segments produced include ground meat and case-ready cuts with or without bone. Other activities, including sausage production, curing, pickling, smoking, marinating, cooking, and canning, are also considered further processing operations.

In the meat industry, further processing activities might be combined with first processing activities at the same site or might be stand-alone operations. Where first and further processing activities occur at the same site, usually some fraction of the carcasses produced is marketed as fresh meat and the remainder is transformed into processed products. Stand-alone further processing operations might receive carcasses, or more commonly carcass parts, from first processing operations for further processing.

4.3.2.1 Raw Material Thawing

The frozen raw materials received by a meat processing plant are handled in one of three ways: wet thawing, dry thawing, or chipping. Materials that are wet thawed are submerged in tanks or vats containing warm water for the time required to thaw the particular pieces of meat. The devices used for wet thawing include simple carts with water covering the meat; vats with water flowing in and out, with the exit temperature of the water controlled at 10 to 16 °C (50 to 60 °F) to avoid heating the outer surfaces of the meat; and equipment in which the meat pieces are suspended in a tank of water and moved by some conveyance through that tank for a time sufficient to thaw the meat (USEPA, 1974).

Dry thawing involves placing the frozen meat pieces in a refrigerated room at a temperature above freezing and allowing sufficient time for the particular pieces of meat to fully thaw (USEPA, 1974).

Chipping involves size-reduction equipment designed to handle frozen pieces of meat and to produce small particles of meat that readily thaw and can be used directly in subsequent mixing or grinding operations. This type of thawing is usually associated with the production of comminuted (flaked) meat products (USEPA, 1974).

Both wet and dry thawing are usually used when the entire piece of meat, or a substantial portion of it, is required for a finished product, such as hams or bacon (USEPA, 1974).

Wet thawing of raw materials generates the largest quantity of contaminated wastewater. Because, the water used to thaw the materials is in contact with the meat, it extracts water-soluble salts and accumulates particles of meat and fat. The water used in thawing is dumped into the sewer after thawing is complete. The waste load generated in dry thawing is from the thawing materials dripping onto the floor and from the washing of these drippings into the sewer. The waste from the chipping of frozen meat materials includes the meat and fat particles that remain on the chipping equipment and are washed into the sewer during cleanup. Juices extruded from the meat product in the chipping process are wasted to the sewer, although the waste load is not large (USEPA, 1974).

4.3.2.2 Carcass/Meat Handling and Preparation

Seven different operations might be involved in handling and preparing meat materials for subsequent processing, depending on the processing plant (Figure 4-1). Each operation is described separately. Not all of the seven operations are usually not required to produce a processed meat product (USEPA, 1974).

Breaking

Meat processors frequently received beef as carcass halves or quarters. Breaking involves the cutting of these half and quarter carcasses into more manageable sizes for further handling and preparation. The waste load originates from the cutting and sawing and includes small meat and fat particles and relatively little liquid, all of which fall to the floor and are washed into the sewer during cleanup (USEPA, 1974).

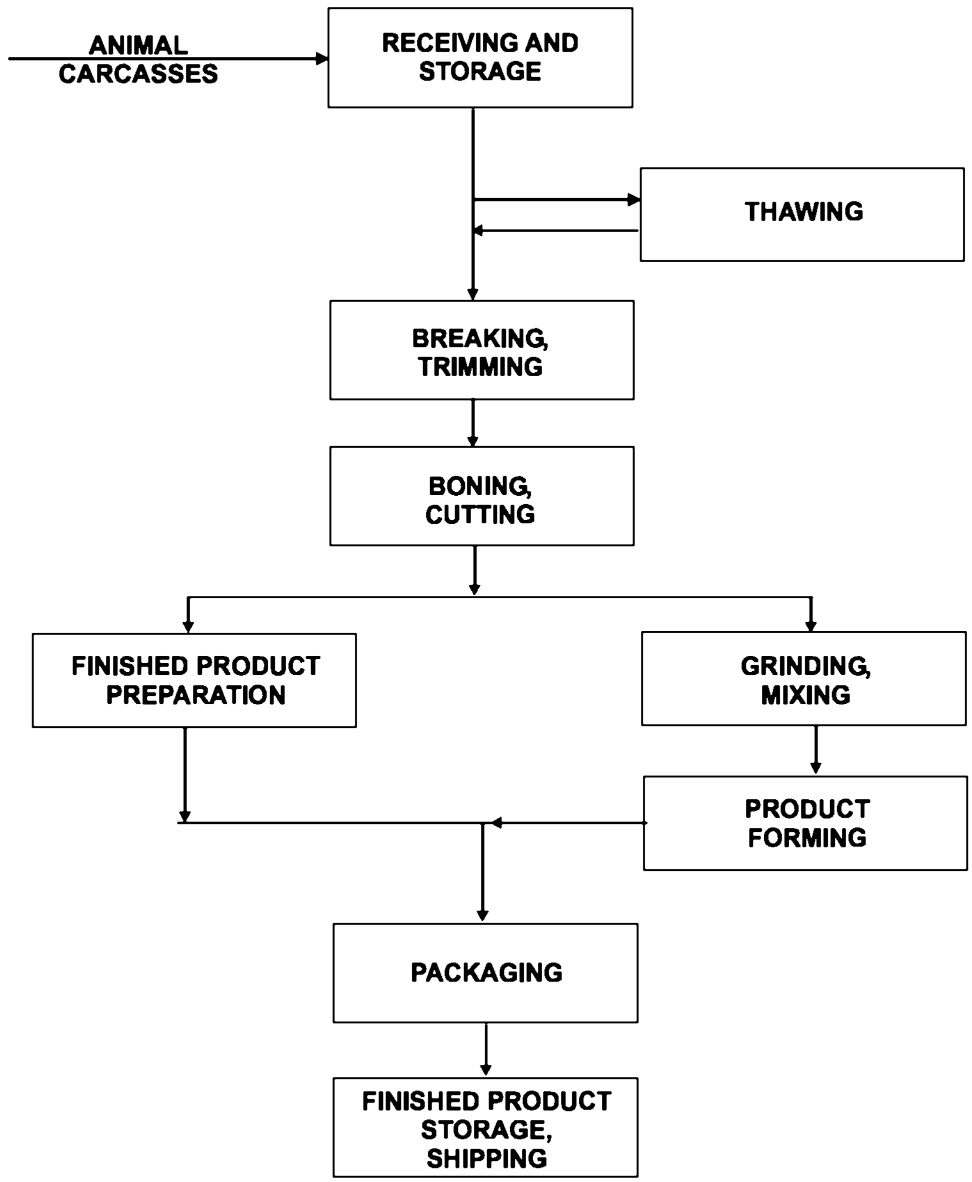

Figure 4-1. General process for meat cuts and portion control procedures (USEPA, 1974).

Trimming

In the trimming operation excess or unwanted fat and specific cuts are removed from larger pieces of meat. The unwanted fat trimmed from meat products is usually disposed of through rendering. The materials for disposal are collected and stored in drums, which are picked up by renderers. The waste load generated in trimming might be greater than that generated by the breaking operation. Trimming requires a greater number of cuts on a specific piece of meat to obtain the required quality or particular cut desired from the raw material. The wastewater generated by this operation results from water used by the personnel involved in the operation during the operating day and water required to clean the equipment and floor of the trimming operation (USEPA, 1974).

Cutting

In the cutting operation, the larger pieces of meat are cut or sawed for the direct marketing of smaller sections or individual cuts, or for further processing in the production of processed meat products. The solid waste materials generated in cutting are similar to those produced in trimming, plus the bone dust from sawing the bones. The large pieces are useful in sausages or canned meats or can be rendered for edible fats and tallows. The waste materials from the equipment and floor washdown contribute to the waste load of the meat processing plant (USEPA, 1974).

Deboning

Some raw materials are prepared for the consumer by removing internal bones prior to manufacturing particular products, such as hams and Canadian bacon. Deboning might also be performed at the same location as trimming, prior to the production of various meat cuts. The bones removed in this operation are disposed of through rendering channels. Meat and fat particles produced from the operation are normally washed into the sewer of a meat processing plant (USEPA, 1974).

Skinning

Pork skin can be removed from a piece of meat by machine or by hand. Skinning is most frequently used in the preparation of pork bellies for processing into bacon and in ham production. The common practice in the industry is to use machines for the skinning process. The skins removed are disposed of through rendering channels. Other products that require skinning, such as picnic hams, are manually skinned, frequently at the same time that the raw hams are deboned. In either type of skinning operation, meat and fat particles are generated and wasted by falling on the floor or by becoming attached to the skinning equipment. The subsequent cleanup washes these particles into the sewer. In addition, tempering frequently precedes pork belly skinning, generating a waste load comparable to that generated by wet thawing of frozen meat materials by direct meat contact with water (USEPA, 1974).

Comminution (Mincing, Bowl Chopping, Flaking)

Comminution is the process of reducing large pieces of meat into small pieces for products such as sausage and hamburger patties. There are three general methods of comminution: mincing, bowl chopping, and flaking. Each method affects the size and shape of meat differently, influencing other meat properties. The general processes for comminuted meat products are illustrated in Figure 4-2.

Meat is minced by being pushed through a perforated plate positioned against a rotating knife with a screw auger. The size of perforation varies, depending on the desired meat particle size. The meat is then broken into very small pieces through bowl chopping. Meat is bowl

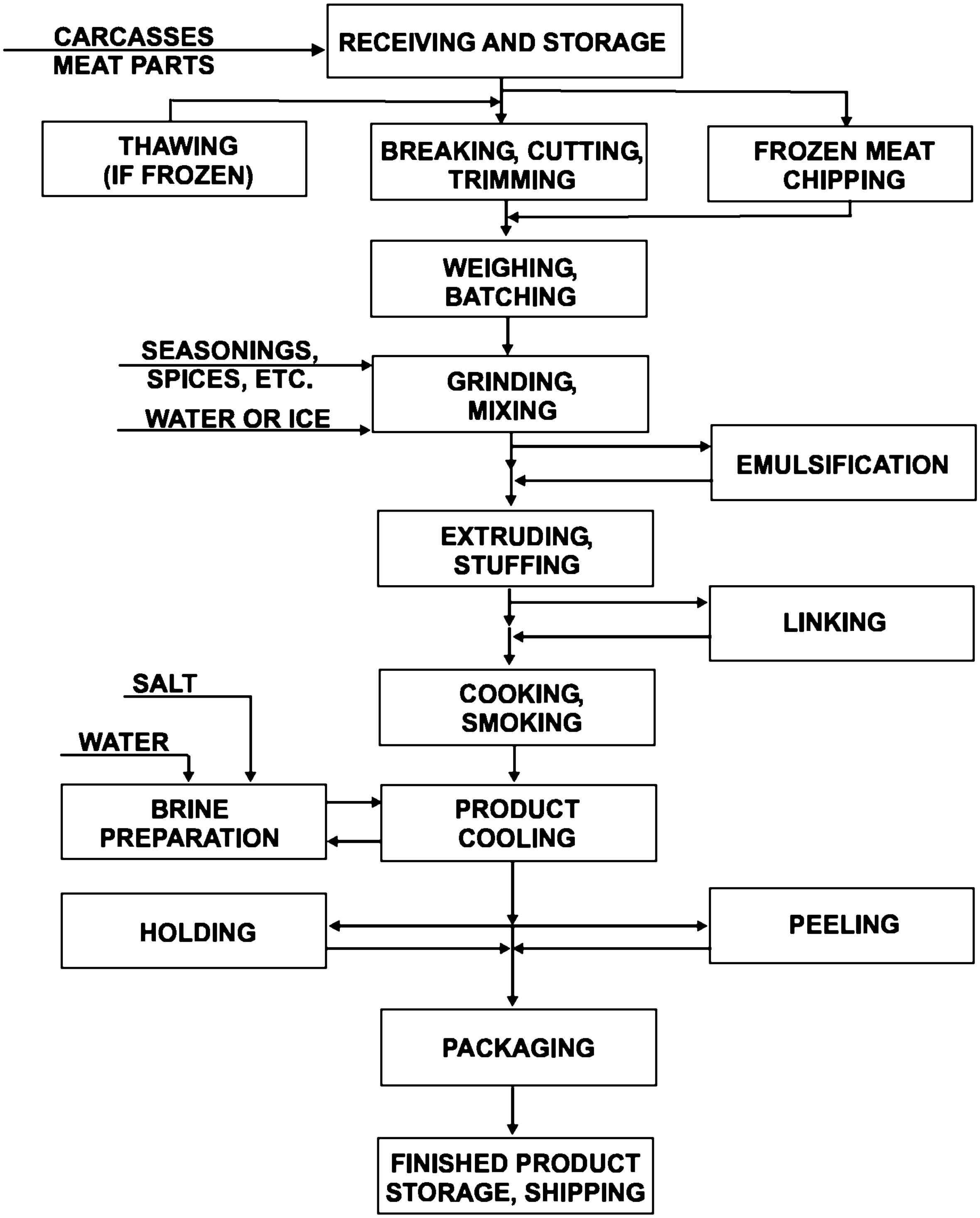

Figure 4-2. (General process for comminuted meat products (sausage, wieners, luncheon meats, etc.) (USEPA, 1974).

chopped by placing it in a rotating bowl and carrying it by conveyor belt through a set of vertically rotating knives. Comminuted (flaked) meat is produced when a sharp blade cuts frozen meat blocks into small flakes.

Hamburger patties are formed of minced or flaked beef traditionally, although other meats can be used. Reformed steaks are made from comminuted meat that is shaped to resemble a natural steak. Sausages are made from chopped or comminuted meat and additional ingredients, which are filled into a casing. The casing can be made from the collagen layer of animal intestines or from the reconstituted collagen from other animal parts (Warriss, 2000).

Grinding, Mixing, and Emulsifying

All processed meat products that are not marketed as cuts or as specific items such as bacon or ham, or used in large pieces, are processed at least through a grinding step to produce a finished product. Grinding is the first step in reducing the size of meat pieces for use in processed meat products such as hamburger, or in preparing for further mixing, blending, or additional size reduction. Grinders are frequently equipped with plates through which meat is forced or extruded. Grinder plates with holes measuring 1/8 to 3/8 inch are most commonly used. In addition to size reduction, grinding equipment may be used to prepare a mixture of various ingredients, such as meat products from different types of animals or lean and fatty meat products. The particle size of the meat ingredients in a product is critical. Larger particle size is required for hamburger or fresh pork sausage products. A slightly smaller particle size is required for manufacturing dry or semi-dry sausages. Various sausages, including wieners and some luncheon meats, are prepared by a substantial size reduction or comminution of the meat raw materials. These products involve a stable sausage emulsion whereby the fat droplets or globules are uniformly dispersed throughout the mixture so that it will take on a homogenous appearance (USEPA, 1974).

Equipment that blends or mixes the various ingredients, including the meat materials, to produce stable emulsions is available to the meat processor. One type of equipment—the silent cutter—uses numerous knife blades spinning at a high velocity to reduce the particle size and to produce a stable emulsion. The other type of equipment used to produce an emulsion has the appearance of a common type of dry blender comparable to the ribbon blender (USEPA, 1974).

Control of the types of raw materials used; the sequence of addition; and the time and intensity of grinding, blending, or emulsifying is critical to the quality of the finished product. Some movement of materials is usually involved in these operations because stepwise processing is required for each batch. This movement is accomplished by pumping or manually using portable containers (USEPA, 1974).

Solid waste materials are generated from these operations by spillage in handling and movement of materials and in cleanup and preparation of equipment for different types of products (USEPA, 1974).

These manufacturing operations are among the major contributors to the waste load in a meat processing plant as a result of equipment cleanup. Because the processing step involves size reduction of lean and fatty materials and the preparation of stable mixtures of meat and other ingredients, these materials tend to coat equipment surfaces and collect in crevices, recesses, and dead spaces in equipment. All these materials are removed in cleanup and washed into the sewer. This is in contrast to larger particles, which can be readily dry-cleaned off a floor before washdown, thereby reducing the raw waste load in the wastewater stream. Any piece of equipment used in any of these operations is cleaned at least once per processing day and may be rinsed off periodically throughout the day, thereby generating a fairly substantial quantity of wastewater and contributing to the raw waste load (USEPA, 1974).

4.3.2.3 Tenderizing and Tempering

Meat can be tenderized by marinating them or by injecting them with salt solutions or acids. Meats have been traditionally marinated in vinegar or wine because its acidic properties break down the muscle structure. Also, the myofibrils swell and hold water, improving tenderness and juiciness. More recently, solutions, especially calcium chloride solutions, have been injected into the meat to achieve the same results (Warriss, 2000).

The processing of some meat products can be enhanced by adjusting the temperature or moisture content prior to a specific processing step. This is particularly true in the production of bacon from pork bellies. If the pork bellies are to be skinned, tempering in a water-filled vat is frequently used to improve skin removal. Hams and bacon are frequently tempered following cooking and smoking by being kept in refrigerated storage long enough for the desired temperature to develop within the particular product. Figure 4-3 shows the general processes for hams and bacon. Some meat processors also find it advantageous to allow the cooked bacon slab to temper in refrigerated storage, following pressing and forming of the slab into the rectangular shape used in the bacon-slicing machines. Holding essentially finished products generates very little, if any, waste load. However, the water-soaking tempering technique employed prior to skinning pork bellies does generate a waste load comparable to that generated by wet thawing of frozen meat materials by the direct meat contact and subsequent dumping of this water into the sewer (USEPA, 1974).

4.3.2.4 Curing

Curing employs salt compounds to preserve meat and develop a characteristic appearance and flavor. There are two methods of curing meats—dry curing, which entails rubbing solid salts into the meat surface, and immersion, a much more common method in which meat is submersed into a liquid solution of salts. Injecting brine into the meat and tumbling the meat with rotating drums often aid in distribution. Other salts, such as potassium nitrate, sodium nitrate, and sodium nitrite, often substitute for common table salt (sodium chloride) in the brine solution. The curing brine typically contains additional substances, including sugars to enhance flavor, ascorbic acid to prevent discoloration, and polyphosphates to improve the water-holding capacity of the meat (Warriss, 2000).

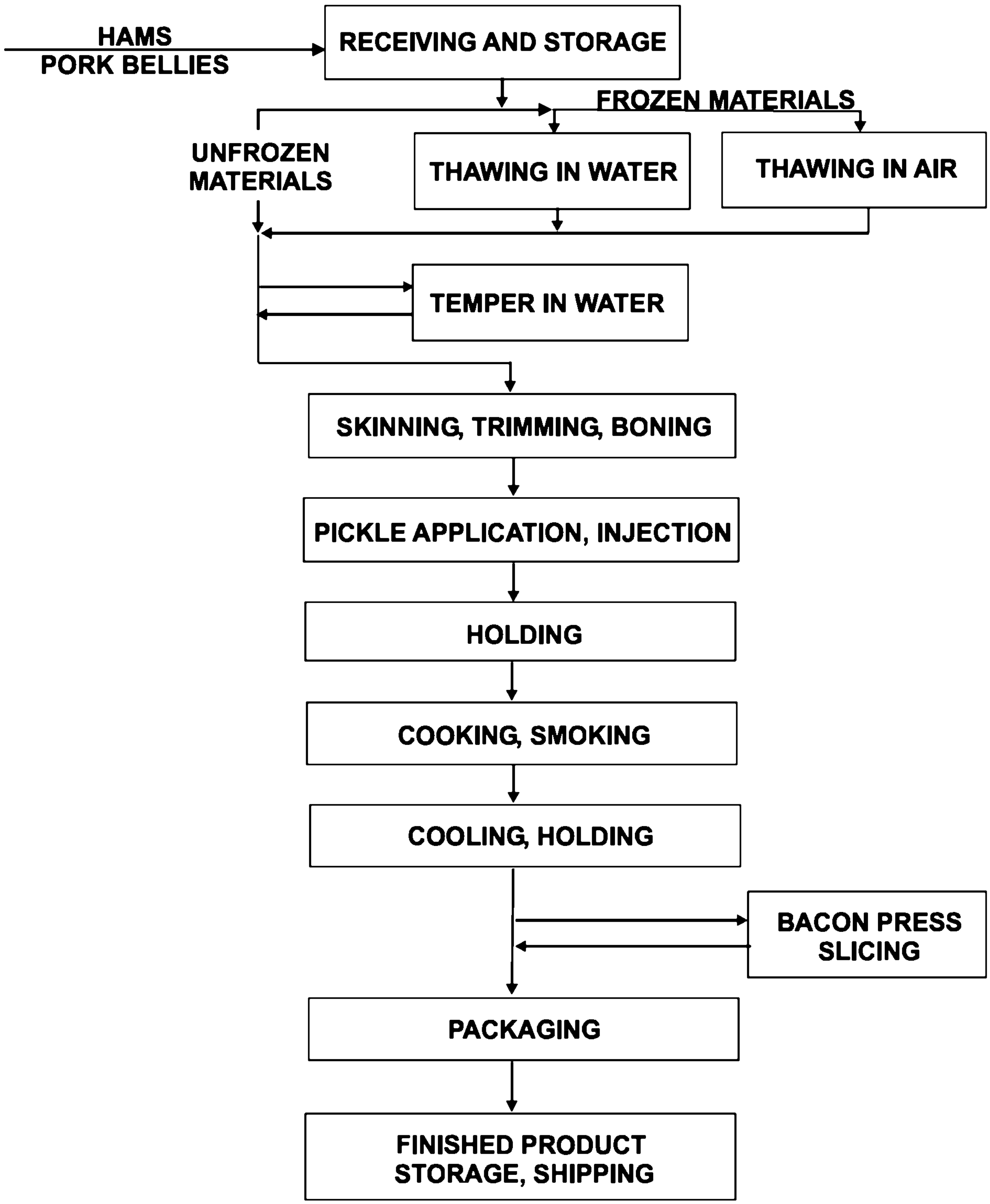

Figure 4-3. General process for hams and bacon (USEPA, 1974).

4.3.2.5 Pickle Application/Injection

A pickle or curing solution is prepared with sugar, sodium nitrite, sodium nitrate, and salt as the main ingredients in water. The pickle solution preparation area is often separated physically within the plant from the actual point of use. Various types of injection are used to introduce the pickle solution into the interior of a meat product. In addition, pickle solution can be applied by holding the meat product in a curing brine long enough for the pickle to be absorbed. The pickle can also be injected or pumped into hams or similar products by introducing the brine through an artery or the vascular system, if it is relatively intact. The product may be injected through numerous needles that penetrate the ham over a large area. Hams, for example, are usually pumped to 110 or 120 percent of their green (or starting) weight. The injection can also be done on both sides to ensure thorough and uniform pickling. Following the pickle injection or application, it is common practice to store the product in tubs with a covering of pickle solution for some time (USEPA, 1974).

Pickling solutions are high in sugar and salt content, particularly the latter. The large amount of spillage in this operation comes from runoff from the pickle injection, from pickle oozing out of the meat after injection, from dumping of cover pickle, and from dumping of residual pickle from the injection machine at the end of each operating day. These practices contribute substantially to the wastewater and waste load from a meat processing plant. Many of the ingredients of pickle solutions represent polluting material in high concentrations and add significantly to the raw waste load from the pickle operation. Cleanup of the tubs or vats holding the product in brine solutions and cleanup of the pickle injection machines is required at least once per day, or after each use in the case of the vats. This necessity generates additional waste load and wastewater from a meat processing plant (USEPA, 1974).

4.3.2.6 Cooking, Smoking, and Cooling

Although smoking has traditionally functioned as a method of preserving meat by drying it and preventing fat oxidation, it is now used primarily to flavor the meat. Liquid smokes that contain liquid extract of smoke commonly substitute for real smoke (Warriss, 2000).

Most of the meat products are cooked as part of the standard manufacturing procedure. Notable exceptions are fresh pork sausage, bratwurst, and bockwurst. Processed meat products can be cooked with moist or dry heat. Cooking sausages coagulates the proteins and reduces the moisture content, thereby firming up the product and fixing the desired color of the finished product. Large walk-in ovens or smokehouses are in general use throughout the industry. These smokehouses are equipped with temperature controls, humidity controls, water showers, and facilities to provide smoke for smoking products (USEPA, 1974).

The smoking of meat products gives the finished meat product a characteristic and desirable flavor, offers some protection against oxidation, and inhibits bacterial growth in the finished product. Smoke is most commonly generated from hardwood sawdust or small-size wood chips. Smoke is generated outside the oven and is carried into the oven through ductwork. A small stream of water quenches the burned hardwood sawdust before dumping the sawdust to waste. Water overflow from this quenching section is commonly wasted into the sewer. One plant slurried the char from the smoke generator, piped it to a static screen for separation of the char from the water, and then wasted the water (USEPA, 1974).

The actual cooking operation generates wastewater when steam or hot water is used as the cooking medium, such as in cooking luncheon meats in stainless steel molds. The steam condensate and hot water are wasted to the sewer from the cooking equipment. It is standard practice to shower the finished product immediately after cooking to cool it. This practice also generates a wastewater stream containing a waste load primarily of grease (USEPA, 1974).

Cleanup of the cooking ovens is not done every day, but at the discretion of the plant management. The typical practice is to clean each oven and the ductwork for the heated air and smoke circulation at least once a week. This cleaning includes the use of highly caustic cleaning solutions to cut grease and deposits from the smoking operation that have been deposited on the walls, ceiling, and ductwork in the ovens. The effluent from such a cleaning operation is noticeably dark-colored. This color is thought to be the result of creosote-type deposits and fatty acids from the smoke. The other waste load generated in oven cleanup is the grease from the walls and floors resulting from cooking the various products (USEPA, 1974).

In total quantity, the waste load and wastewater generated in this cleanup is not particularly significant. However, there is the noticeable coloration of the wastewater during cleanup and, depending on the extent of the use of caustic, an increase in the pH of the wastewater (USEPA, 1974).

Facilities cool processed meat products in different ways, depending on the type of product. Sausage products can be cooled while still in the oven or smokehouse with a spray of cold water or brine solution. Alternatively, they can be cooled in the aisle immediately outside the smokehouse to save heat and increase productivity. The brine solution is used to achieve a lower spray temperature and thereby a more rapid cooling of the product. The brine is recirculated until it is judged to be too contaminated to permit efficient use, at which point it is usually discharged into the sewer (USEPA, 1974).

Hams and bacon products (Figure 4-5) are not exposed to water but instead are moved quickly from the smokehouse to a refrigerated room with a very low temperature (-35 °C, or -31 °F) and higher-than-normal air circulation to achieve rapid cool-down. The hams and bacon might drip a small quantity of juice or grease onto the floor of the cold room before the surface temperature of the product reaches a point that precludes any further dripping. Cleanup of the floor results in wasting these drippings into the sewer (USEPA, 1974).

Canned meat products and products prepared in stainless steel molds are usually cooled by submersing them in cold water. The water is usually contained in a tank or raceway, where it flows at a very low speed in a direction countercurrent to the movement of the cans or molds. Depending on the type of installation and product, it was found that the water used in cooling need not be dumped and in fact can be continually recirculated with only a nominal amount of blow-down to remove accumulated solids, just as would be done in operating a boiler. In other situations, usually where smaller quantities of water are involved and luncheon meat molds are being cooled, the water is dumped more frequently (up to once a day). This dumping is necessary because the seal on the molds is not tight enough to prevent leakage of juices and grease to the exterior of the molds (USEPA, 1974).

The only cleanup of cooling equipment that would generate a waste load is cleanup of the floors in the cold rooms where hams and bacon are cooled. This load is small in comparison to others from the plants (USEPA, 1974).

4.3.2.7 Mechanically Recovered Meat

Mechanically recovered meat (MRM) is meat separated from bone by first grinding it to produce a paste. The paste is then forced through a perforated stainless steel drum to separate meat and bone particles. High-pressure air also can be used to remove meat from bone (Warriss, 2000).

4.3.2.8 Canning and Retorting

Canning is another method of preserving and packaging meat for convenient consumption. After meat is sealed in a container, it is heated using steam under pressure at a temperatures of at least 116 °C (240 °F) to achieve adequate sterilization. Lower temperatures, however, are used in the canning of cured ham; sterilization by heat is not necessary because of the bactericidal effect of curing agents. The containers used for meat canning are usually steel, which might be coated with tin or a temperature-resistant plastic polymer (Warriss, 2000). Figure 4-4 shows processes typicallyused for canning meat products.

The containers used to hold the canned meat products must be prepared before they are filled and covered. The cans are thoroughly cleaned and sterilized. The wet cans are transported from the preparation area to the processing area for filling and covering. Water is present all along the can lines from preparation to filling and covering. The cans go through one last steaming just before they enter the can filling machine (USEPA, 1974).

Can filling is a highly mechanized, high-speed operation. It requires moving the meat product to the canning equipment and delivering that product into a container. The high speed and the design of the equipment result in an appreciable amount of spillage of the meat product as the cans are filled and conveyed to the covering equipment. At the can covering station, a small amount of steam is introduced under the cover just before the cover is sealed to create a

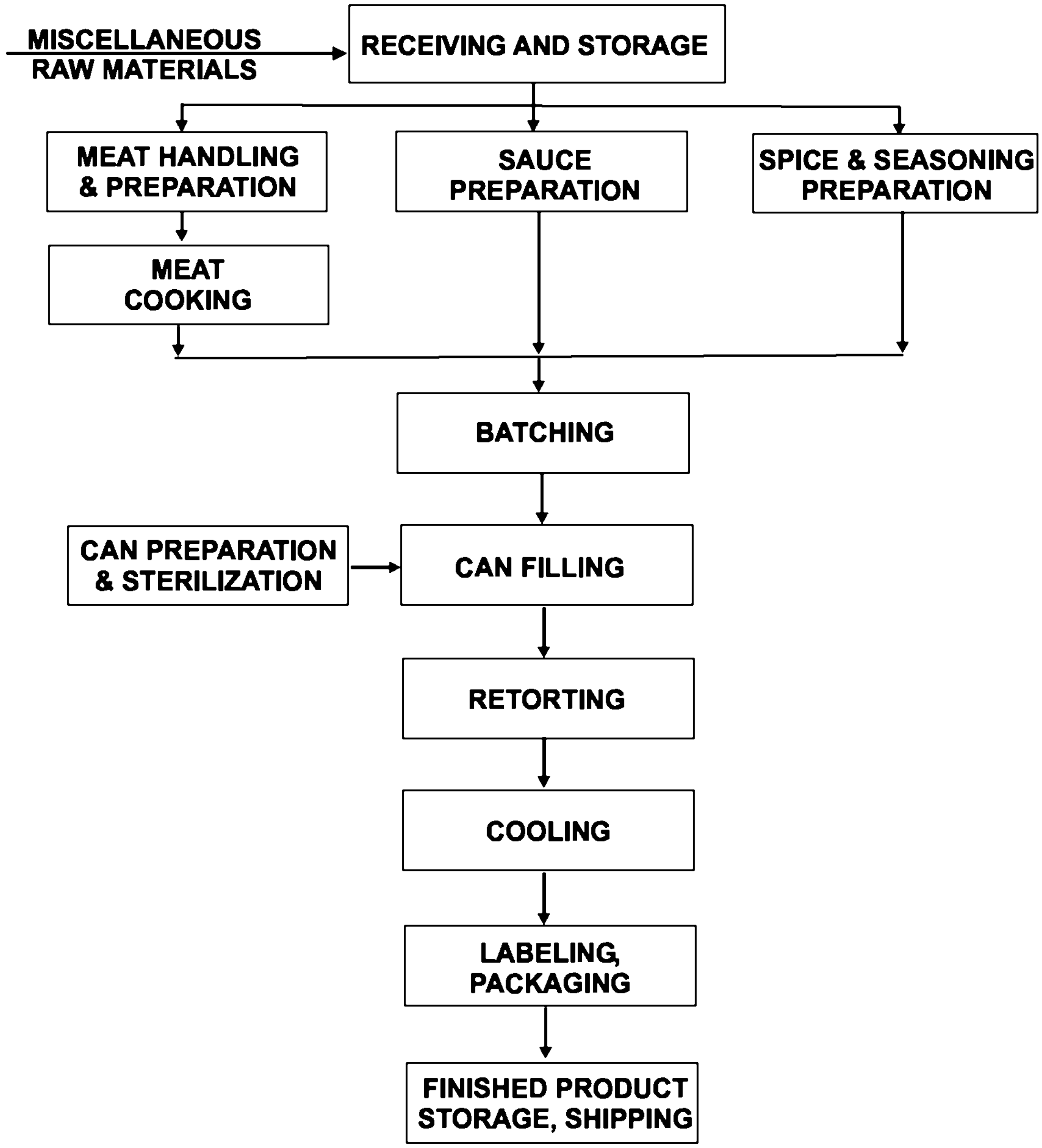

Figure 4-4. General process for canned meat products (USEPA, 1974).

vacuum within the can when it cools. This steam use also generates a quantity of condensate, which drains off the cans and equipment onto the floor.

The operation of the filling and covering equipment results in a substantial quantity of wastewater containing product spills that is wasted to the sewer. Canning plants that have more than one filling and covering line have a waste load that is roughly proportional to the number of such lines in use (USEPA, 1974).

All the equipment is washed at least once a day at the end of the processing period. If a can-filling machine is to be used for different products during the day, it is usually cleaned between product runs. Meat products are frequently canned with gravy-type sauces, or the meat product itself has been comminuted to a small particle size and mixed to produce a flowable mixture. This type of canned product results in greater contamination of equipment wash water because of the tendency of the product mixture to coat surfaces it comes in contact with and to fill all dead spaces and crevices in the equipment. The equipment is highly mechanized with many moving parts and is designed to be cleaned intact rather than being dismantled first, as is grinding and mixing equipment. Cleaning the equipment while it is intact requires a high-velocity water stream or steam to remove all food particles. The tendency of operating personnel is to use more water than necessary to clean the equipment. This practice results in large quantities of wastewater with substantial waste loads from canning operations (USEPA, 1974).

The equipment used in transporting the meat product to the can-filling equipment also must be cleaned after it has been used on a specific product, and it is always cleaned at the end of the processing day. This equipment is usually broken down, and the product characteristics that contribute to large waste loads, as described above, also generate large waste loads in cleanup of the transport equipment (USEPA, 1974).

Some ham products are canned by manually placing ham pieces in cans. Manpower is used in place of mechanical equipment because the pieces are randomly sized and the packer is able to create a full, uniform appearance for the canned product. A small amount of gelatin is added to provide moisture to the product. The quantity of waste generated from this type of operation is probably somewhat less than that from high-speed canning equipment (USEPA, 1974).

4.3.2.9 Freezing

Blast, belt, plate, and cryogenic freezers are used for freezing meat. The specific type used depends on the type of product being frozen. Blast freezers blow frigid air (-40 °C, or -40 °F) over the meats in a tunnel. Belt freezers freeze small meats, such as burgers, that are carried on a conveyor belt. Plate freezers consist of cold metal plates that are pressed onto the meat surface. Finally, cryogenic freezing freezes items through immersion into liquid nitrogen (-196 °C, or -321 °F) (Warriss, 2000).

4.3.2.10 Packaging

Packaging for transport, distribution, and sale is the final step in further meat processing. Appropriate packaging fulfills three purposes. The first is to protect meat from contamination and inhibit microbial growth, the second is to reduce evaporative weight loss and surface drying, and the last is to enhance the appearance of the meat. Plastic film and antioxidants play an important role in successful packaging (Warriss, 2000).

Various packaging techniques are used in the meat processing industry. These techniques include use of the standard treated cardboard package, the Cry-O-Vac (plastic film sealed under vacuum) type of package, and the bubble enclosure package used for sliced luncheon meats and wieners, along with the boxing of smaller containers of pieces of finished product for shipment. In some packaging techniques a substantial amount of product handling is involved, which can result in some wasted product. The sizes of the pieces of wasted finished product, however, are such that there is little reason for the product to be wasted to the sewer; instead, it should be returned for subsequent use in another processed product or directed to a rendering channel (USEPA, 1974).

The only time water is generated by the packaging operation is during cleanup of the equipment. Small amounts of water are adequate for cleaning this equipment, and only small quantities of wastewater are generated (USEPA, 1974).

4.3.2.11 Seasonings, Spices, and Sauce Preparation

A wide variety of chemicals are used to improve product characteristics such as taste, color, texture, appearance, shelf life, and other characteristics important to the meat processing industry. These chemicals include salt, sugar, sodium nitrate, sodium nitrite, sodium erythrobate, ascorbic acid, and spices like pepper, mustard, and paprika. Other common materials added in the preparation of processed meat products are dry milk solids, corn syrup, and water, as a liquid or as ice (USEPA, 1974).

Other than water, most of these materials are solids and are handled in the solid state. The product formulations for the various finished products produced by a meat processor call for specific quantities of chemicals and seasonings. These spices and chemicals are preweighed and prepared for use in a specific batch in a dry spice preparation area. They are weighed into containers and added to batches in the grinding or mixing operation. Very little waste of either a dry or wet nature is generated by the specific operation of seasoning and spice formulation. Sauces are prepared for use in canned meat products particularly. Sauces are wet mixtures of seasonings, spices, and other additives described above, as well as meat extracts and juices, and are used to prepare a gravy-type of product. Significant quantities of waste are generated in the preparation and handling of sauces and in kettle cleaning. The residual materials are washed out of the kettles directly into the sewer and contribute significantly to the raw waste load of a meat processor that prepares a canned meat product (USEPA, 1974).

4.3.2.12 Weighing and Batching

The meat processing industry uses batch-type manufacturing operations in all but a few instances. The types and amounts of materials that go into each unit of production, or batch, are controlled according to specifications established by the individual meat processing companies in accordance with government standards for the finished product. The lean and raw materials that go into each batch are weighed and placed in portable tubs. The portable tubs of weighed raw material are identified for a specific product and moved to the next manufacturing operation (USEPA, 1974).

The weighing and batching area is frequently located in one of the refrigerated raw material storage areas. The operation involves considerable manual handling of meat products and pieces of trim fat. Liquids, including meat juices and water, frequently drip from the raw materials onto the floor of the batching area. Particles also drop off in the handling process. The tubs used to hold the raw materials and the batches of raw material contain liquids and solids that are wasted to the sewer after the batches have been dumped into subsequent processing equipment. The tubs and handling equipment are cleaned as needed during the production period and at least once a day (USEPA, 1974).

4.3.2.13 Extrusion, Stuffing, and Molding

Following the preparation of a stable emulsion or mixture of ingredients for a processed meat product such as wieners or sausage, the mixture is again transported by pump or in a container to a manufacturing operation, where the mixtures are formed or molded into the finished product. Sausage casings and stainless steel molds are commonly used as containers in this operation. Either natural casings, which are the intestines from some types of animals, or synthetic casings, which are used only in the formation of the products and then peeled and disposed of before the product goes to the consumer, may be used in producing sausages and wieners and in some kinds of luncheon meats. The stainless steel molds are most commonly used to obtain the square shape characteristic of some luncheon meats (USEPA, 1974).

In the casing, stuffing, or mold-filling operation, a product mixture is placed in a piece of equipment from which the product mixture is forced by air pressure or pumped into the container to form a uniform, completely filled container resembling the shape of the finished product (USEPA, 1974).

Water is used to prepare the natural casings for use in the stuffing operation, and the stainless steel molds are cleaned and sterilized after every use. The primary source of waste load and wastewater is the cleanup of the equipment used in this operation. As in the previous operation, the residual emulsions and mixtures contribute significantly to the waste load because of their propensity to stick to most surfaces with which they come in contact and to fill crevices and voids. All equipment used in this operation is broken down at least once a day for a thorough cleaning. This cleanup is designed to remove all remnants of the mixtures handled by the equipment, and this material is wasted with the wastewater into the sewer, thereby contributing to the waste load (USEPA, 1974).

Some spillage of material occurs in this operation. Spillage occurs during transport of the material from grinding and emulsifying to the extrusion operation, and particularly in the extrusion or stuffing of the container and overflows (USEPA, 1974).

4.3.2.14 Linking

Linking is simply the formation of links or specific-sized lengths of product in a casing. It is done by twisting or pinching the casing at the desired length for the specific finished product, mechanically or manually. A small stream of water is used to lubricate the casing to avoid breakage or splitting. When the full length of each casing has been linked, the product is hung on a rail hanger, called a "tree," in preparation for the next manufacturing operation (usually cooking and smoking) (USEPA, 1974).

Unless a casing splits or breaks, no significant amount of raw waste load should be contributed by this operation. The equipment used is thoroughly washed after use. The hangers that hold the products through the cooking and smoking step become coated with greasy substances, which are washed off and into the sewer after each use. In addition, a standard maintenance practice is to coat the hangers with a thin film of edible oil to protect them from rusting. This oil is ultimately washed off in the overshowering or in the washing of the hangers following each use. Some large operations use automated spray cabinets for tree washing (USEPA, 1974).

4.3.2.15 Casing Peeling

Synthetic casings made from a plastic material are used in the production of a large number of wieners in the meat processing industry. These casings are not edible and therefore must be removed from the wieners after cooking and cooling but prior to packaging for sale to the consumer. The peeling equipment includes a sharp knife that slits the casing material, a small spray of steam to part the casing from the finished wiener, and a mechanism to peel the casing away from the wiener. Casing material is solid waste that results from this operation; it is collected and disposed of as part of the plant refuse. The slitting mechanism occasionally penetrates the wiener in addition to the casing and cuts the wiener, rendering it useless as a finished product. However, these pieces of wiener are not wasted but are used in other products prepared in the plant. The steam used in the casing peeling results in a small water stream from this operation, but it is so small that it is of no real consequence (USEPA, 1974).

The equipment is cleaned at the end of every processing day and can contribute a small quantity of waste as a result of wiener particles that are attached to various parts of the mechanism and are subsequently washed into the sewer during cleanup. The volume of waste-water and the waste load are relatively insignificant in comparison with other waste sources (USEPA, 1974).

4.3.2.16 Product Holding/Aging

Some processed meat products require holding or aging as part of the production process. Hams, dry sausage, and some bacon, for example, require intermediate or finished holding periods before the product is shipped out of the meat processing plant. The holding operation requires space and some means of storing the particular meat product in the holding area. These holding areas are refrigerated, and some drippings accumulate on the floor. The floor area, like other processing floors, is cleaned once every processing day. The quantity of wastewater and the waste load from the cleanup of these holding areas are minimal compared to those of many other sources within meat processing plants (USEPA, 1974).

4.3.2.17 Bacon Pressing and Slicing

After bacon has been smoked, cooled, and held for the required time, two processing steps are required before the product is ready for packaging (Figure 4-5). Bacon slabs are irregular in shape after smoking and cooling, and bacon slicing equipment is designed to handle a slab with a fairly rectangular shape. This design facilitates the production of the typical uniform bacon slice the consumer expects. The bacon slabs are placed in a molding press, which forms the slabs into the desired rectangular shape (USEPA, 1974).

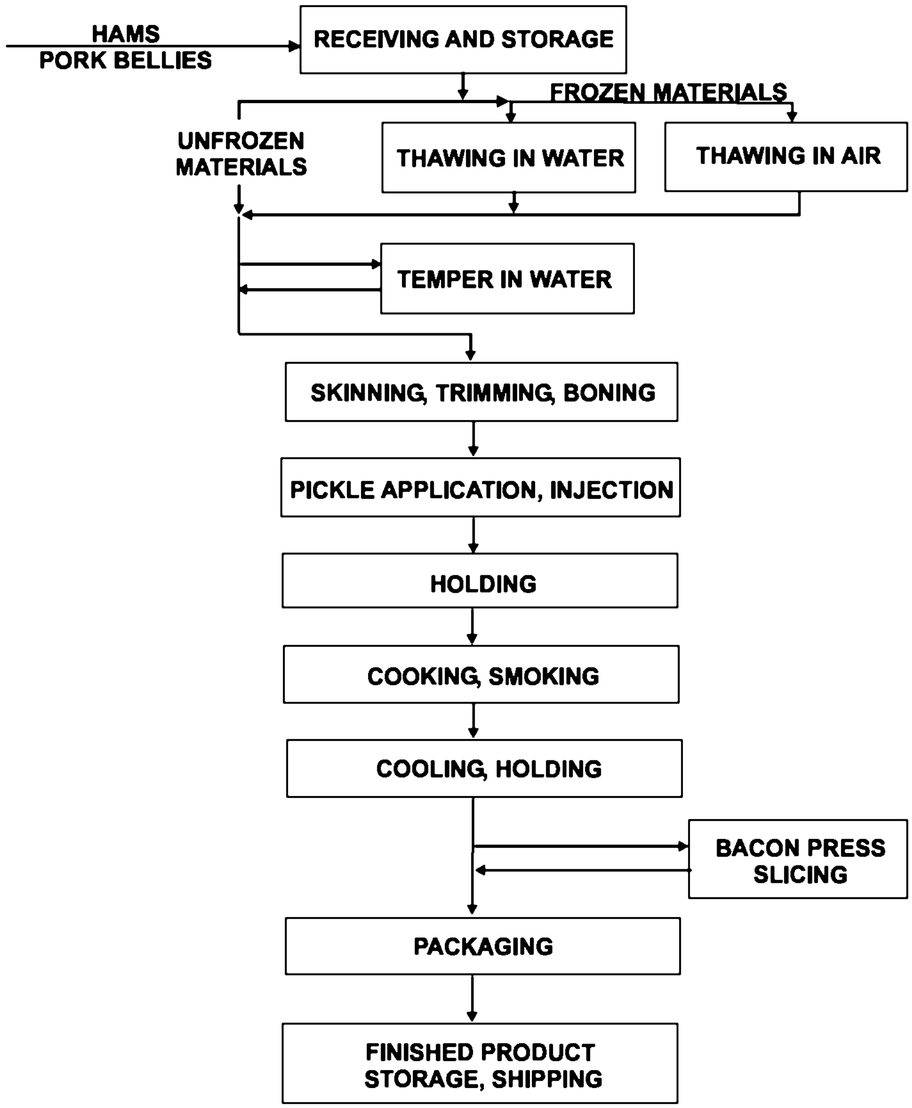

Figure 4-5. General process for hams and bacon. (USEPA, 1974).

Two different slicing procedures are used in the processing industry after the slabs have been made rectangular. Some plants slice the bacon slabs immediately after pressing. Others prefer to return the molded bacon slabs to a refrigerated holding area to allow the temperature of the slab to cool down. Each approach is successful, and the method actually used appears to depend only on individual preference for a given operation (USEPA, 1974).

Bacon slicing is usually a high-speed operation in which slabs are rapidly cut, the strips of bacon are placed on a cardboard or similar receptacle until a specified weight is reached, and then the bacon is fed onto a conveying system that delivers it to packaging (USEPA, 1974).

Little waste is generated in bacon pressing and slicing except for random pieces of bacon that fall on the floor. These pieces are large enough to be readily picked up by dry cleaning the floors before washdown. The equipment is cleaned at the end of every processing day. There are some particles, as well as a fairly complete covering of grease, on all parts of the equipment that come in contact with the bacon slabs. All this material is washed off in the cleanup operation. The quantity of wastewater generated in cleanup and the waste load from this cleanup are again relatively small in comparison to other sources (USEPA, 1974).

4.3.2.18 Receiving, Storage, and Shipping

The meat-type raw materials and virtually all the finished product in a meat processing plant require refrigerated storage. Some of the raw materials and finished products are frozen and require freezer storage. The meat-type raw materials are brought into meat processing plants as carcasses, quarters, primal cuts, and specific cuts or parts packaged in boxes. The seasonings, spices, and chemicals are usually purchased in the dry form and are stored in dry areas convenient to the sauce and spice formulation area (USEPA, 1974).

The meat processing plants of companies with nationwide sales and plants throughout the country also use the storage facilities of meat processing plants as distribution centers for products not manufactured at each plant (USEPA, 1974).

The cleaning of freezers is always a dry process, and only on rare occasions does it generate a wastewater load. Refrigerated storage space does require daily washdown, particularly of the floors, where juices and particles have accumulated from the materials stored in the refrigerated area. The general policy of the industry is to encourage dry cleaning of all floors, including storage areas, before the final washdown of the floors. Frequently, actual practices do not include dry cleaning of the floors before washdown (USEPA, 1974).

Shipping and receiving always involve truck transportation. The primary source of waste material in this operation is the transport of carcasses, quarters, and large cuts of meat from the trucks to the storage area within the meat processing plant (USEPA, 1974).

Meat and fat particles falling from the raw material are the primary source of waste material in this operation. The receipt and transport of other raw materials and finished products essentially generate no waste load (USEPA, 1974).

4.4 POULTRY PROCESSING INDUSTRY DESCRIPTION

Poultry Processing (NAICS 311615) includes the slaughter of poultry and small game animals (e.g., quails, pheasants, and rabbits) and exotic poultry (e.g., ostriches) and the processing and preparing of these products and their by-products. Slaughtering is the first step in processing poultry into consumer products. Poultry slaughtering (first processing) operations typically encompass the following steps:

- Receiving and holding of live animals
- Stunning prior to slaughter
- Slaughter
- Initial processing

Poultry first processing facilities are designed to accommodate this multistep process. In most facilities, the major steps are carried out in separate rooms.

In addition, many first processing facilities further process carcasses, producing products that might be breaded, marinated, or partially or fully cooked. Also, many first processing facilities include rendering operations that produce edible products such as fat and inedible products, primarily ingredients for animal feeds, including pet foods.

The 1997 U.S. Census of Manufacturers reported 260 companies engaged in poultry slaughtering. These companies own or operate 470 facilities, employ 224,000 employees, and produce about $32 billion in value of shipments. The poultry slaughtering sector has relatively few facilities with fewer than 20 employees; as in the meat sectors, however, a few very large facilities dominate the sector. Almost 50 percent of the sector employment and over 40 percent of the value of shipments were accounted for by 75 facilities, which employ more than 1,000 workers each. Eighty percent of employment and 74 percent of total shipments are produced by facilities that employ more than 500 workers. Yet these facilities compose only 36 percent of the poultry processing industry.

The products of the poultry processing sector can be divided into two major categories, broilers and turkeys. Broilers account for more than half of the industry's shipments; processed poultry accounts for about 30 percent of the shipments; and turkeys account for about 12 percent.

Poultry processing is largely concentrated in the southeastern states. Arkansas and Georgia have the largest number of facilities and the highest employment and value of shipments. Alabama and North Carolina rank third and fourth in all these measures. California is the only state in the top 10 poultry-producing states that is not in the Southeast. California ranks 10^{th} in terms of employment and value of shipments and 8^{th} in number of facilities.

EPA is using revised production rate thresholds to exclude most smaller poultry product processing facilities from the final revisions to 40 CFR Part 432 because the technologies on which the options were based are not cost-effective for low-production facilities with the lowest production threshold. Based on the current screener survey data, EPA defines small poultry first and further processing facilities as those that produce fewer than 100 million pounds LWK and 7 million pounds LWK per year, respectively.

4.5 DESCRIPTION OF POULTRY FIRST AND FURTHER PROCESSING OPERATIONS

Poultry processing plants are highly automated facilities designed for slaughtering live birds with whole carcasses as the end product. The operations of these plants differ significantly from their meat counterparts in several respects. For example, poultry slaughtering (first processing) operations typically involve more steps than do meat first processing operations. A poultry processing plant can encompass up to 10 steps, including unloading, stunning, killing, bleeding, scalding, defeathering, eviscerating, chilling, freezing, and packaging (Sams, 2001).

Each operation occurs in a separate section of the processing plant, and the involve operations the use of different types of equipment. Because broiler chickens constitute most of the poultry industry's annual production, and the same sequence of operations is used in the processing of turkeys and other birds, the following sections describe only broiler processing operations unless otherwise noted.

Poultry processing begins with the assembly and slaughter of live birds and can end with the shipment of dressed carcasses or continue with a variety of additional activities. Poultry processing operations are also classified as first or further processing operations or as an integrated combination. First processing operations include those operations which receive live poultry and produce a dressed carcass, either whole or in parts. In this classifications system, first processing operations simply produce dressed whole or split carcasses or smaller segments for sale to wholesale distributors or directly to retailers. First processing operations offer supply products for further processing activities such as breading, marinating, and partial or complete cooking, which can occur on- or off-site.

Following the same logic applied to the meat processing industry, EPA considers the reduction of whole poultry carcasses into halves, quarters, or smaller pieces, which might be with or without bone and might be ground as part of first processing when performed at first processing facilities. Consequently, EPA considers cutting, boning, and grinding operations to be further processing operations when performed at facilities not also engaged in first processing activities.

4.5.1 Poultry First Processing Operations

Common to all poultry first processing operations is a series of operations necessary to transform live birds into dressed carcasses. Figure 4-6 illustrates these operations, and the following sections describe them.

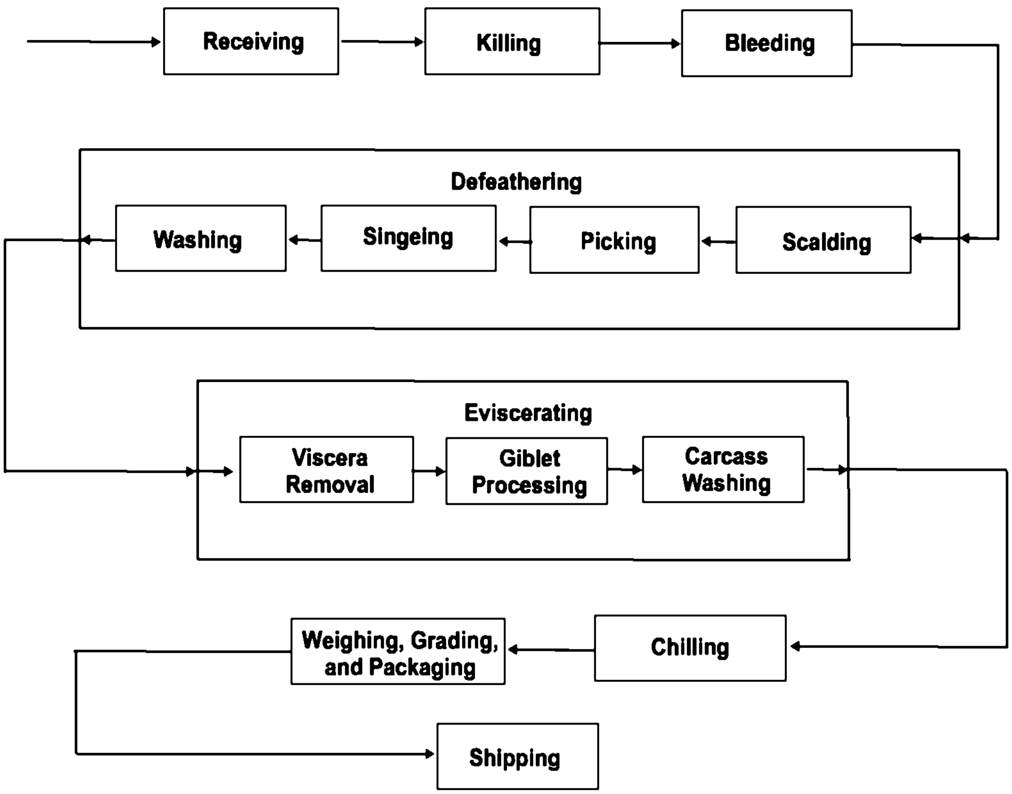

Figure 4-6. General process for poultry first processing operations (USEPA, 1975).

4.5.1.1 Receiving Areas

Birds are transported to processing plants with delivery scheduled so that all birds are processed on the day they are received. Live bird holding areas are usually covered and have cooling fans to reduce bird weight loss and mortality during hot weather conditions (Sams, 2001).

Broiler chickens are typically transported to processing plants in cage modules stacked on flatbed trailers. Each cage module can hold about 20 average-size broiler chickens. The cage modules are removed from the transport trailer and tilted using a folklift truck to empty the cage. Alternatively, tilting platforms can be used to empty the cage modules after they have been removed from the transport trailer. When the cage module tilts, the lower side of the cage opens and the birds slide onto a conveyor belt, which moves them into the hanging area inside the plant. In the hanging area, the live birds are hung by their feet on shackles attached to an overhead conveyer system, commonly referred to as the killing line, that moves the birds into the killing area. The killing line moves at a constant speed, and up to 8,000 birds per hour (133 birds per minute) can be shackled in a modern plant, although in practice this number is much lower because workers cannot unload broilers fast enough to fill every shackle (Wilson, 1998). Cage modules are also used to transport ducks, geese, and fowl.

Turkeys are usually transported in cages permanently attached to flatbed trailers. The cages are emptied manually into a live bird receiving area outside the confines of the processing plant. Turkeys are unloaded manually to minimize bruising. They are more susceptible than broilers to bruising from automatic unloading because of their heavier weight and irregular body shape. Turkeys are then immediately hung on shackles attached to an overhead conveyer system that passes from the unloading area into the processing plant (Sams, 2001).

Following the unloading process, cages and transport trucks might be washed and sanitized to prevent disease transmission among grower operations. The washing and sanitizing of cages and trucks is common in the turkey industry but not in the broiler chicken industry (USEPA, 1975).

4.5.1.2 Killing and Bleeding

Almost all birds are rendered unconscious through stunning just prior to killing. Some exemptions are made for religious meat processing (e.g., kosher, halal). Stunning immobilizes the birds to increase killing efficiency, cause greater blood loss, and increase defeathering efficiency. Stunning is performed by applying a current of 10 to 20 milliamps per broiler and 20 to 40 milliamps per turkey for approximately 10 to 12 seconds (Sams, 2001). Poultry are killed by severing the jugular vein and carotid artery or less typically by debraining. Usually a rotating circular blade is used to kill broilers, while manual killing is often required for turkeys because of their varying size and body shape. Decapitation is not performed because it decreases blood loss following death (Stadelman, 1988).

Immediately after being killed, broilers are bled as they pass through a "blood tunnel" designed to collect blood to reduce wastewater biochemical oxygen demand (BOD) and total nitrogen concentrations. The blood tunnel is a walled area designed to confine and capture blood splattered by muscle contractions following the severing of the jugular vein and corotid artery. The blood collected is processed with recovered feathers in the production of feather meal, a by-product feedstuff used in livestock and poultry feeds as a source of protein. On average, broilers are held in the tunnel from 45 to 125 seconds for bleeding, with an average time of 80 seconds; turkeys are held in the tunnel from 90 to 210 seconds, with an average time of 131 seconds. Blood loss approaches 70 percent in some plants, but generally speaking only 30 to 50 percent of a broiler's blood is lost in the killing area. Depending on plant operating conditions, blood is collected in troughs and transported to a rendering facility by vacuum, gravity, or pump systems, or it is allowed to congeal on the plant floor and collected manually. Virtually all plants collect blood for rendering on- or off-site and thereby limit the amount of blood present in their wastewater (USEPA, 1975).

4.5.1.3 Scalding and Defeathering

After killing and bleeding, birds are scalded by immersing them in a scalding tank or by spraying them with scalding water. Scalding is performed to relax feather follicles prior to defeathering. Virtually all plants use scald tanks because of the high water usage and inconsistent feather removal associated with spray scalding. Scalding tanks are relatively long troughs of hot water into which the bled birds are immersed to loosen their feathers. Depending on the intended market of the broilers, either soft (semi-scald) or hard scalding is used. Soft scalding is used for the fresh, chilled market, whereas hard scalding is preferred for the frozen sector (Mead, 1989). The difference between these two types of scalding techniques lies in the scalding temperature used. Soft scalding is performed at about 53 °C (127 °F) for 120 seconds; it loosens feathers without subsequent skin damage. Hard scalding is performed at 62 to 64 °C (144 to 147 °F) for 45 seconds; it loosens both feathers and the first layer of skin. Sometimes chemicals are added to scald tanks to aid in defeathering by reducing surface tension and increasing feather wetting. The U.S. Department of Agriculture (USDA) requires that all scald tanks have a minimum overflow of 1 liter (0.26 gallon) per bird (FSIS, 2001) to reduce the potential for microbial contamination (Sams, 2001).

Because scalding and mechanical defeathering do not completely remove duck and goose feathers, immersion in a mixture of hot wax and rosin follows. After this mixture partially solidifies, it is removed with the remaining feathers (Stadelman et al., 1988).

The next stage is automated defeathering, which is done by machines with multiple rows of flexible, ribbed, rubber fingers on cylinders that rotate rapidly across the birds. The abrasion caused by this contact removes the feathers and occasionally the heads of the birds. At the same time, a continuous spray of warm water is used to lubricate the bird and flush away feathers as they are removed. Feathers are flumed to a screening area using scalding overflow for dewatering prior to processing for feather meal production. Different defeathering machines might be used for different types of birds (USEPA, 1975).

Following defeathering, pinfeathers might be removed manually because they are still encased within the feather shaft and thus are resistant to mechanical abrasion. After pinfeather removal, birds pass through a gas flame that singes the remaining feathers and fine hairs. Next, feet and heads are removed. Feet are removed by passing them through a cutting blade, and heads are removed by clamps that pull upward on the necks. Removing the head from a bird is advantageous because the esophagus and trachea are removed with it. Removing the head also loosens the crop and lungs for easier automatic removal during evisceration (Mead, 1989). At this point, the blood, feathers, feet, and heads of broilers are collected and sent to a rendering facility, where they are transformed into by-product meal (Sams, 2001). Chicken feet might also be collected for sale, primarily in export markets.

After removal of the feet, the carcasses are rehung on shackles attached to an overhead conveyer, known as an evisceration line, and washed in enclosures using high-pressure cold water sprays prior to evisceration. The purpose of this washing step is to sanitize the outside of the bird before evisceration to reduce microbial contamination of the body cavity. This transfer point is often referred to as the point separating the "dirty" and "clean" sections of the processing plant (Wilson, 1998). The killing-line conveyor then circles back, and the shackles are cleaned before they return to the unloading bay (USEPA, 1975).

4.5.1.4 Evisceration

Evisceration is a multistep process that begins with removing the neck and opening the body cavity. Then, the viscera are extracted but remain attached to the birds until they are inspected for evidence of disease. Next, the viscera are separated from the bird, and edible components (hearts, livers, and gizzards) are harvested. The inedible viscera, known as offal, are collected and combined with heads and feet for subsequent rendering. Entrails are sometimes left attached for religious meat processing (e.g., Buddhist, Confucius). Depending on the plant design, a wet or dry collection system is used. Wet systems use water to transport the offal by fluming it to a screening area for dewatering before rendering. Dry systems, which are not common, use a series of conveyor belts or vacuum or compressed air stations for offal transport (USEPA, 1975).

Automation of the evisceration process varies depending on plant size and operation. A fully automated line can eviscerate approximately 6,000 broilers per hour (Mead, 1989). The type of equipment available for plant use varies by location and manufacturer. Many parts of the process can be performed manually, especially for turkeys. Though a fully automated evisceration line can be used for broilers, the variation in size among turkeys makes automation more difficult. Female turkeys (hens) are significantly smaller than male turkeys (toms) (USEPA, 1975).

When broilers first enter the evisceration area, they are rehung on shackles by their hocks to a conveyor line that runs directly above a wet or dry offal collection system (Wilson, 1998). The birds' necks are disconnected by breaking the spine with a blade that applies force just above the shoulders. As the blade retracts the neck falls downward and hangs by the remaining skin while another blade removes the preen gland from the tail. The preen gland produces oil that is used by birds for grooming and has an unpleasant taste to humans (Sams, 2001). Next, a venting machine cuts a hole with a circular blade around the anus for extraction of the viscera. Great care must be taken not to penetrate the intestinal lining of a broiler because the resulting fecal contamination results in condemnation during inspection (USEPA, 1975).

Following venting, the opening of the abdominal wall is enlarged to aid in viscera removal. At this point all viscera are drawn out of the broiler by hand, with the aid of scooping spoons, or more commonly by an evisceration machine. The evisceration machine immobilizes the broiler and passes a clamp through the abdominal opening to grip the visceral package. Once removed, this package is allowed to hang freely to aid in the inspection process. Every bird must be inspected by a USDA inspector or a USDA-supervised plant worker for evidence of disease or contamination before being packaged and sold. The inspector checks the carcass, viscera, and body cavity to determine wholesomeness with three possible outcomes: pass, conditional, and fail. If the bird is deemed conditional, it is hung on a different line for further inspection or to be trimmed of unwholesome portions. Failed birds are removed from the line and disposed of, usually by rendering (Stadelman, et al., 1988).

The viscera are removed from the birds that have passed inspection and are pumped to a harvesting area where edible viscera are separated from inedible viscera. A giblet harvester is used to collect the edible viscera, including heart, liver, neck, and gizzard, and to prepare each appropriately. The heart and liver are stripped of connective tissue and washed. The gizzard is split, its contents are washed away, its hard lining is peeled off, and it is given a final wash. The minimum giblet washer flow rate required by USDA is 1 gallon of water for every 20 birds processed (25 CFR 61.144). Meanwhile, the inedible viscera, including intestines, proventriculus, lower esophagus, spleen, and reproductive organs, are extracted and sent to a rendering facility. Finally, the crop and lungs are mechanically removed from each bird. The crop is pushed up through the neck by a probe, and the lungs are removed by vacuum. A final inspection is required to ensure the carcass is not heavily bruised or contaminated, and then the carcass is cleaned (USEPA, 1975). Bruised birds are diverted to salvage lines for recovery of parts.

The second carcass washing of the broilers is very thorough. Nozzles are used to spray water both inside and outside the carcass. These high-pressure nozzles are designed to eliminate the majority of remaining contaminants on both the carcass and the conveyor line, and the water is often mixed with chlorine or other antimicrobiological chemicals. From this area, the conveyor system travels to the chilling area (USEPA, 1975).

Kosher and halal poultry producers pack the birds (inside and out) in salt for 1 hour to absorb any residual blood or juices. The birds are then rinsed and shipped to kosher/halal meat distributers. On an average day a typical kosher poultry facility (generating approximately 2 million gallons of wastewater per day) would use approximately 80,000 pounds of salt in its operations (Thorne, 2001). Industry has stated that most kosher operations (meat and poultry) are in urban areas with sewer connections.

4.5.1.5 Chilling

After birds have been eviscerated and washed, they are chilled rapidly to slow the growth of any microorganisms present to extend shelf life and to protect quality (Sams, 2001). USDA regulations require that broilers be chilled to 4 °C (40 °F) within 4 hours of death and turkeys within 8 hours of death (9 CFR 381.66). Most poultry processing plants use large chilling tanks containing ice water; very few use air chilling. Several types of chilling tanks are used, including (1) a large enclosed drum that rotates about a central axis, (2) a perforated cylinder mounted within a chilling vat, and (3) a large open chilling tank containing a mechanical rocker to provide agitation. In all cases, birds are cascaded forward with the flow of water at a minimum overflow rate per bird specified by (USDA FSIS, 1986).

Most poultry plants use two chilling tanks in series, a pre-chiller and a main chiller. The direction of water flow is from the main chiller to the pre-chiller, which is opposite to the direction of carcass movement. Because water and ice are added to only the main chiller, the water in the pre-chiller is somewhat warmer than that in the main chiller. Most plants chlorinate chiller makeup water to reduce potential carcass microbial contamination. The USDA requires 0.5 gallon (2 liters) of overflow per bird in the chillers (FSIS, 2001); the typical flow is about 0.75 gallon (3 liters) per bird (Sams, 2001). The effluent from the first chiller is usually used for fluming offal to the offal screening area (USEPA, 1975).

USDA requires a pre-chiller water temperature of less than 18.3 °C (65 °F) (9 CFR 381.66), and temperature values typically range between 7 and 12 °C (45 and 54 °F) (Stadelman, 1988). Agitation makes the water a very effective washer, and the pre-chiller often cleans off any remaining contaminants. Most broiler carcasses enter the pre-chiller at about 38 °C (100 °F) and leave at a temperature between 30 and 35 °C (86 and 95 °F). The cycle lasts 10 to 15 minutes, and water rapidly penetrates the carcass skin during this time period (Sams, 2001). Water weight gained in the pre-chiller is strictly regulated and monitored according to poultry classification and final destination of the product by USDA. Cut-up and ice-packed products are allowed to retain more water than their whole carcass pack or whole frozen counterparts (USDA FSIS, 1986).

The main chill tank's water temperature is approximately 4 °C (39 °F) at the entrance and 1 °C (34 °F) at the exit because of the countercurrent flow system. Broiler carcasses stay in this chiller for 45 to 60 minutes and leave the chill tank at about 2 to 4 °C (36 to 39 °F). Air bubbles are added to the main chill tanks to enhance heat exchange. The bubbles agitate the water and prevent a thermal layer from forming around the carcass. If not agitated, water around the carcass would reach thermal equilibrium with the carcass and retard heat transfer (Sams, 2001).

If air chilling is used, it normally involves passing the conveyor of carcasses through rooms of air circulating at between -7 and 2 °C for 1 to 3 hours. In some cases water is sprayed on the carcasses, increasing heat transfer by evaporative cooling (Sams, 2001). Giblets, consisting of hearts, livers, gizzards, and necks, are chilled similarly to carcasses, though the chilling systems for giblets are separate and smaller (USEPA, 1975).

4.5.1.6 Packaging and Freezing

After the birds are chilled, they are packed as whole birds or processed further. Whole birds are sold in both fresh and frozen forms. Chickens are primarily sold as fresh birds, and turkeys are primarily sold as frozen birds. Fresh birds not sold in case-ready packaging are packed in ice for shipment to maintain a temperature of 0 °C (32 °F). Poultry sold frozen is cooled to approximately -18 °C (0 °F) (Wilson, 1998).

4.5.2 Poultry Further Processing Operations

Further processing can be as simple as splitting a carcass into two halves or as complex as producing a breaded or marinated, partially or fully cooked product. Therefore, further processing might involve receiving, storage, thawing, cutting, deboning, dicing, grinding, chopping, canning, and final product preparation. Final product preparation includes freezing, packaging, and shipping. Further processing might be performed after first processing in an integrated operation, or it might be performed at a separate facility. Further processing is a highly automated process designed to transform eviscerated broiler carcasses into a wide variety of consumer products. Depending on the type of product being produced, plant production lines might overlap, especially for producing cooked, finished products (USEPA, 1975). The following sections describe poultry first processing operations, and Figure 4-7 illustrates these operations.

4.5.2.1 Receiving and Storage

If further processing takes place at a location separate from first processing, carcasses, cut-up parts, and deboned meat are usually transported by truck. The vast majority of first processing products received for further processing are whole carcasses. Further processing operations separate from first processing or killing operations might receive poultry that has already been further processed to some degree, typically cut up or deboned. Further processing plants that are separate from killing operations usually process poultry received packed in ice or frozen, whereas further processing operations combined with killing operations usually process whole carcasses directly following chilling. Thus, further processing plants separate from killing operations require refrigerated or freezer storage facilities before further processing, whereas further processing operations combined with killing operations do not require such facilities except for the preservation of final products. Seasonings, spices, and chemicals are usually received in dry form and stored in dry areas conveniently located near sauce, spice, butter, and breading formulation areas (USEPA, 1975).

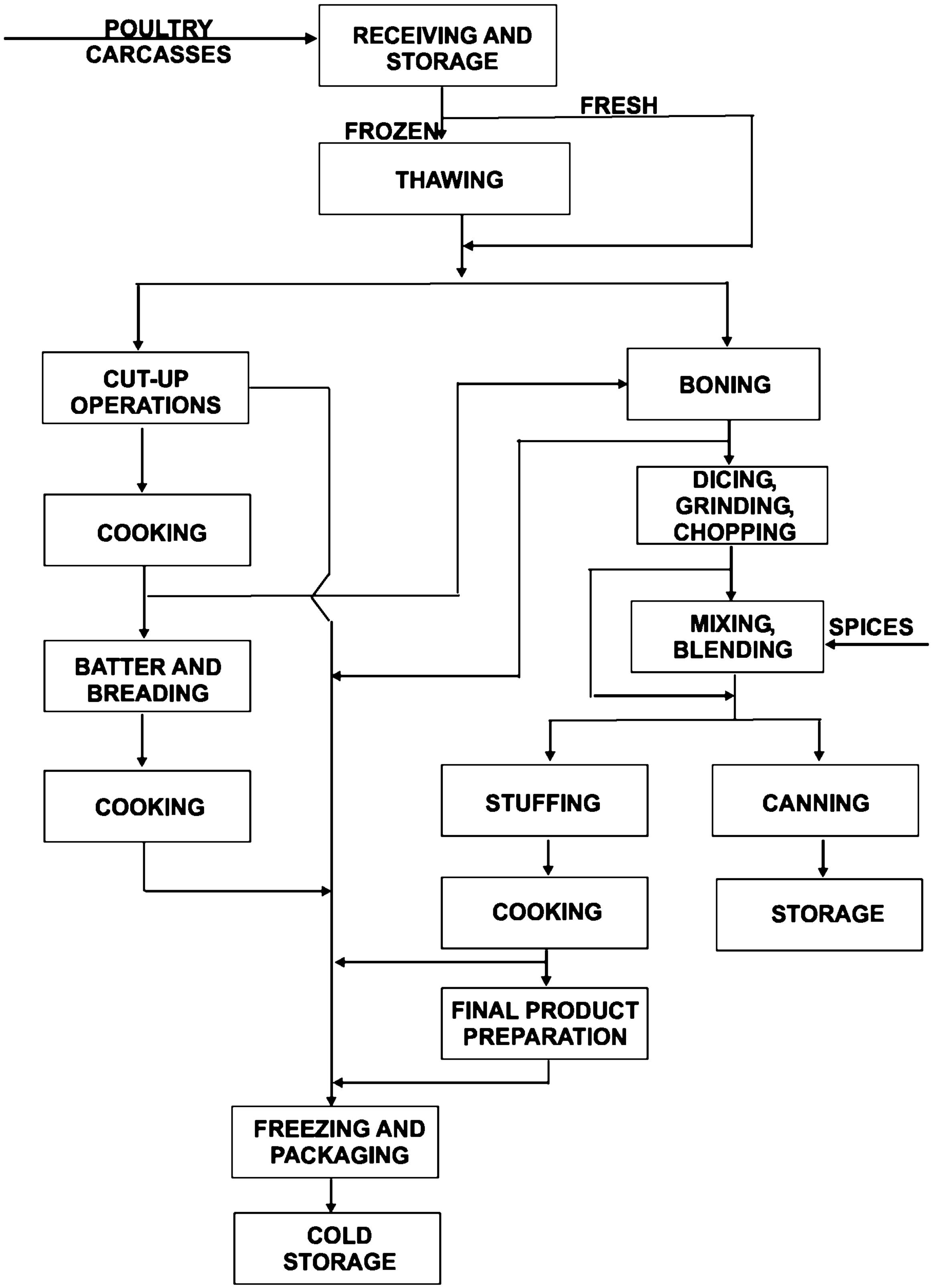

Figure 4-7. General process for poultry further processing operations

4.5.2.2 Thawing

Frozen poultry carcasses and components thereof received by further processing plants can be thawed by immersing them in water, by spraying them with water, or by thawing them in air with adequate protection against contamination. In immersion, poultry is submerged in tanks or vats of lukewarm potable water for the time required to thaw the poultry throughout. To prevent spoilage, USDA does not permit the temperature of the continuously running tap water to exceed 21 °C (70 °F) (9 CFR 381.65). Ice or other cooling agents can be used to keep the thawing water within the acceptable temperature range. The vats used for thawing range from pushcarts of 10 to 20 cubic feet in volume to substantially larger permanently installed tanks. Agitation can be induced to enhance thawing by adding water continuously or by pumping filtered air through flexible hoses into the immersion tank (USEPA, 1975). In thawing units that have no freshwater added (no overflow) or where the thawing water leaves the unit for reconditioning before returning to the thawing unit, the water is not allowed to exceed 10 °C (50 °F), as required by the USDA (9 CFR 381.65).

Complete thawing is necessary to permit thorough examination of poultry prior to any further processing. When the poultry has adequately thawed for reinspection, the product is removed from the water and drained. Some plants prefer to place frozen poultry directly into cooking kettles prior to thawing. This practice is permitted only when representative samples of the entire lot have been thawed and found to be in sound and wholesome condition. In this case, cookers filled with water are heated to enable the cooking process to begin immediately following completion of thawing. USDA requires that thawing practices and procedures result in no net gain in weight over the frozen weight (9 CFR 381.65).

If the only further processing operation is repackaging whole carcasses or parts for shipment to market, USDA regulations prohibit recooling the thawed parts in slush ice. Mechanical refrigeration is required; however, the whole carcasses or parts may be held in tanks of crushed ice with open drains, pending further processing or packaging (9 CFR 381.65).

4.5.2.3 Cutting

Cutting of poultry is normally the first further processing step for fresh ice-packed and just-thawed poultry. Cutting involves disjointing poultry and sawing it into various parts. The specifics of these parts became regulated by the government in 1986, when USDA's Food Safety Inspection Service (FSIS) published guidelines for cuts of poultry (FSIS, 2001). Using these guidelines as the standard, further processing plants cut poultry into parts manually or automatically. Mechanized equipment that processes entire carcasses into various cut portions is available. The following parts are removed in descending order: neck skin, wings, breasts, backbone, and finally thighs (which can be separated from the drumsticks, if desired). If further portion uniformity is desired, manual cuts can be made or a machine can be used to make horizontal and vertical cuts. Up to 2,000 birds an hour can be processed in this way. The only manual labor required is feeding carcasses into the machine (Mead, 1989).

4.5.2.4 Deboning

After poultry has been cut into parts, the parts can be deboned (separation of meat from bone). Both raw and cooked poultry can be deboned. Frequently turkeys, because of their size, are deboned raw, while chickens and similarly sized poultry can be deboned raw or cooked (USEPA, 1995). Chicken cooked before deboning retains its characteristic chicken flavor, while chicken cooked after deboning tastes like meat; therefore, cooked chicken is deboned for products for which chicken flavor is desired, and raw chicken is deboned for products for which a meat flavor is desired. Additional seasonings can be added to the raw chicken after it has been deboned to further enhance its flavor (Mead, 1995). Deboning is usually performed with specially designed machines, but it can be done manually. The bones are collected for rendering (USEPA, 1975).

When deboning is mechanized, the meat retains its original shape or is ground into a thick paste. If the original shape is desired, the portions are fed into machines where a specially designed mold fits over the poultry cut. As the mold compresses the portions, the meat slides away from the bone. If cooked meat is to be used in other food products, it is placed into a machine that acts much like a hydraulic press, compacting the meat and bone against several different screens. The meat passes through these screens while the bone remains behind, creating a thick paste of condensed poultry meat (Mead, 1989).

4.5.2.5 Grinding, Chopping, and Dicing

Many poultry products such as patties, rolls, and luncheon meats require size reduction of boned meat. Grinding, chopping, and dicing vary the degree of size reduction: grinding produces the greatest degree of size reduction, chopping the next, and dicing the least. Each of these operations is accomplished by mechanical equipment. In grinding, the meat is forced past a cutting blade and then extruded through orifice plates with holes between 1/8 and 3/8 inch in diameter. Likewise, poultry is usually chopped by forcing the meat past a cutter and through an orifice plate; however, the holes are greater than 3/8 inch in diameter. (The specific orifice size is chosen based on the desired nature of the final product.) Dicing is more like a cutting operation in that it makes distinct cuts in the meat to produce square-shaped chunks (USEPA, 1975).

4.5.2.6 Cooking

Some further-processed poultry products are cooked at some point in processing. This step is done in preparation of a final product or in preparing whole birds for subsequent deboning, the latter applying particularly to processing chickens. Partially and fully cooked poultry products are frequently prepared in further processing operations, especially for the hotel, restaurant, institutional, and fast-food markets (USEPA, 1975).

Most poultry products are cooked by immersion in water in steam-jacketed open vats. Gas-fired ovens are used for some products, such as breasts that are not breaded. A small number of microwave ovens are used in place of immersion cookers, and deep fat frying is used for breaded products (USEPA, 1975).

Chicken parts, whole birds, and products such as rolls and loaves can be cooked by immersion in hot water cookers. Overflow wires are used in these cookers to collect edible chicken or turkey fat during the actual cooking operation. At the end of the processing day, the contents of cooking vats are dumped into the wastewater collection system (USEPA, 1975).

Gas-fired ovens require essentially no water for operation. A small quantity of steam may be added for humidity control, but it is usually vented through the facility's stack system (USEPA, 1975).

The use of microwave ovens frequently requires a preliminary injection of spices and preservatives using multiple-needle injection equipment similar to the equipment used in ham and bacon processing. The solution remaining at the end of the operating day is discarded into the wastewater collection system (USEPA, 1975).

All cooked products are cooled before any further processing. The most common cooling technique for cooked products is immersion into a cold-water tank with continuous overflow (USEPA, 1975).

4.5.2.7 Batter and Breading

Fully cooked poultry parts or fresh fabricated products may be battered and breaded to produce a desired finished product. The batter is a water-based pumpable mixture, usually containing milk and egg solids, flour, spices, and preservatives. A new batch of batter is prepared each operating day. The batter is pumped through the application equipment, and the excess flows back to the small holding tank. Some of the batter clings to the application equipment; it is cleaned off during the day (USEPA, 1975).

The breading is a mixture of solids deposited on the poultry product after the batter is applied. No liquid is used in breading the products, and the residual solids are not discarded into the wastewater collection system. The breading is "set," "browned," or cooked by deep fat frying in vegetable oil. The breaded products are conveyed through a deep-fat fryer heated directly by gas flame or heated by the circulation of hot oil from a heater separate from the fryer. The vegetable oil in the fryer is reused repeatedly. When vegetable oil disposal is necessary (after the end of each production shift), it is shipped to a renderer (USEPA, 1975).

4.5.2.8 Mixing and Blending

Some of the further-processed products require the mixing of several ingredients, including ground or chopped meat, dry solids, spices, and water. The required speed and intensity for intermixing these ingredients vary, depending on the product, from a gentle blending action to an intense, high-shear mixing action. Gravies and sauces are prepared in mixers that are usually steam jacketed for heating. The ingredients are pumped or manually transported to the mixing equipment for the preparation of batches of the product mix (USEPA, 1975).

4.5.2.9 Stuffing and Injecting

Following preparation of a mixture of ingredients for a processed poultry product, the mixture is pumped or transported manually in a container to a manufacturing operation, where the mixtures are formed into the finished products. Either natural or synthetic sausage casings are commonly used as containers in this operation (USEPA, 1975).

To stuff cases, a product mixture is placed in a piece of equipment from which the product mixture is forced by air pressure or pumped to fill the casing uniformly and completely to form the finished product. Water is used to lubricate casings for use in the stuffing operation (USEPA, 1975).

Whole bird stuffing, which is performed primarily with turkeys, involves pumping a stuffing mixture into the body cavity of a dressed bird at a stuffing station, followed by trussing and freezing of the stuffed bird (USEPA, 1975).

Whole birds are often injected with edible fats and oils, such as butter, margarine, corn oil, and cottonseed oil, to enhance their palatability. This is primarily done with turkey carcasses. This step is normally accomplished by inserting small, perforated needles into the carcass in such a manner as to direct the injected fat or oil between the tissue fibers. The preferred method is to inject longitudinally into the carcass without penetrating the skin of the carcass, so the intact overlying skin will retard escape of the injected materials. The injection material can be used for 1 day after preparation, but it must be discarded at the end of the second processing day. Most plants minimize or avoid any disposal of this high-cost material by preparing only the amount needed (USEPA, 1975).

4.5.2.10 Canning

The containers used to hold canned poultry products must be prepared before filling and covering. The cans are first cleaned and sterilized. Then the sterilized cans are transported from the preparation area to the processing area for filling and closure. Water is frequently present all along the can lines from preparation to filling and covering to remove any spilled product from equipment used, from outer can surfaces, and from condensed steam. The cans go through a final steaming just before they enter the can filling area. Cans can be filled by hand or mechanically; however, canning of whole birds or disjointed parts necessitates hand filling (USEPA, 1975).

Can filling by machine is a high-speed operation. The poultry food products are moved to the canning equipment and then automatically delivered into containers. The high speed and the design of the equipment result in an appreciable amount of product spillage as the cans are filled and conveyed to the closure equipment. At the can closure station, a small amount of steam is introduced under the cover just before the cover is sealed to create a vacuum in the can when it cools. Steam use also generates condensate, which drains off the cans and equipment onto the floor. The operation of the filling and covering equipment results in a substantial quantity of wastewater containing product spills, which is wasted to the wastewater collection system. Filling cans by hand does not appear to generate as much spillage. Canning plants that have more than one filling and covering line have a waste load that is generally proportional to the number of such lines in use (USEPA, 1975).

Canned poultry food products are preserved by heating to destroy any bacteria present. This is accomplished by cooking or by retorting (the pressurized cooking of canned products). Steam is used as the heating medium in retorting, and it is common practice to bleed or vent steam from the retort vessels to maintain a constant cooking pressure. Cooking without pressure is used for cured boneless canned poultry products; the products are considered perishable and must be kept refrigerated. Virtually no wastewater or solid waste is generated by retorting or cooking operations unless a can in a particular batch accidentally opens and spills its contents. This event requires wasting of the contents of that can and cleanup of the cooking vessel. Such accidents rarely happen, and therefore the retorts or cooking vessels, as a matter of normal practice, are not cleaned (USEPA, 1975).

4.5.2.11 Final Product Preparation

Many of the final products from a poultry plant are ready to serve after heating and are prepared for the hotel, restaurant, and institutional markets. These products are portion-controlled, might have gravy or a sauce added, and are packaged in containers of an appropriate size and design for immediate heating and serving. Poultry meat patties, slices of turkey loaf, and chicken parts are examples of the types of poultry products prepared in this manner. Equipment is used to convey and slice the meat product and deposit it into containers. The same equipment delivers and adds the sauce or gravy to the meat in the container, as required for specific products. As the final operation, this equipment closes the individual containers (USEPA, 1975).

4.5.2.12 Freezing

The first step in the freezing of further-processed poultry products is usually blast freezing, in which the product is frozen by high-velocity air within the range of -40 to -29 °C (-40 to –20 °F), or passing the product through a carbon dioxide or nitrogen tunnel in which the change in phase of carbon dioxide or nitrogen from liquid to gas causes rapid surface freezing. The products are then placed in holding freezers in which the temperature is maintained at between -29 and -18 °C (-20 and 0 °F) (USEPA, 1975).

4.5.2.13 Packaging

Packaging protects products against damage, contamination, and dessication. It also can extend the shelf life of fresh poultry and improves product presentation (Mead, 1995). A variety of packaging techniques are used for further-processed poultry products. These techniques include Cry-O-Vac packaging in which plastic film is sealed under a vacuum, bubble enclosure packaging, used for sliced luncheon meats, and the boxing of smaller containers or pieces of finished product for shipment (USEPA, 1975).

In some packaging techniques, a substantial amount of product handling is involved, which can result in some wasted finished product. However, pieces of wasted finished product are usually returned for subsequent use in another processed product or directed to a renderer (USEPA, 1975).

4.5.2.14 Shipping

Shipping involves the transportation of finished products and material collected for rendering. Truck transportation is the primary mode of shipping, and products are distributed according to market orders (USEPA, 1975).

Trucks must be pre-chilled prior to loading to maintain the shelf life of fresh poultry products. Fresh poultry must be maintained at temperatures near freezing with 90 to 100 percent humidity during transport to maintain a shelf life of 1 to 4 weeks (USDA, 1997). Each truck is loaded through overhead doors leading directly from inside the facility into the truck. Therefore, typically no loading dock is exposed to the elements, so that the pollutants in any runoff from truck loading areas are only those commonly associated with vehicle parking areas. The pollutant load is wastewater concentrated by cleanup of inside loading areas, and it is variable depending on the method of packaging. Ice-packed products generate a higher pollutant load from icemelt than do packaged products. Loading areas, however, are not a significant source of wastewater pollutant loads.

4.6 DESCRIPTION OF RENDERING OPERATIONS

This section provides an overview of the U.S. rendering industry, which prepares edible and inedible rendered products. This section is divided into three subsections: industry characterization, process description, and emerging technologies.

4.6.1 Industry Characterization

The Rendering and Meat By-product Processing (NAICS 311613) sector includes facilities engaged in the rendering of inedible (not suitable for human consumption) stearin, grease, and tallow from animal fat, bones, and meat scraps, and the manufacturing of animal oils, including fish oil, and fish and animal meal. The edible (suitable for human consumption) rendering industry is included in Standard Industrial Classification (SIC) Code 2011. Many facilities not classified as rendering facilities perform rendering operations but are not classified as renderers because they are also engaged in slaughtering (first processing). These facilities are often on-site (or integrated) rendering facilities that are part of an animal or poultry slaughtering facility. Integrated rendering plants normally process only one type of raw material, whereas independent rendering plants often handle several types of raw material that require either multiple rendering systems or significant modifications in the operating conditions for a single system.

The rendering sector consists of 137 companies that own or operate 240 facilities. The sector employs 8,800 workers and generates $2.6 billion in shipments. Texas and California have the largest number of rendering facilities. Unlike the meat or poultry industry sectors, the rendering industry sector includes few large facilities; only 11 rendering facilities employed more than 100 workers per facility in 1997. Rendering facilities tend to collect most of their raw material from farms, animal feeding operations, first processors, further processors, and restaurants (e.g., grease from traps and fryers). Rendering collection areas for raw material are limited by cost of transportation and travel time for the raw material to reach the rendering facility. Many rendering facilities have limited overlap of collection areas with other rendering facilities. The 132 rendering facilities that employ between 20 and 99 workers account for the largest share of the industry shipments (66 percent).

As with the meat and mixed meat animal first and further processing sectors, EPA is using revised production rate thresholds to exclude most smaller rendering facilities from the January 31, 2002, final revisions to 40 CFR Part 432. Based on the current screener survey data, EPA is defining small rendering facilities as those which produce less than 10 million pounds of rendered product per year.

4.6.2 Rendering (Meat and Poultry By-Product Processing) Description

Rendering processes are processes used to convert the by-products of meat and poultry processing into marketable products, including edible and inedible fats and proteins for agricultural and industrial use. Materials rendered include viscera; meat scraps, including fat, bone, blood, feathers, hatchery by-products (e.g., infertile eggs, dead embryos); and dead animals. Lard and food-grade tallow are examples of edible rendering products. Inedible rendering products include industrial and animal feed-grade fats, meat and poultry by-product meals, feather meal, dried blood, and hydrolyzed hair.

As noted above, rendering plants that operate in conjunction with animal slaughterhouses or poultry processing plants are called integrated rendering plants. Plants that collect their raw materials from a variety of off-site sources are called independent rendering plants. Independent plants obtain animal by-product materials from various sources, such as butcher shops, supermarkets, restaurants, fast-food chains, poultry processors, slaughterhouses, farms, ranches, feedlots, and animal shelters (USEPA, 1995).

Edible rendering plants separate fatty animal tissue into edible fats and proteins. The edible rendering plants are normally operated in conjunction with meat packing plants. USDA FSIS is responsible for regulating and inspecting meat and poultry first and further processing facilities and facilities engaged in edible rendering (suitable for human consumption) to ensure food safety. The U.S. Food and Drug Administration (FDA) covers inedible rendering operations. Inedible rendering plants are operated by independent renderers or are part of integrated rendering operations. These plants produce inedible tallow and grease, which are used in livestock and poultry feed, pet food, soap, chemical products such as fatty acids, and fuel blending agents.

4.6.2.1 Edible Rendering

A typical edible rendering process is shown in Figure 4-8. Fat trimmings, usually consisting of 14 to 16 percent fat, 60 to 64 percent moisture, and 22 to 24 percent protein, are ground and then conveyed by belt to a melt tank. The melt tank heats the materials to about 43 °C (110 °F), and the melted fatty tissue is pumped to a disintegrator, which ruptures the fat cells.

The proteinaceous solids are separated from the melted fat and water by a centrifuge. The melted fat and water are then heated with steam to about 93 °C (200 °F) by a shell and tube heat exchanger. A second-stage centrifuge then separates the edible fat from the water, which also contains any remaining protein fines. The water is discharged as sludge, and the "polished" fat is pumped to storage. Throughout the process, direct heat contact with the edible fat is minimal, and no cooking vapors are directly emitted (USEPA, 1995).

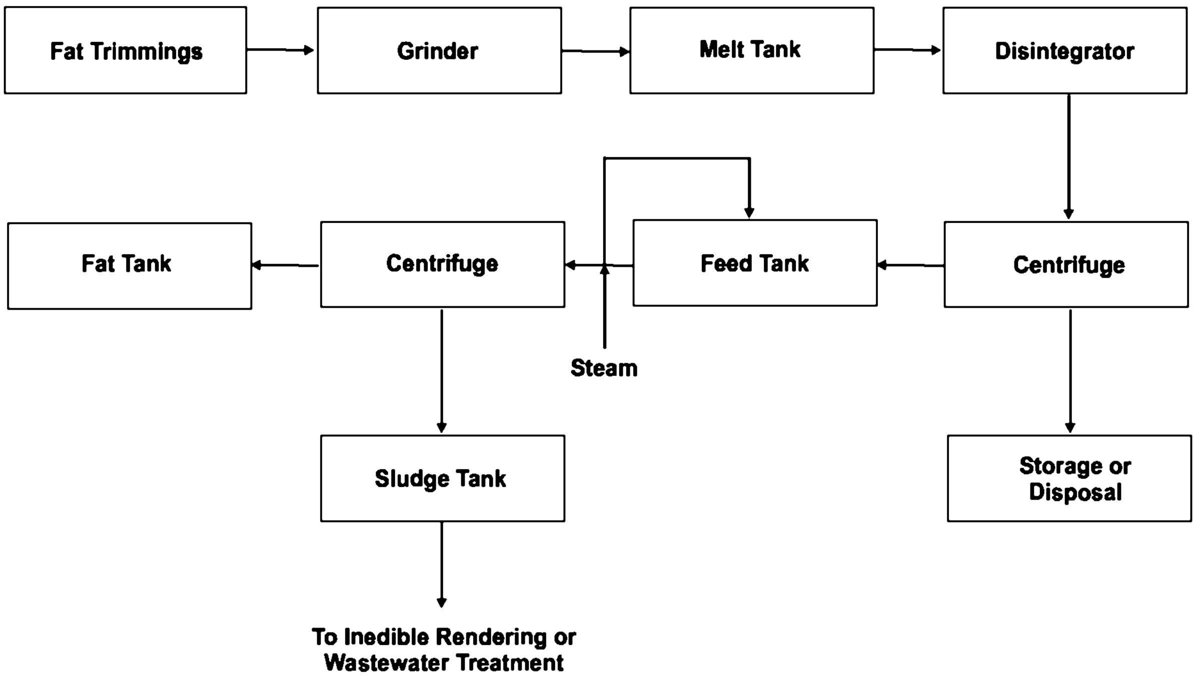

Figure 4-8. General process for edible rendering (USEPA, 1995).

Edible lard and tallow are the main foodstuffs produced from continuous edible rendering of animal fatty tissue. Either the low-temperature option or the high-temperature option edible rendering process can be used to render edible fat. The low-temperature option uses temperatures below 49 °C (120 °F), and the high temperature option uses temperatures between 82 and 100 °C (180 and 210 °F) to melt animal fatty tissue and to separate the fat from the protein. A better separation of fat from protein can be achieved with the high-temperature option; however, the protein obtained from the low-temperature option is of acceptable quality, wheras the protein obtained from the high-temperature option cannot be sold as an edible product (Prokop, 1985).

4.6.2.2 Inedible Rendering

Table 4-1 shows the fat, protein, and moisture contents for several raw materials processed by inedible rendering plants. There are two processes for inedible rendering: the wet process and the dry process. Wet rendering separates fat from raw material by boiling in water. The process involves adding water to the raw material and using live steam to cook the raw material and separate the fat. Dry rendering is a batch or continuous process in which the material being rendered is cooked in its own moisture and grease with dry heat in open, steam-jacketed drums until the moisture has evaporated. Following dehydration, as much fat as possible is removed by draining, and the residue is passed through a screw press to remove some of the remaining fat and moisture. Then the residue is granulated or ground into a meal. At present, only dry rendering is used in the United States. The wet rendering process is no longer used because of both its adverse effect on the fat quality and the high cost of energy (USEPA, 1995).

Table 4-1. Composition of raw materials for inedible rendering

Source	**Tallow/grease Wt %**	**Protein Solids Wt %**	**Moisture Wt %**
Packinghouse offal[a] and bone			
Steers	30 35	15 20	45 55
Cows	10 20	20 30	50 70
Calves	10 15	150 20	65 75
Sheep	25 30	20 25	45 55
Hogs	25 30	10 15	55 65
Poultry offal	10	25	65
Poultry feathers	None	33	67
Dead stock (whole animals)			
Calves	10	22	68
Sheep	22	25	53
Hogs	30	28	42
Butcher shop fat and bone	31	32	37
Blood	None	16 18	82 84
Restaurant Grease	65	10	25

Source: USEPA, 1995.

[a] Waste parts, especially the viscera and similar parts from a butchered animal.

Inedible rendering can be divided into two subcategories: feed-grade and pet food-grade rendering. In addition, the poultry industry uses a third subcategory of inedible rendering called glomerate rendering. Glomerate rendering is the oldest rendering process, dating back to the beginnings of slaughterhouses when all animal by-products were rendered and fed back to animals as a feed. The glomerate process involves combining meat and feathers and cooking them together to produce feed for poultry. Because more plants further process poultry than they did in the past, a greater amount of bones, backs, and necks are included in the rendering process. The ratio of meat to feathers varies throughout the day, generally resulting in increased protein concentrations toward the end of the day. Glomerate rendering is not widely used today because of the highly variable protein concentrations of the final products (Christensen, 1996).

Feed-grade rendering has the largest market because livestock and poultry feed manufacturers purchase the products produced in bulk to use as feed ingredients. This process requires that fat and protein and hog hair or poultry feathers be separated, though crude techniques are used. The meat is cooked down into meal, and the feathers or hair are hydrolyzed before they are sold to livestock and poultry feed manufacturers (Christensen, 1996).

Pet food-grade rendering is the most profitable type of rendering and has an $8 billion market worldwide each year. Strict separation of materials is required because purchasers are very concerned about the texture, color, ash content, and quality of the final product. Blood, feathers, and hair cannot be included in pet food (Christensen, 1996).

The following sections describe the two typical inedible rendering processes, batch rendering and continuous rendering. Both can be used to produce either feed-grade or pet food-grade protein meal and fat. As discussed previously, the grade of the rendered products depends on the types of raw materials included and excluded. Since the 1960s continuous rendering systems have been installed to replace batch systems at most plants. Only a few batch cooker plants remain in operation in North America (Lehmann, 2001).

4.6.2.2.1 Batch Rendering Process

Figure 4-9 shows the basic inedible rendering process using multiple batch cookers. In the batch process, the raw material from the receiving bin is screw conveyed to a crusher, where it is reduced to 2.5 to 5 centimeters (1 to 2 inches) in size to improve cooking efficiency. Cooking normally requires 1.5 to 2.5 hours, but adjustments in the cooking time and temperature might be required to process the various materials. A typical batch cooker is a horizontal, cylindrical vessel equipped with a steam jacket and an agitator. To initiate the cooking process, the cooker is charged with raw material and the material is heated to a final temperature ranging from 121 to 135 °C (250 to 275 °F). Following the cooking cycle, the contents are discharged to the percolator drain pan. Vapor emissions from the cooker pass through a condenser, which condenses the water vapor and emits the noncondensibles as volatile organic compound (VOC) emissions (USEPA, 1995).

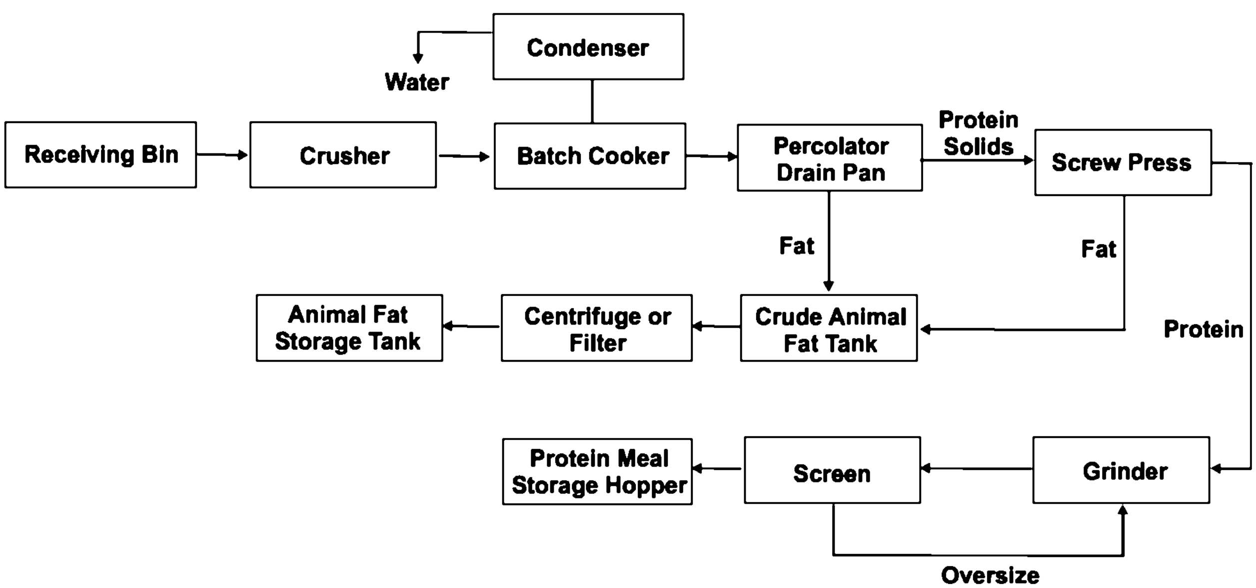

Figure 4-9. General process for inedible rendering by batch cooking (USEPA, 1995).

The percolator drain pan contains a screen that separates the liquid fat from the protein solids. From the percolator drain pan, the protein solids, which still contain about 25 percent fat, are conveyed to a screw press. The screw press completes the separation of fat from solids and yields protein solids that have a residual fat content of about 10 percent. These solids, called cracklings, are then ground and screened to produce protein meal. The fat from both the screw press and the percolator drain pan is pumped to the crude animal fat tank, centrifuged or filtered to remove any remaining protein solids, and stored in the animal fat storage tank (USEPA, 1995).

4.6.2.2.2 Continuous Rendering Process

A typical continuous rendering process is shown in Figure 4-10. The system is similar to a batch system, except that a single, continuous cooker is used rather than several parallel batch cookers. The typical continuous cooker is a horizontal, steam-jacketed cylindrical vessel equipped with a mechanism that continuously moves the material horizontally through the cooker. Continuous cookers process the material faster than batch cookers and typically produce a higher quality fat product. From the cooker, the material is discharged to the drainer, which serves the same function as the percolator drain pan in the batch process. The remaining operations are generally the same as the batch process operations (USEPA, 1995). In the 1980s newer continuous rendering systems were developed to precook the raw material and to remove moisture from the liquid fat prior to the cooker/dryer stage. These systems use an evaporator operated under vacuum and heated by the vapors from the cooker/dryer. One system, termed waste-heat dewatering (WHD), consists of treating the raw material in a preheater followed by a

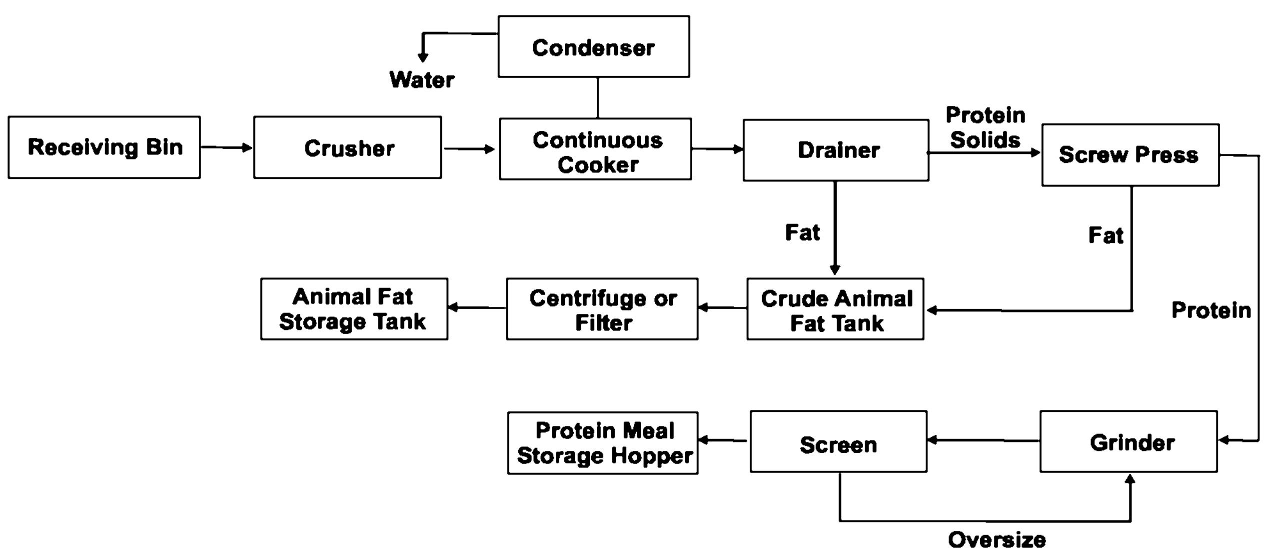

Figure 4-10. General process for inedible continuous rendering (USEPA, 1995).

twin-screw press. The solids from the press are directed to the cooker/dryer. The liquid fat is sent to an evaporator operated under a vacuum and heated by the hot vapors from the cooker/drier to a temperature of 70 to 90 °C (160 to 200 °F). In the evaporator, the moisture evaporates from the liquid fat and passes to a water-cooled condenser. The dewatered fat is recombined with the solids from the screw press prior to entry into the cooker/dryer. These pretreatment systems can reduce fuel costs by 30 to 40 percent and increase production throughput by up to 75 percent (USEPA, 1995). Several inedible continuous rendering systems are available, including the Duke system, the Anderson C-G (Carver-Greenfield) system, and the Atlas Stord WHD system.

Duke Continuous Rendering System (Inedible Rendering)

The process of the Duke system is similar to that of the batch cooker described earlier. The main difference is that the Duke system operates continuously. The cooker portion of the system, called the Equacooker, is a horizontal, steam-jacketed, cylindrical vessel equipped with a rotating shaft. Paddles, which are attached to the rotating shaft, lift the material and move it horizontally through the cooker. The rotating shaft also has steam-heated coils to provide increased heat transfer. The Equacooker is divided into three separate compartments equipped with baffles to restrict and control the flow of materials through the cooker. Adjusting the speed of the variable-speed drive for the twin-screw feeder controls the feed rate to the Equacooker, while the discharge rate is controlled by the control wheel rotation speed. The control wheel has buckets that collect the cooked material from the Equacooker and discharge it into the drainor. A site glass column adjacent to the control wheel shows the operating level in the cooker; a photoelectric cell unit shuts off the twin-screw feeder when the upper level limit is reached. The Drainor is an enclosed screw conveyor that contains a section of perforated troughs, which allow the free melted fat to drain through as the solids are conveyed to the Pressor or screw press for additional separation of tallow. Like any other screw press used with a batch cooker, the Pressor reduces the grease level of the crackling (Prokop, 1985).

The central control panel, which consolidates the process controls for the system, houses a temperature recorder, stream pressure indicators, equipment speed settings, motor load gauges, and stop and start buttons. This design facilitates operation of the controls so that only one person is needed to operate the Equacooker portion of the Duke system (Prokop, 1985).

Anderson C-G (Carver-Greenfield) System (Inedible Rendering)

The Anderson C-G system differs from most other systems in several respects. Instead of using screw conveyors, recycled fat carries the raw material as a pumpable slurry. An additional grinding step is included to further reduce the size of the particles. In addition, the conventional evaporator system with a vacuum is powered by an electrical motor, rather than by steam injectors, to remove moisture from the slurry (Prokop, 1985).

The process begins with a triple-screw feeder that feeds the partially ground raw material continuously, and at a controlled rate, to a fluidizing tank. In the tank, fat that has been recycled through the system at a temperature of 104 °C (22 °F) suspends the material and carries it to a disintegrator to further reduce the particle size. The final particle size ranges from 0.25 to 1 inch. The slurry is next pumped to an evaporator, which can be a single- or double-stage unit, and is held under a vacuum. Because the vacuum facilitates moisture removal, the C-G system can operate at a lower temperature than other processes. The evaporator consists of a vertical shell and tube heat exchanger connected to a vacuum system. Gravity aids the flow of the slurry through the tubes of the heat exchanger while steam is injected into the shell. Next, the water vapor is separated from the slurry in the vapor chamber, which is under a vacuum pressure of 660 to 710 millimeters (26 to 28 inches) of mercury. Water vapor then travels through a shell and tube condenser that is connected to a steam-injection vacuum system.

Once the vapors are condensed, they exit the condenser through a barometric leg, allowing the vacuum to be maintained.

In a two-stage evaporator system, the vapor from the second stage functions as a heating medium for the first stage. Providing steam economy, the two-stage evaporator is especially useful for materials that have a high moisture content. The remaining dry slurry of fat and cracklings is then pumped from the evaporator to a centrifuge that separates the solids from the liquid. A portion of the fat is recycled back to the fluidizing tank, while the remainder is removed from the system. Discharged solids from the centrifuge are screw-conveyed to expellers (screw presses), which reduce the fat content of solids from 26 percent by weight to 6 to 10 percent (Prokop, 1985).

As in the Duke process, the central control panel allows a single person to operate the cooking process. The panel includes level indicators and controls to stabilize the flow through the fluidizing and other process tanks in addition to the vacuum chamber. It also monitors evaporator vacuum and temperature measurements. The panel also has equipment speed settings, motor current readings, and start/stop push buttons (Prokop, 1985).

Atlas Stord WHD System/(Inedible Rendering)

The Atlas Stord system, formerly called the Stord Bartz WHD system, consists of a preheater, twin-screw press, and evaporator system. It is typically installed with an existing rendering system. As with other processes, the raw material is screw-conveyed from the raw material bin over an electromagnet and is fed to either a prebreaker or hogor for coarse grinding. The ground material travels through a preheater to melt the fat and condition the animal fibrous tissue properly for the subsequent pressing operation. The preheater is a horizontal, steam-jacketed, cylindrical vessel that has an agitator and rotating shaft to ensure continuous flow and adequate heat transfer. The temperature of the material is controlled within the preheater at 60 to 82 °C (140 to 180 °F), depending on the type of raw material.

After it is heated, the material is then subjected to the twin-screw press, where it is separated into a solid phase and a liquid phase. The press consists of intermeshing, counter-rotating screws that move inside a press cage assembly. A perforated screen, through which the liquid is pressed, is secured by vertical support plates. The shape of the screen follows the contour of the rotating flights of the twin screws. The material fills the space between the screws and the press cage. The twin screws have a lower-diameter shaft and deeper flights at the feed end, providing a larger volume of space. As the screws rotate, the volume of space decreases, creating an increased pressure on the material to squeeze the liquid out through the perforated screen.

After the liquid, consisting of melted fat and water, is squeezed out, a presscake of solids of fat and moisture remains. The solids are screw-conveyed to the existing cooker or dryer, where the moisture is removed. The screw press completes the final separation of fats from solids. The liquid extracted by the screw press is pumped from the feed tank to the evaporator, which is a tubular heat exchanger that is mounted vertically and is integral with the vapor chamber. Vapors from the existing cooker or dryer serve as the heating medium for evaporation. The liquid enters the evaporator at the top and flows by gravity downward through the tubes, then discharges into the vapor chamber maintained under a vacuum of 24 to 26 inches of mercury. A shell and tube condenser with circulating cooling water condenses the vapor. Because the system makes use of vapors from the existing cooker, fuel costs are reduced by 30 to 40 percent (Prokop, 1985).

4.5.3 Blood Processing and Drying

Blood processing and drying is an auxiliary process in meat rendering operations. Currently, less than 10 percent of the independent rendering plants in the United States process whole animal blood. Whole blood from animal slaughterhouses, containing 16 to 18 percent total protein solids, is processed and dried to recover protein as blood meal. The blood meal is a valuable ingredient in animal feed because it has a high lysine content. Continuous cookers have replaced the batch cookers originally used in the industry because of the improved energy efficiency and product quality provided by continuous cookers. In the continuous process, whole blood is introduced into a steam-injected, inclined tubular vessel in which the blood solids coagulate. The coagulated blood solids and liquid (serum water) are then separated in a centrifuge, and the blood solids are dried in either a continuous, gas-fired, direct-contact ring dryer or a steam tube, rotary dryer (USEPA, 1995). Blood from poultry processing is usually processed with feathers to increase the available protein content of feather meal.

4.5.4 Poultry Feather and Hog Hair Processing

The raw material is introduced into a batch cooker and is processed for 30 to 45 minutes at temperatures ranging from 138 to 149 °C (280 to 300 °F) and pressures ranging from 40 to 50 pounds per square inch. This process converts keratin, the principal component of feathers and hog hair, into amino acids. The moist meal product, containing the amino acids, is passed either through a hot air, ring-type dryer or over steam-heated tubes to remove the moisture from the meal. If a hot air dryer is used, the dried product is separated from the exhaust by cyclone collectors. In the steam-heated tube system, fresh air is passed countercurrent to the flow of the meal to remove the moisture. The dried meal is then transferred to storage. The exhaust gases are passed through controls prior to discharge to the atmosphere (USEPA, 1995).

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SECTION 5

SUBCATEGORIZATION

This section presents the subcategorization for the final rule for the meat and poultry products (MPP) effluent limitations guidelines (ELGs). Section 5.1 introduces EPA's subcategorization criteria. Section 5.2 describes each subcategory in detail and discusses the differences between the existing subcategorization and the subcategorization for the final rule. The final subcategorization is the same as that proposed in the February 25, 2002, revisions to 40 CFR Part 432 (67 FR 8582), with some refinement to the size definitions in one of the subcategories.

5.1 SUBCATEGORIZATION PROCESS

Section 304(b)(2)(B) of the Clean Water Act (CWA) (33 U.S.C. 1314(b)(2)(B)) requires EPA to consider a number of different factors when developing ELGs. For example, when developing limitations that represent the best available technology economically achievable (BAT) for a particular industry category, EPA must consider, among other factors,

- Age of the equipment and facilities
- Location
- Manufacturing processes employed
- Types of treatment technologies to reduce effluent discharges
- Cost of effluent reductions, and
- Non-water quality environmental impacts.

The statute also authorizes EPA to take into account other factors that the Administrator deems appropriate. In addition, it requires the BAT model technology EPA chooses to be economically achievable, which usually involves considering both compliance costs and the overall financial condition of the industry.

EPA took these factors into account in considering whether different ELGs were appropriate for subcategories within the MPP industry. For this industry, EPA broke the industry down into subcategories with similar characteristics. This breakdown recognized the major differences among companies within the industry, which might reflect, for example, different processes or economies of scale. Subdividing an industry into subcategories results in more tailored regulatory standards, thereby increasing regulatory predictability and diminishing the need to address variations among facilities through a variance process. See *Weyerhaeuser Co.* v. *Costle*, 590 F. 2d 1011, 1053 (D.C. Cir. 1978).

For the final MPP rule, EPA used industry survey data, EPA sampling data, and other data collected by or provided to EPA subsequent to the proposal for the subcategorization analysis. EPA analyzed various subcategorization criteria for trends in discharge flow rates, pollutant concentrations, and treatability to determine where subcategorization was warranted. Equipment and facility age and facility location were not found to affect wastewater generation or wastewater characteristics; therefore, age and location were not used as a basis for subcategorization. An analysis of non-water quality environmental characteristics (e.g., solid waste and air emission effects) also showed that these characteristics did not constitute a basis for subcategorization. See Section 12 of this document for more information on non-water quality environmental impacts.

Even though the size (e.g., acreage, number of employees, production rates) of a facility does not influence wastewater flow rates or pollutant loadings, size was used as a basis for subcategorization because more stringent limitations would not be cost-effective for small meat, poultry, and rendering facilities. In addition, small facilities discharge a very small portion of the total industry discharge. Therefore, this final rule does not revise the limitations and standards for existing and new small facilities in Subcategories A through J, and does not establish effluent limitations for existing small facilities in Subcategories K and L. However, the final rule establishes less stringent requirements for new small facilities in Subcategories K and L. See Section 2 of this document for definition of "small" and "non-small" facilities for each subcategory. Additional discussion related the why EPA established new source performance standards for small poultry facilities is provided in Section 13.2 of this document and in the *Economic and Environmental Benefits Analysis of the Final Meat and Poultry Products Rule* (EPA-821-R-04-010).

Data collected for the final rule indicate that slaughtering operations use substantial amounts of water for initial processing (kill through carcass shipping or cut-up). Slaughtering or first processing operations typically involve taking the live animal and producing whole or cut-up meat carcasses (which then might be further processed). Wastewaters from first processing operations are generated from a variety of sources that generally include the areas where animals are killed and bled; hides, hair, or feathers are removed; animals are eviscerated; carcasses are washed and chilled; and carcasses are trimmed and cut to produce whole carcasses or carcass parts. As a result of these operations, wastewaters that contain varying levels of blood, animal parts, viscera, fats, bones, and the like are generated. In addition, federal food safety concerns require frequent and extensive cleanup of slaughtering operations, which also contributes to wastewater generation. These cleanup wastewaters contain not only slaughtering residues and particulate matter but also products used for cleaning and disinfection (detergents and sanitizing agents).

Alternatively, most further processing operations generate wastewaters from sources different from slaughtering operations. These sources, and the resulting wastewater characteristics, are dependent on the type of finished product desired. Further processing refers to operations that use whole carcasses or cut-up meat or poultry products to produce fresh or frozen products, and it can include the following types of processing: cutting and deboning, cooking, seasoning, smoking, canning, grinding, chopping, dicing, forming, breading, breaking, trimming, skinning, tenderizing, marinating, curing, pickling, extruding, and linking. Unlike slaughtering operations, most further processing operations do not use significant amounts of water, except for cleanup. Wastewaters generated from further processing operations contain some soft and hard tissue (e.g., muscle, fat, and bone), blood, and other substances used in final product preparation (e.g., breading, spices), as well as products used for cleaning and disinfection (detergents and sanitizing agents).

Rendering operations primarily process slaughtering by-products (e.g., animal fat, bone, blood, hair, feathers, dead animals). The amount of water used and the characteristics of the wastewater generated by rendering operations are highly dependent on a number of factors, including the type of product produced (e.g., edible versus inedible), the rendering process used (batch versus continuous, wet process versus dry process), and the source and type of raw materials used (e.g., poultry processors, slaughterhouses, butcher shops, supermarkets, restaurants, fast-food chains, farms, ranches, feedlots, animal shelters). In general, rendering operations involve cooking the raw materials to recover fats, oil, and grease; remaining residue is dried and then granulated or ground into a meal using a continuous dry rendering process. A significant portion of wastewater pollutant loadings generated from rendering operations is condensed steam from cooking operations. Unlike slaughtering and further processing operations, rendering cleanup operations are usually less rigorous, generating a smaller proportion of the total expected wastewater flow.

5.2 SUBCATEGORIES FOR THE FINAL RULE

EPA is establishing new or revised ELGs and standards for 9 of the 10 existing subcategories in the MPP point source category (40 CFR Part 432). The Agency is establishing no new or revised EIGs or pretreatment standards for the small processor category. Specifically, EPA is establishing new limitations and standards that are the same for large facilities in the following MPP subcategories: Simple Slaughterhouses (Subpart A), Complex Slaughterhouses (Subpart B), Low-Processing Packinghouses (Subpart C), and High-Processing Packinghouses (Subpart D). In addition, EPA is establishing new limitations and standards that are the same for facilities in the following MPP subcategories: Meat Cutters (Subpart F), Sausage and Luncheon Meats Processors (Subpart G), Ham Processors (Subpart H), and Canned Meats Processors (Subpart I).

EPA is also retaining the Renderer (Subpart J) subcategory and new limitations and standards for facilities in this subcategory. This rule does not revise the existing limitations and standards for small facilities in Subparts A through J (which would include by definition all Subpart E [Small Processor] facilities). Finally, EPA is adding two MPP subcategories in 40 CFR Part 432: Poultry First Processing (Subpart K) and Poultry Further Processing (Subpart L). These two new subcategories will cover both small and large poultry processing facilities, although new source small facilities in each of the subcategories are required to meet less stringent requirements than the non-small poultry facilities. EPA chose less stringent performance standards for new small poultry processing facilities because more stringent limits would not be cost-effective.

EPA believes that the similarities among Simple Slaughterhouses, Complex Slaughterhouses, Low-Processing Packinghouses, and High-Processing Packinghouses (Subcategories A through D), including the commonality of slaughter of live animals, represents a rational basis for establishing new limitations and standards that are the same for all four subcategories. This approach allows the use of the same effluent limitations for all four subcategories, with possible additional allowances reflecting the degree of further processing and rendering. Data collected by EPA for the final rule indicate limited variability in wastewater characteristics among first processing facilities.

For the final rule, EPA established the same limitations and standards applicable to all meat further processing subcategories (meat cutters, sausage and luncheon meat processors, ham processors, and canned meat processors). The decision to group meat further processors for purposes of establishing the same effluent limitations is also based on the expected similarities among these four subcategories. For the final rule, there was very limited data available to EPA for meat further processing facilities to enable a quantitative analysis of the potential differences in production processes or wastewater characteristics among the subcategories. However, based on the limited data, EPA expects similarities among facilities in Subcategories F through I in the absence of slaughtering and on-site rendering activities.

The rationale that EPA used for establishing two new subcategories for poultry, first processing and further processing, with separate limitations and standards, is in part the same as that used for grouping Subcategories A through D and F through I for meat. Included were the presence (Subcategory K) or absence (Subcategory L) of slaughtering. However, based on analysis of data collected for the final rule, EPA also identified differences in between poultry and meat processing facilities, resulting in the decision to establish subcategories separate from red meat. These differences include, for example, reduced water use for poultry processing facilities, as compared to meat processing facilities. Immediately following, each subcategory is described in more detail in terms of its manufacturing processes and wastewater characteristics.

5.2.1 Meat Slaughterhouses and Packinghouses—Subparts A, B, C, and D

EPA is retaining the existing subcategories. EPA believes that retaining the existing subcategorization scheme will simplify implementation for the permit writers, as well as generate appropriate limitations and standards for the facilities.

In addition to the existing mass-based limitations, which are different for each of the subcategories, the final regulation requires all meat direct dischargers subject to Subparts A through D that slaughter more than 50 million pounds live weight kill (LWK) per year to achieve the same concentration-based effluent limitations for the additional parameters being regulated. EPA finds that the slaughtering and initial processing operations used in all four of these subcategories are the key factors in determining wastewater characteristics and treatability. Moreover, EPA believes there are no significant differences between these four subcategories in terms of the age, location, and size of the facilities.

5.2.2 Meat Further Processing—Subparts F, G, H and I

EPA is retaining the existing subcategories. EPA believes that retaining the existing subcategorization scheme will simplify implementation for the permit writers, as well as generate appropriate limitations and standards for the facilities.

The final regulations requires all facilities that generate greater than 50 million pounds per year of finished meat products without performing slaughtering to be regulated by the same concentration-based ELGs for the additional parameters being regulated. Subpart E (Small Processor) facilities are excluded from these new requirements by definition. The existing ELGs allow discharges based on the amount of finished product that is further processed on-site. The expected wastewater characteristics and treatability for the four subcategories are sufficiently similar to group them together for the purpose of revising or setting new limitations and standards (See DCN 300000). Moreover, EPA believes there are no significant differences between these four subcategories in terms of the age, location, and size of the facilities. EPA believes that this subcategorization scheme will simplify implementation for the permit writers, as well as generate appropriate limitations and standards for the facilities.

5.2.3 Renderer—Subpart J

Subpart J applies to independent rendering facilities, which are facilities that only render raw materials and process hides and do no first or further processing. The final subcategorization scheme requires all independent rendering facilities that render more than 10 million pounds per year of raw material to be regulated by the same concentration-based ELGs. This scheme is a change from the current guidelines, which apply only to independent renderers that render more than approximately 27.4 million pounds raw material per year (or 75,000 pounds raw material per day for a facility that operates 365 days per year). The existing limitations and standards allow discharges based on the amount of raw material rendered on-site.

5.2.4 Poultry First Processing—Subpart K

EPA has divided the poultry first processors into two segments, small and non-small. Small poultry first processors slaughter 100 million pounds of poultry per year or less (measured as live weight killed); non-small poultry first processors slaughter more than 100 million pounds of poultry per year. In the February 25, 2002, *Federal Register* notice, EPA proposed that the cutoff between small and non-small processors be 10 million pounds. Based on comments received in response to the proposed rule and on further analysis, EPA decided to raise the production threshold.

EPA is not establishing limitations for existing small facilities because the cost of compliance with limitations for any of the analyzed technology options in relation to the effluent reduction benefits is wholly disproportionate, even though the technologies are available and applicable to this type of wastewater. See Section 9 of this document for a discussion of the technology options, and see Section 13 of this document for more details on how EPA developed the two segments and the specific requirements for each.

5.2.5 Poultry Further Processing—Subpart L

EPA has divided the poultry further processors into two segments, small and non-small. Small poultry further processors generate 7 million pounds of finished product per year or less; non-small poultry further processors generate more than 7 million pounds of finished product per year. See Section 9 of this document for a discussion of the technology options, and see

Section 13 of this document for more details on how EPA developed the two segments and specific requirements for each segment. The ELGs allow discharges to be regulated by the same concentration-based ELGs.

5.3 REFERENCES

USEPA (U.S. Environmental Protection Agency). 1974. *Development Document for Effluent Limitations Guidelines and New Source Performance Standards—Red Meat Processing Segments of the Meat Products Point Source Category*. EPA-440/1-74-012a. U.S. Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Division, Washington, DC. (DCN 00162)

USEPA (U.S. Environmental Protection Agency). 1975. *Development Document for Proposed Effluent Limitation Guidelines and New Source Performance Standards for the Poultry Processing Point Source Category*. EPA-440/1-75-031b. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Effluent Guidelines Division, Washington, DC. (DCN 00140)

SECTION 6

WASTEWATER CHARACTERIZATION

In this section, the sources and general composition of the wastewaters generated by the meat and poultry products (MPP) industry are described. In addition, data collected by the EPA in a series of sampling episodes at selected meat and poultry processing facilities to quantify rates of wastewater generation and characterize composition before treatment are presented along with comparable data from other sources. The series of sampling episodes was part of the EPA data collection effort for final rule development. An overview of the data collection for the final rule development is presented in Section 3 of this document. Wastewaters generated during meat processing, poultry processing, and rendering are discussed in Sections 6.1 through 6.4.

6.1 MEAT PROCESSING WASTES

6.1.1 Volume of Wastewater Generated

In meat processing, water is used primarily for carcass washing after hide removal from cattle, calves, and sheep or hair removal from hogs and again after evisceration, for cleaning, and sanitizing of equipment and facilities, and for cooling of mechanical equipment such as compressors and pumps. A large quantity of water is used for scalding of hogs for hair removal before evisceration. Since most meat-processing facilities operate only five days per week with one killing and processing shift and followed by cleaning operations, the rate of water use and wastewater generation varies with both time of day and day of the week. In order to comply with Federal requirements for complete cleaning and sanitation of equipment after each killing and processing shift, a regular processing shift, usually of 8- or 10-hour duration, is followed by a 6- to 8-hour cleanup shift every day. During killing and processing, water use and wastewater generation are relatively constant and low compared to the cleanup period that follows. Water use and wastewater generation essentially cease after the cleanup period until processing begins the next day. In addition, there is little water use or wastewater generation on non-processing days, which usually are Saturdays and Sundays. Thus, meat processing wastewater flow rates can be highly variable, especially on an hourly basis.

A number of studies also have shown that the volume of water used and wastewater generated on a per unit of production basis, such as live weight killed (LWK) or finished product produced also can vary substantially among processing plants. Some of this variation is a reflection of different levels of effort among plants to minimize water use to reduce the cost of wastewater treatment. For example, Johns (1995) reported water use ranging from 312 to 601 gallons per 1,000 pounds (lb) live weight for processing of beef cattle. In an earlier EPA analysis of data from 24 simple slaughterhouses (operations producing fresh meat ranging from whole carcasses to smaller cuts of meat with two or fewer by-product recovery activities, such as rendering and hide processing), wastewater flows ranged from 160 to 1,755 gallons per 1,000 lb LWK with a mean value of 639 gallons per 1,000 lb LWK (USEPA, 1974). About one-half of these operations slaughtered beef cattle; with the remainder evenly divided between hogs and mixed kill. Two of the 24 simple slaughterhouses handled less 95,000 lb LWK per day and the remainder handled between 95,000 and 758,000 lb LWK per day. For 19 medium and large complex slaughterhouses (operations with three or more byproduct recovery activities), wastewater flows ranged from 435 to 1,500 gallons per 1,000 lb LWK with a mean value of 885 gallons per 1,000 lb LWK.

Table 6-1 presents the ranges of rates of wastewater flow on a 1,000 lb of LWK basis at three hog and three cattle processing facilities sampled by the EPA. Two of the hog processing facilities are first processing facilities with on-site rendering while activities at the third facility include further processing in addition to first processing and rendering. While all three of the cattle processing facilities are first processing facilities with on-site rendering, two also process hides on-site. As the values listed in Table 6-1 indicate, there is a considerable degree of variation among both hog and cattle processing facilities. Table 6-2 presents median rates of wastewater flow per unit of production derived from MPP detailed survey responses.

Table 6-1. Rates of Wastewater Generated at Three Hog and Three Cattle Processing Facilities (gallons/1,000 lbs LWK)[a]

Meat Type	First Processing	Further Processing	Rendering	Total
Hogs	123-309	118	50-133	291-442
Cattle (first processing and rendering)	390	NA[b]	142	532
Cattle (first processing, rendering and hide processing)	241-302	NA	63-84	304-386

[a] Data generated during the EPA sampling of MPP facilities
[b] NA not applicable

Table 6-2. Wastewater Volumes Produced by Meat Facilities per Unit of Production [a]

	Process Wastewater Generated (gallons per 1,000 lbs of production unit)	
	First Processing[b]	Further Processing[c]
Non-small facilities	352	135

[a] Median values derived from the 58 MPP detailed survey responses (as describe in Section 3.2.6).
[b] Production unit for first processing operations is 1,000 lb of live weight killed (LWK). These numbers include facilities that may also generate wastewater from cutting operations.
[c] Production unit for further processing operations is 1,000 lb of finished product.

6.1.2 Description of Waste Constituents and Concentrations

The principal sources of wastes in meat processing are from live animal holding, killing, hide or hair removal, eviscerating, carcass washing, trimming, and cleanup operations. When present, further processing, rendering, and hide processing operations[1] also are significant sources of wastes. Meat processing wastes include blood not collected, viscera, soft tissue removed during trimming and cutting, bone, urine and feces, soil from hides and hooves, and various cleaning and sanitizing compounds. Further processing, rendering, and hide processing produce additional sources of fat and other soft tissues, as well as substances including brines, cooking oils, and tanning solutions. Wastewater characteristics of rendering operations are discussed in Section 6.3.

[1]Note that although not part of meat processing operations, hide processing wastewaters are often commingled with meat processing wastewaters prior to treatment. The existing regulations at 40 CFR Part 432, as well as the new regulations, address wastewaters from hide processing operations when discharged with meat processing wastewaters.

The principal constituents of meat processing wastewaters are a variety of readily biodegradable organic compounds, primarily fats and proteins, present in both particulate and dissolved forms. Screening of meat processing wastewaters is usually performed in most facilities to reduce concentrations of particulate matter before effecting pre-treatment.

Meat processing wastewaters remain high strength wastes, even after screening, in comparison to domestic wastewaters, based on concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrogen, and phosphorus.

Blood not collected, solubilized fat, urine, and feces are the primary sources of BOD in meat processing wastewaters. For example, blood from beef cattle has a reported BOD of 156,500 mg/L with an average of 32.5 pounds of blood produced per 1,000 pounds LWK (Beefland International, Inc., 1971). Thus, the efficacy of blood collection is a significant factor in determining the amount of BOD in meat processing wastewater.

Another significant factor in determining the BOD of meat processing wastewaters is the manner in which manure (urine and feces) is handled at the facility. Generally, manure is separated from the main waste stream and treated as a solid waste. Beef cattle manure has a BOD of approximately 27,000 mg/kg on an as excreted basis, and the BOD of swine manure is approximately 37,000 mg/kg of manure (American Society of Agricultural Engineers, 1999).

The efficiency of fat separation and removal from the waste stream is an important factor in determining the BOD concentration in meat processing wastewaters. Fat removed from wastewater can be handled as a solid waste or by-product. The high BOD of animal fats is directly attributable to their rapid biodegradability and high-energy yield for microbial cell maintenance and growth, especially under aerobic conditions. The significance of fat as a component of BOD in meat processing wastewaters generally is determined indirectly as the concentration of oil and grease (Standard Methods APHA 1995). In the determination of oil and grease, the concentration of a specific substance is not determined. Instead, groups of compounds with similar physical characteristics are determined quantitatively based on their common solubility in an organic extracting solvent. Over time, petroleum ether has been replaced by trichlorotrifluoroethane (Freon) and most recently by n-hexane as the preferred extracting solvent. Thus, oil and grease concentrations in meat processing wastewaters may be reported as Freon or n-hexane extractable material (HEM).

Blood and manure are also are significant sources of nitrogen in meat processing wastewaters. The principal form of nitrogen in these wastewaters before treatment is organic nitrogen with some ammonia nitrogen. During collection of wastewater samples, some ammonia nitrogen is produced by the microbially mediated mineralization of organic nitrogen. Nitrite and nitrate nitrogen generally are present only in trace concentrations (less than 1 mg/L) in meat processing wastewaters; however, these nitrate and nitrite concentrations are increased when nitrites are used in processes such as the curing of bacon and ham. The phosphorus in meat processing wastewaters is primarily from blood, manure, and cleaning and sanitizing compounds, which can contain trisodium phosphate (sodium phosphate, tribasic).

Due to the presence of manure in meat processing wastewaters, densities of total coliform, fecal coliform, and fecal streptococcus groups of bacteria generally are on the order of several million colony forming units (cfu) per 100 mL. Although members of these groups of microorganisms generally are not pathogenic, they do indicate the possible presence of pathogens of enteric origin such as *Salmonella ssp.* and *Campylobacter jejuni*. They also indicate the possible presence of gastrointestinal parasites including *Ascaris sp.*, *Giardia lamblia*, and *Cryptosporidium parvum* and enteric viruses.

Meat processing wastewaters also contain a variety of mineral elements, some of which are present in the water that is used for processing meat. In addition, water supply systems and mechanical equipment may be significant sources of metals, including copper, chromium, molybdenum, nickel, titanium, and vanadium. Manure, especially hog manure, may be significant sources of copper, arsenic, and zinc, because these constituents are commonly added to hog feed. Although pesticides such as dichcorvos, malathion, and carbaryl are commonly used in the production of meat animals to control external parasites, label-specified withdrawal periods before slaughter typically should limit concentrations to non-detectable or trace levels. Failure to observe specified withdrawal periods is an unlawful act (*7 U.S.C 136 Et. Seq*).

Table 6-3 summarizes the results of the analyses of samples of wastewater before treatment collected during sampling episodes at two hog and three cattle processing facilities. Table 6-4 presents calculated estimates of selected pollutants generated per 1,000 lb of LWK. The values listed in these two tables suggest that variation among individual facilities is not limited to the volume generated per unit of production. Average effluent concentrations for all pollutants of concern evaluated by the EPA for potential regulation are provided in Section 11.

Table 6-3. Characteristics of Wastewater Generated at Two Hog and Three Cattle Processing Facilities[a]

Parameter	Hog		Cattle	
	First Processing and Rendering	First Processing, Further Processing, and Rendering	First Processing and Rendering	First Processing, Rendering, and Hide Processing
Flow (MGD[b])	3.30	0.59	1.76	0.74-2.18
Live weight killed (1,000 lb/day)	7,449	2,012	3,942	2,443-5,645
BOD_5 (mg/L)	5,264	3,960	7,237	3,673-6,404
Total suspended solids (mg/L)	2,848	2,584	1,153	1,510-3,332
Hexane Extractables (mg/L)	158	464	146	619-3021
Total Kjeldahl nitrogen (mg/L)	330	59	306	67-78
Total phosphorus (mg/L)	104	58	35	30-58
Fecal coliform bacteria (CFU[c]/100 mL)	$2.6x10^5$	$1.6x10^6$	$7.3x10^5$	$1.2x10^6$-$1.6x10^6$

[a] Data generated during EPA sampling of MPP facilities.
[b] MGD Million gallons per day.
[c] CFU Colony forming units.

Table 6-4. Estimates of Pollutants Generated per Unit of Production at Two Hog and Three Cattle Processing Facilities[a]

Parameter	Hog		Cattle	
	First Processing and Rendering	First Processing, Further Processing, and Rendering	First Processing and Rendering	First Processing, Rendering, and Hide Processing
BOD_5 (lb/1,000 lb LWK[b])	17.8	8.9	26.3	8.6-18.9
Total suspended solids (lb/1,000 lb LWK)	9.6	5.8	4.2	3.5-9.9
Hexane extractables (lb/1,000 lb LWK)	0.54	1.04	0.53	1.44-8.94
Total Kjeldahl nitrogen (lb/1,000 lb LWK)	1.12	0.13	1.11	0.16-0.23
Total phosphorus (lb/1,000 lb LWK)	0.35	0.13	0.13	0.09-0.23
Fecal coliform bacteria (CFU[c]/1,000 lb LWK)	$4.3x10^9$	$1.8x10^{10}$	$1.3x10^{10}$	$1.4x10^{10}$-$2.3x10^{10}$

[a] Data generated during EPA sampling of MPP facilities.
[b] LWK Live weight killed.
[c] CFU Colony forming units.

6.2 POULTRY PROCESSING WASTES

6.2.1 Volume of Wastewater Generated

In poultry processing, water is used primarily for scalding in the process of feather removal, bird washing before and after evisceration, chilling, cleaning and sanitizing of equipment and facilities, and for cooling of mechanical equipment such as compressors and pumps. Although water also is typically used to remove feathers and viscera from production areas, overflow from scalding and chiller tanks is used.

A number of studies also have shown that the volume of water used and wastewater generated by poultry processing on a per unit of production basis (such as per bird killed) can vary substantially among processing plants. Again, some of this variation is a reflection of different levels of effort among plants to reduce their wastewater treatment costs by minimizing their water use. One study of 88 chicken processing plants found wastewater flows ranged from

4.2 to 23 gallon per bird with a mean value of 9.3 gallon per bird (USEPA, 1975). No standard deviation was reported; therefore, the distribution of individual values could not be determined. Using the reported mean live weight per bird of 3.83 pounds, 9.3 gallon per bird translates into 2,428 gallon per 1,000 lb LWK, which is significantly higher than the mean flow of 639 gallon per 1,000 lb LWK used for meat processing. For 34 turkey processing plants, the mean wastewater flow was 31.2 gallon per bird with individual plant values ranging from 9.6 to 71.4 gallon per bird. Again, no standard deviation was reported. Based on the reported mean live weight per bird of 18.2 pounds, the mean flow of 31.2 gallon per bird translates into 1,714 gallon per 1,000 lb LWK. Again, this value is substantially higher than that for meat processing, but also substantially lower than the value calculated for chickens. Two of the factors that contribute to the higher rate of wastewater generation for poultry processing are the 1) required continuous overflow from scalding tanks, and 2) use of carcass immersion in ice bath chillers with a required continuous overflow for removal of body heat after evisceration.

Table 6-5 presents the rates of wastewater generated per 1,000 lb of LWK at five broiler processing facilities sampled by the EPA. Two were first processing facilities, one was a first processing facility with on-site rendering, and two combined first processing, further processing, and rendering. As the values listed in Table 6.5 indicate, there also is a considerable degree of variation among individual poultry processing facilities. Table 6.6 presents median rates of wastewater flow per unit of production derived from MPP detailed survey responses.

Table 6-5. Rates of Wastewater Generation at Five Broiler Processing Facilities[a]

Processing Type	Gallons per 1,000 lb live weight killed
First processing	580-1,663
First processing and rendering	1,256
First processing, further processing, and rendering	1,272-2,440

[a] Data generated during EPA sampling of MPP facilities.

Table 6-6. Wastewater Volumes Produced by Poultry Facilities per Unit of Production[a]

	Process Wastewater Generated (gallons per 1,000 lbs of production unit)	
	First Processing[a]	Further Processing[b]
Non-small Facilities	1,323	301

[a] Median values derived from the 58 MPP detailed survey responses (as described in Section 3.2.6).
[b] Production unit for first processing operations is 1,000 lb of live weight killed (LWK). These numbers include facilities that may also generate wastewater from cutting operations.
[c] Production unit for further processing operations is 1,000 lb of finished product.
Data source: MPP detailed surveys

6.2.2 Description of Waste Constituents and Concentrations

The principal sources of wastes in poultry processing are live bird holding and receiving, killing, defeathering, eviscerating, carcass washing, chilling, cut-up, and cleanup operations. Further processing and rendering operations are also major sources of wastes. These wastes include blood not collected, feathers, viscera, soft tissue removed during trimming and cutting, bone, soil from feathers, and various cleaning and sanitizing compounds. Further processing and rendering can produce additional sources of animal fat and other soft tissue, in addition to other substances such as cooking oils.

Thus, the principal constituents of poultry processing wastewaters are a variety of readily biodegradable organic compounds, primarily fats and proteins, present in both particulate and dissolved forms. To reduce wastewater treatment requirements, poultry processing wastewaters are screened to reduce concentrations of particulate matter before treatment. An added benefit of screening is increased collection of materials and subsequent increased production of rendered by-products. Because feathers are not rendered with soft tissue, wastewater containing feathers is not commingled with other wastewater. Instead, wastewater containing feathers is screened separately and then combined with unscreened wastewater to recover soft tissue before treatment during the screening process of these mixed wastewaters.

However, poultry processing wastewaters remain high strength wastes even after screening in comparison to domestic wastewaters based on concentrations of BOD, COD, TSS, nitrogen, and phosphorus after screening. Blood not collected, solubilized fat, and feces are principal sources of BOD in poultry processing wastewaters. As with meat processing wastewaters, the efficacy of blood collection is a significant factor in determining the BOD concentration in poultry processing wastewaters.

Another significant factor in determining the BOD of poultry processing wastewaters is the degree to which manure (urine and feces), especially from receiving areas, is handled separately as a solid waste. Chicken and turkey manures have BOD concentrations in excess of 40,000 mg/kg on an as excreted basis (American Society of Agricultural Engineers, 1999). Although the cages and trucks used to transport broilers to processing plants usually are not washed, cages and trucks used to transport live turkeys to processing plants are washed to prevent transmission of disease from farm to farm. Thus, manure probably is a more significant source of wastewater BOD for turkey processing operations than for broiler processing operations.

Primarily because of immersion chilling, fat is a more significant source of BOD in poultry processing wastewaters than in meat processing wastewaters. Additional sources of BOD in poultry processing wastewaters are feather and skin oils desorbed during scalding for feather removal. Thus, the oil and grease content of poultry processing wastewaters typically is higher than that in meat processing wastewaters.

Blood not collected, as well as urine and feces, also are significant sources of nitrogen in poultry processing wastewaters. The principal form of nitrogen in these wastewaters before treatment is as organic nitrogen with some ammonia nitrogen produced by the microbially mediated mineralization of organic nitrogen during collection. Nitrite and nitrate nitrogen generally are present only in trace concentrations, less than 1 mg/L. The phosphorus in poultry processing wastewaters is primarily from blood, manure, and cleaning and sanitizing compounds such as trisodium phosphate (trisodium phosphate tribasic), and trisodium phosphate in detergents.

Due to the presence of manure in poultry processing wastewaters and commingling of processing and sanitary wastewaters after screening, and dissolved air flotation of the former, densities of the total and fecal coliform and fecal streptococcus groups of bacteria generally are on the order of several million colony-forming units per 100 milliliters (cfu/100 mL). As discussed earlier, members of these groups of microorganisms generally are not pathogenic. They do, however, indicate the possible presence of pathogens of enteric origin, such as *Salmonella sp.* and *Campylobacter jejuni*, gastrointestinal parasites, and pathogenic enteric viruses. *Giardia lamblia*, and *Cryptosporidium parvum* are not of concern in poultry processing wastewaters.

Poultry processing wastewaters also contain a variety of mineral elements, some of which are present in the potable water used for processing poultry. Water supply systems and mechanical equipment may be significant sources of metals including copper, chromium, molybdenum, nickel, titanium, and vanadium. In addition, manure is a significant source of arsenic and zinc. Although pesticides such as carbaryl, also are commonly used in the production of poultry to control external parasites, label-specified withdrawal periods before slaughter typically should limit concentrations to non-detectable or trace levels. Failure to observe specified withdrawal periods is an unlawful act (7 U.S.C. 136 et seq.).

Table 6-7 summarizes the results of the analyses of samples of wastewater before treatment collected during sampling episodes at the five broiler processing facilities described earlier. Table 6-8 presents calculated estimates of selected pollutants generated per 1,000 lb of LWK. The values listed in these two tables suggest that variation among individual broiler processing facilities also is not limited to the volume generated per unit of production. Average effluent concentrations for all pollutants of concern evaluated by the EPA for potential regulation are provided in Section 11.

Table 6-7. Characteristics of Wastewater Generated at Five Broiler Processing Facilities[a]

Parameter	First Processing	Further Processing and Rendering	First Processing, Further Processing, and Rendering
Flow (MGD[b])	0.60-1.10	1.29	1.24-1.97
Live weight kill (1,000 lb/day)	661-1,025	1,026	808-974
BOD_5 (mg/L)	948-1,856	1,680	1,488-2,166
Total suspended solids (mg/L)	714-776	1,040	510-1,526
Hexane extractables (mg/L)	487-1,501	430	243-685
Total Kjeldahl nitrogen (mg/L)	14-34	102	65-112
Total phosphorus (mg/L)	6-11	17	15-48
Fecal coliform bacteria (CFU[c]/100 mL)	$2.6x10^5$-$1.2x10^6$	$1.6x10^5$	$8.5x10^5$-$1.6x10^6$

[a] Data generated during EPA sampling of MPP facilities.
[b] MGD Million gallons per day.
[c] CFU colony forming units.

Table 6-8. Pollutant Generation per Unit of Production in Broiler Processing[a]

	Broiler		Turkey
	First Processing	Further Processing and Rendering	First Processing, Further Processing, and Rendering
Parameter	Average	Average[b]	Average
BOD_5 (lb/1,000 lb LWK[b])	8.4-12.11	16.2	14.5-40.5
Total suspended solids (lb/1,000 lb LWK)	3.5-9.1	10.0	9.5-15.2
Hexane Extractables (lb/1,000 lb LWK)	1.78-2.20	4.14	4.54-6.68
Total Kjeldahl nitrogen (lb/1,000 lb LWK)	0.15-0.18	0.98	1.09-1.22
Total phosphorus (lb/1,000 lb LWK)	0.05-0.08	0.16	0.28-0.47
Fecal coliform bacteria (CFU[c]/1,000 lb LWK)	$1.6x10^{10}$-$2.7x10^{10}$	$7.6x10^{10}$	$7.7x10^{10}$-$7.9x10^{10}$

[a] Data generated during EPA sampling of MPP facilities.
[b] LWK Live weight killed.
[c] CFU Colony forming units.

6.3 RENDERING WASTEWATER GENERATION AND CHARACTERISTICS

The slaughter of livestock and poultry produces a considerable amount of inedible viscera and other solid wastes, including feathers from poultry and hair from hogs. Inedible viscera and other soft tissue, fat, and bone, which are collected as solid wastes and removed from wastewater by screening, are converted by rendering into valuable byproducts such as meat meal and meat and bone meal. In the rendering process, these materials are cooked in their own moisture and fat in vented steam-jacketed vessels until the moisture has evaporated. Then, as much fat as possible is removed and the solid residue is passed through a screw press, dried, and granulated or ground into a meal for sale as a livestock or poultry or pet food ingredient. In some situations, dissolved air flotation (DAF) solids are disposed of by rendering, although DAF solids reduce the quality of rendered products, especially if metal salts are used for flocculation/coagulation prior to DAF.

Rendering operations also may include blood drying to produce blood meal for sale as a feed ingredient or fertilizer. They also may include the hydrolysis of hair or feathers for the production of livestock and poultry feed ingredients. Typically, blood from poultry processing operations is combined with feathers to increase the value of the resulting feather meal as a source of protein.

Rendering may be performed at the same site as other meat or poultry processing operations or at a separate location, usually by an independent entity. When rendering is performed in conjunction with other meat or poultry processing operations, wastes from locations without on-site rendering also may be processed.

6.3.1 Volume of Wastewater Generated

Rendering operations are intensive users of water and significant generators of wastewater. Water is used throughout the rendering process, including for raw material cooking and sterilization, condensing cooking vapors, plant cleanup, truck and barrel washing when materials from off-site locations are being processed, odor control, and steam generation (USEPA, 1975). Most of these activities also generate wastewater. According to the National Rendering Association (2000), rendering plants produce approximately one-half ton (120 gallons) of water for each ton of rendered material. Variations in wastewater flow per unit of raw material processed are largely attributable to the type of condensers used for condensing the cooking vapors and, to a lesser extent, to the initial moisture content of the raw material.

Based on a survey of National Rendering Association (NRA) members, an average size rendering plant generates about 215,000 gallons per day of process wastewater and an average of 34,000 gallons per day from other sources (National Rendering Association, 2000). The NRA estimates that the average plant discharges about 243,300 gallons per day or 169 gallons per minute.

The major sources of wastewater at rendering plants are produced from raw material receiving operations (especially when materials from off-site locations are being processed), condensing cooking vapors, drying, plant cleanup, and truck and barrel washing (USEPA, 1975). Condensates formed during raw material sterilization and drying are the largest contributors to the total wastewater in terms of volume and pollutant load (Metzner and Temper, 1990). At those rendering plants where hide curing is also performed as an ancillary operation, additional volumes of raw waste are generated, although those operations are not covered by this rule. Note, however, that hide processing wastewaters may be commingled with MPP wastewaters prior to treatment, and the commingled wastewater would be subject to this rule.

Condensates recovered from cooking and drying processes contain high concentrations of volatile organic acids, amines, mercaptans, and other odorous compounds. Thus, rendering plant condensers can be sources of significant emissions of noxious odors to the atmosphere if water scrubbing is not used for emissions control. There is little increase in final effluent volume when water scrubbing is used, because recycled final effluent is used for scrubber operation. Up to 75 percent of a plant's final effluent may be used (USEPA, 1975).

Liquid drainage from raw materials receiving areas can contribute significantly to the total raw waste load (USEPA, 1975). Large amounts of raw materials commonly accumulate in receiving areas (in bins or on floors). Fluids from these raw materials drain off and enter the internal plant sewers (USEPA, 1975). At rendering plants that process poultry, drainage of liquids can be significant because of the use of fluming to transport feathers and viscera in the processing plant. In such plants, liquid drainage may account for approximately 20 percent of the original raw material weight.

The other important source of wastewater from rendering operations is water used for cleaning equipment and facilities, the cleanup of spills, and trucks when materials are received from off-site locations for rendering. Cleanup of rendering equipment and facilities is less intensive than that in processing facilities and usually occurs only once per day, even though rendering usually is a 24-hour operation and commonly occurs on a seven day per week schedule. The wastewater generated during cleanup operations usually accounts for about 30 percent of total rendering plant wastewater flow (USEPA, 1975).

Approximately 30 percent of the total raw BOD waste load originates in the cooking and drying process (USEPA, 1975). Factors such as rate of cooking, speed of agitation, cooker overloading, foaming, and presence of traps can result in volume and composition differences among different rendering plants. Other important sources of process wastewater include plant and truck wash-down activities, and the cleanup of spills.

Table 6-9 presents the rates of wastewater flow per 1,000 lb of rendered product (RP) at one broiler, three hog, and three cattle processing facilities with on-site rendering sampled by EPA. The broiler, two of the hog, and all three of the cattle processing facilities were first processing facilities while the remaining hog processing facility combined first and further processing. Again, the degree of variation among facilities is noteworthy. Table 6-10 presents median rates of wastewater flow per unit of production derived from MPP detailed survey responses.

Table 6-9. Rates of Wastewater Generation at Broiler, Hog, and Cattle Processing Facilities with On-site Rendering[a]

Meat type	Gallons/1,000 lb of rendered product
Broiler	200
Hogs	211-302
Cattle	273-1,374

[a] Data generated during EPA sampling of MPP facilities.

Table 6-10. Wastewater Volumes Produced by Rendering Operations per Unit of Production

	Process Wastewater Generated (gallons per 1,000 lbs of raw material)
	Rendering[a]
Non-small facilities	578

[a] Median values derived from the 58 MPP detailed survey responses (as described in Section 3.2.6).
[b] These estimates reflects wastewater generated by on-site and off-site (independent) renderers.

6.3.2 Description of Waste Constituents and Concentrations

The principal constituents in wastewaters from rendering operations are the same as those in meat and poultry processing wastewaters. In addition, it appears that there is little difference in rendering wastewater constituents or concentrations attributable to the source of materials being processed. A 1975 survey found that the range and average of BOD wastewater values for plants processing more than 50 percent poultry by-products could not be differentiated from those plants processing less than 50 percent poultry by-products (USEPA, 1975). Additionally, the study found that plant size does not affect the levels of pollutants in the waste stream. However, management and operating variables, such as rate of cooking, speed of agitation, cooker overloading, foaming, and presence or absence of traps, were found to influence both wastewater volume and the concentrations of various wastewater constituents, as would be expected.

Another factor affecting the composition of rendering process wastewaters is the degree of decomposition that has occurred before rendering (USEPA, 1975). In warm weather, significant decomposition can occur, especially with materials from off-site sources. One result is increased wastewater ammonia nitrogen concentrations during summer months.

Table 6-11 provides a sense of the significance of various sources of wastewater from rendering operations relative to typical analyte composition before treatment. In this table, concentrations found in samples collected from a continuous dry rendering plant in Columbus, Ohio are presented (Hansen and West, 1992). Samples from blood, cooker condensate, and wash-up water were analyzed. The cooker condensate was mostly composed of condensed volatile fats and oils with some ammonia. The wash-up water consisted of plant cleanup water mixed with drainage from the raw product storage hopper. (The relative proportions were not measured.)

Table 6-11. Pollutant Concentrations for a Dry Continuous Rendering Plant

Parameter	Raw Blood[a] (mg/L)	Condensate Batch 1[a,b] (mg/L)	Condensate Batch 2[a,b] (mg/L)	Wash-up water[c] (mg/L)
Total COD	150,000	6,000	2,400	7,600
Soluble COD	136,000	6,000	2,400	3,200
Total Kjeldahl nitrogen (TKN-N)	16,500	740	430	270
Ammonia nitrogen	3,500	740	430	40
*COD: TKN	9.1	8.1	5.6	28.1
Total Phosphorus (P)	183	<4	<4	15.1
*COD: P	820	>1500	>600	503
Freon extractables (FOG)	620	260	110	35
Potassium	793	<6	<6	20.9
Calcium	55	<1	<1	26.4
Magnesium	27	<1	<1	7.3
Iron	164	2	2	9.4
Sodium	818	0.1	0.1	37.1
Copper	0.7	<0.2	<0.2	0.1
Zinc	1.3	<0.15	<0.15	0.46
Manganese	0.05	0.05	0.05	0.01
Lead	<0.6	<3	<3	<1.3
Chromium	0.3	<0.2	<0.2	0.12
Cadmium	0.05	<0.01	<0.01	<0.04
Nickel	<0.2	<1	<1	<0.4
Cobalt	<0.02	<0.01	<0.01	<0.04
Sulfate (SO_4-S)	300	<2	<2	4.6
Total Chloride	1700	<2	<2	86

[a] Each value is the mean of three samples analyzed in duplicate.

[b] The strength of condensate varied from winter to summer; however, only condensate collected during the summer was used in these studies. Cold ambient temperatures around the forced air condensers affected the COD strength of the cooker condensate. The COD strength of the blood and wash-up water was similar for both batches; therefore, data for each batch is not included separately.

[c] Each point is the mean of duplicate analyses of one sample.

[d] < and > symbols both indicate the limits of the analyses were exceeded.

* These parameters are ratios and have no units.

Source: Hansen and West, 1992

Although the blood accounted for only a small percentage of the total volume of wastewater, it clearly is a highly significant source of COD, TKN, ammonia nitrogen, and grease in rendering plant wastewater.

Table 6-12 summarizes the results of the analyses of samples of wastewater before treatment collected during sampling episodes at one broiler and one cattle processing facility with on-site rendering described earlier. Average effluent concentrations for all pollutants of concern evaluated by the EPA for potential regulation are provided in Section 11.

In 2000, the NRA collected data from its membership to provide a general characterization of rendering process wastewaters. Table 6-13 presents the results of this survey. The data are only for wastewater generated and final effluent characteristics, and do not cover specific sources of generated wastewater. The final effluent data indicate pollutant loads after treatment has been applied. The NRA did not report data on metals in generated wastewater or on nutrients in generated or discharged wastewater.

In Table 6-14, calculated estimates of selected pollutants generated per 1,000 lb of rendered product are summarized. Again, the values listed in these two tables indicate that there is a considerable degree of variation among individual facilities.

6.4 CONCLUSIONS

The number of meat and poultry processing facilities that were sampled by the EPA to characterize the volumes of wastewater generated on a normalized per unit of production basis and the concentrations of pollutants present clearly represent only a small fraction of the number of facilities in the MPP industry. However, the results obtained in these sample episodes in combination with other sources of information suggests that there is a considerable degree of variation among facilities even within each segment of the industry in both the volume of wastewater generated per unit of production and the concentrations of specific pollutants. The sampling episode results demonstrate that the differences between two facilities with the same

Table 6-12. Characteristics of Wastewaters Generated at Broiler and Cattle On-Site Rendering Operations[a]

Parameter	Broiler	Cattle
Flow (MGD[b])	0.29	0.15
Rendered product (1,000 lb/day)	1442	112
BOD_5 (mg/L)	1,984	3,870
Total suspended solids (mg/L)	3,248	837
Hexane extractables (mg/L)	1,615	362
Total Kjeldahl nitrogen (mg/L)	180	141
Total phosphorus (mg/L)	38	58
Fecal coliform bacteria (CFU[c]/100 ml)	1.2×10^6	1.2×10^6

[a] Data generated during the EPA sampling of MPP facilities.
[b] MGD Million gallons per day.
[c] CFU colony forming units.

Table 6-13. Wastewater Characterization of "Typical" National Rendering Association (NRA) Member Render Plant[a]

Parameter	Generated Wastewater (mg/L)	Discharged Wastewater (mg/L)
Chemical oxygen demand (mg/L)	123,000	8,000
Biochemical oxygen demand (mg/L)	80,000	5,100
Total suspended solids (mg/L)	8,400	268
Fat and other greases (mg/L)	3,200	116
Metals (average zinc) (mg/L)	NA	0.68
Fecal coliform bacteria (CFU[c]/100 ml)	2.5×10^8 cfu/mL	4.5×10^4 cfu/mL

[a] NRA, 2000.
[b] NA not available.
[c] CFU colony forming units.

Table 6-14. Estimates of Pollutants Generated per Unit of Production in On-Site Broiler and Cattle Rendering Operations[a]

Parameter	Broiler	Cattle
BOD_5 (lb/1,000 lb RP[b])	3.31	44.4
Total suspended solids (lb/1,000 lb RP)	5.42	9.60
Hexane extractables (lb/1,000 lb RP)	2.70	4.15
Total Kjeldahl nitrogen (lb/1,000 lb RP)	0.30	1.62
Total phosphorus (lb/1,000 lb RP)	0.06	0.67
Fecal coliform bacteria (CFU[c]/1,000 lb RP)	9.1×10^9	6.2×10^{10}

[a] Data generated during the EPA sampling of MPP facilities.
[b] RP rendered product.
[c] CFU colony forming units.

activity such as only first processing of broilers or first processing of cattle with on-site rending and hide processing can be substantial. This suggests that differences in-plant waste management practices, such as minimizing water use and separate collection of solid wastes, are critical factors in determining the volume of wastewater and the masses of individual pollutants generated per unit of production. Thus, it seems reasonable to conclude that any mean or median values characterized as typical values probably will describe the wastewater generated at a relatively small fraction of the total number of facilities in each segment of the MPP industry. However, it also seems reasonable to conclude that the impact of this variability will be limited to the cost of wastewater treatment to comply with the final rule promulgated and not the ability to comply. This variability also suggests that estimates of compliance costs for existing facilities may be reduced by implementation of more effective in-plant waste management practices.

6.5 REFERENCES

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SECTION 7

SELECTION OF POLLUTANTS AND POLLUTANT PARAMETERS FOR REGULATION

EPA conducted a study of meat and poultry products (MPP) wastewater to determine the presence of priority, conventional, and nonconventional pollutant parameters. The Agency defines priority pollutant parameters in Section 307(a)(1) of the Clean Water Act (CWA). In Table 7-1, EPA lists the 126 specific priority pollutants listed in 40 CFR Part 423, Appendix A. Section 301(b)(2) of the CWA requires EPA to regulate priority pollutants if the Agency determines that they are present in significant concentrations. Most of the priority pollutants listed in Table 7-1 were not further considered for regulation in the MPP effluent limitations guidelines (ELGs) and standards because EPA's technical evaluation of the industry did not identify them as significant contributors to MPP wastewaters. Section 304(a)(4) of the CWA defines conventional pollutant parameters to include biochemical oxygen demand (BOD), total suspended solids (TSS), oil and grease, pH, and fecal coliform bacteria. These pollutant parameters are subject to regulation, as specified in Sections 304(a)(4), 304(b)(1)(a), 301(b)(2)(e), and 306 of the CWA. Nonconventional pollutant parameters are those which are neither priority nor conventional pollutant parameters. This group includes nonconventional metal pollutants, nonconventional organic pollutants, and other nonconventional pollutant parameters such as chemical oxygen demand (COD). Sections 301(b)(2)(f) and 301(g) of the CWA give EPA the authority to regulate nonconventional pollutant parameters, as appropriate, based on technical and economic considerations.

This section identifies and discusses the pollutants in meat and poultry processing wastewaters considered for regulation by EPA. It presents the criteria used for identifying the pollutants of concern and selecting of the pollutants to be regulated. Section 7.1 discusses the pollutants considered for regulation, including classical, biological, toxic, and non-conventional pollutants. Section 7.2 explains how EPA selected the pollutants of concern by reviewing analytical data from influent wastewater samples to determine which pollutants were detected at treatable levels. Section 7.3 discusses how EPA selected the pollutants for regulation using the applicable CWA provisions regarding the pollutants subject to each statutory level and the pollutants of concern identified for each subcategory.

Table 7-1. Priority Pollutant List[a]

1 Acenaphthene	66 Bis(2-ethylhexyl) phthalate
2 Acrolein	67 Butyl benzyl phthalate
3 Acrylonitrile	68 Di-n-butyl phthalate
4 Benzene	69 Di-n-octyl phthalate
5 Benzidine	70 Diethyl phthalate
6 Carbon tetrachloride (tetrachloromethane)	71 Dimethyl phthalate
7 Chlorobenzene	72 Benzo(a)anthracene (1,2-benzanthracene)
8 1,2,4-Trichlorobenzene	73 Benzo(a)pyrene (3,4-benzopyrene)
9 Hexachlorobenzene	74 Benzo(b)fluoranthene (3,4-benzo fluoranthene)
10 1,2-Dichloroethane	75 Benzo(k)fluoranthene (11,12-benzofluoranthene)
11 1,1,1-Trichloroethane	76 Chrysene
12 Hexachloroethane	77 Acenaphthylene
13 1,1-Dichloroethane	78 Anthracene
14 1,1,2-Trichloroethane	79 Benzo(ghi)perylene (1,12-benzoperylene)
15 1,1,2,2-Tetrachloroethane	80 Fluorene
16 Chloroethane	81 Phenanthrene
17 *Removed*	82 Dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
18 Bis(2-chloroethyl) ether	
19 2-Chloroethyl vinyl ether (mixed)	83 Indeno(1,2,3-cd)pyrene (2,3-o-phenylenepyrene)
20 2-Chloronaphthalene	84 Pyrene
21 2,4,6-Trichlorophenol	85 Tetrachloroethylene (tetrachloroethene)
22 Parachlorometa cresol (4-chloro-3-methylphenol)	86 Toluene
23 Chloroform (trichloromethane)	87 Trichloroethylene (trichloroethene)
24 2-Chlorophenol	88 Vinyl chloride (chloroethylene)
25 1,2-Dichlorobenzene	89 Aldrin
26 1,3-Dichlorobenzene	90 Dieldrin
27 1,4-Dichlorobenzene	91 Chlordane (technical mixture & metabolites)
28 3,3'-Dichlorobenzidine	92 4,4'-DDT (p,p'-DDT)
29 1,1-Dichloroethylene	93 4,4'-DDE (p,p'-DDX)
30 1,2-Trans-Dichloroethylene	94 4,4'-DDD (p,p'-TDE)
31 2,4-Dichlorophenol	95 Alpha-endosulfan
32 1,2-Dichloropropane	96 Beta-endosulfan
33 1,3-Dichloropropylene (trans-1,3-dichloropropene)	97 Endosulfan sulfate
34 2,4-Dimethylphenol	98 Endrin
35 2,4-Dinitrotoluene	99 Endrin aldehyde
36 2,6-Dinitrotoluene	100 Heptachlor
37 1,2-Diphenylhydrazine	101 Heptachlor epoxide
38 Ethylbenzene	102 Alpha-BHC
39 Fluoranthene	103 Beta-BHC
40 4-Chlorophenyl phenyl ether	104 Gamma-BHC (lindane)
41 4-Bromophenyl phenyl ether	105 Delta-BHC
42 Bis(2-Chloroisopropyl) ether	106 PCB-1242 (Arochlor 1242)
43 Bis(2-Chloroethoxy) methane	107 PCB-1254 (Arochlor 1254)
44 Methylene chloride (dichloromethane)	108 PCB-1221 (Arochlor 1221)
45 Methyl chloride (chloromethane)	109 PCB-1232 (Arochlor 1232)
46 Methyl bromide (bromomethane)	110 PCB-1248 (Arochlor 1248)

Table 7-1. Priority Pollutant List[a] (Continued)

47 Bromoform (tribromomethane)	111 PCB-1260 (Arochlor 1260)
48 Dichlorobromomethane (bromodichloromethane)	112 PCB-1016 (Arochlor 1016)
49 *Removed*	113 Toxaphene
50 *Removed*	114 Antimony (total)
51 Chlorodibromomethane (dibromochloromethane)	115 Arsenic (total)
52 Hexachlorobutadiene	116 Asbestos (fibrous)
53 Hexachlorocyclopentadiene	117 Beryllium (total)
54 Isophorone	118 Cadmium (total)
55 Naphthalene	119 Chromium (total)
56 Nitrobenzene	120 Copper (total)
57 2-Nitrophenol	121 Cyanide (total)
58 4-Nitrophenol	122 Lead (total)
59 2,4-Dinitrophenol	123 Mercury (total)
60 4,6-Dinitro-o-cresol (phenol, 2-methyl-4,6-dinitro)	124 Nickel (total)
61 N-Nitrosodimethylamine	125 Selenium (total)
62 N-Nitrosodiphenylamine	126 Silver (total)
63 N-Nitrosodi-n-propylamine (di-n-propylnitrosamine)	127 Thallium (total)
64 Pentachlorophenol	128 Zinc (total)
65 Phenol	129 2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD)

Source: 40 CFR Part 423, Appendix A.

[a] Priority pollutants are numbered 1 through 129 but include 126 pollutants, because EPA removed three pollutants (17, 49, and 50)from the list.

7.1 POLLUTANTS CONSIDERED FOR REGULATION

For meat processing wastewaters, EPA considered 52 pollutants (24 classical pollutants and biological pollutants, 22 metals, and 6 pesticides) for regulation. For poultry processing wastewaters, the Agency considered 51 pollutants (23 classicals and biologicals, 22 metals, and 6 pesticides) for regulation. EPA considered these conventional, nonconventional, and priority pollutants based on their use or generation in the MPP industry and on the presence of an EPA-approved analytical method for analyzing these parameters in wastewater. This section describes the various classes of pollutants and bulk parameters considered for regulation and discusses why EPA did consider regulating antibiotics and animal drugs.

7.1.1 Antibiotics and Animal Drugs

Not included as pollutants considered for regulation are antibiotics and other animal drugs. Although a number of pharmaceutical agents are used in the production of livestock and poultry therapeutically and at subtherapeutic levels to increase rate of weight gain and feed conversion efficiency, antibiotics and other drugs were not considered as pollutants for possible regulation based on the following rationale.

Under the authority of the Federal Food, Drug, and Cosmetic Act (9 U.S.C. 301 et seq.) the Food and Drug Administration (FDA) in the U.S. Department of Health and Human Services regulates all use of antibiotics and other animal drugs in the production of livestock and poultry for human consumption. In addition, routine monitoring to ensure that residues or specific metabolites, when appropriate, in meat and poultry do not exceed established tolerances is part of the U.S. Department of Agriculture's Food Safety Inspection Service's (FSIS) meat and poultry inspection process. Any meat or poultry found to have drug or pesticide residues exceeding established tolerance limits is considered to be adulterated and is condemned as not fit for human consumption. Because condemnation results in a significant financial loss, livestock and poultry producers and processors have a significant incentive to prevent the presence of drug and pesticide residues at the time of slaughter. Monitoring for drug and pesticide residues by the FSIS is conducted under the authorities of the Federal Meat Inspection Act, as amended by the Wholesome Meat Act (21 U.S.C. 601 et seq.), and the Poultry Products Inspection Act, as amended by the Wholesome Poultry Products Act (21 U.S.C 451 et seq.).

In the FDA drug approval process, all new drugs marketed for veterinary use must be approved. There are two types of approval for veterinary drugs, including those routinely used in animal feeds (21 CFR 558.3). Category I drugs require no withdrawal period before slaughter at the lowest use level for each species for which they are approved. Category II drugs require a withdrawal period at the lowest use level for each species for which they are approved or are regulated on a "no residue" basis or with a "zero" tolerance (because of a carcinogenic concern) regardless of whether a withdrawal period is required. The basis for FDA's establishing minimum withdrawal periods and tolerances of new animal drugs in edible products of food-producing animals is set forth in 21 CFR 556.1. If there is an expectation of, or uncertainty about, the presence of residues, a withdrawal period or a maximum concentration in specified tissue is established. Withdrawal periods and tolerances or the absence thereof for all animal drugs approved for use in food-producing animals are set forth in 21 CFR 556.20–556.770. For example, Bacitracin zinc has no required withdrawal period but has a limit of 0.5 parts per million (ppm) in uncooked edible tissue of cattle, swine, and poultry (21 CFR 556.70).

Virginiamycin also has no required withdrawal period before slaughter but has limits of 0.4 ppm in uncooked edible kidney, skin, and fat; 0.3 ppm in liver; and 0.1 ppm in muscle. There are no residue tolerance limits for broiler chickens and cattle. Generally, residue concentration limits are no more than 1 ppm.

As noted above, all livestock and poultry slaughtered at federally inspected facilities is inspected by the FSIS under the authority of the Federal Meat Inspection Act as amended and the Poultry Products Inspection Act. All meat and poultry found to be adulterated must be condemned as unfit for human use. In the Federal Meat Inspection Act, the definition of the term *adulterated* includes the presence of any poisonous or deleterious substance that might render the carcass or any part of it injurious to health.

Regulations promulgated under the authority of the Poultry Products Inspection Act are more specific and require that all carcasses, organs, or other parts of carcasses be condemned, if it is determined on the basis of a sound statistical sample that they are adulterated because of the presence of any biological residue (9 CFR 381.80). *Biological residue* is defined as any substance, including metabolites, remaining in live poultry at the time of slaughter or in any of its tissues after slaughter as the result of treatment or exposure of the live poultry to a pesticide, organic compound, metallic or inorganic compound, hormone, hormone-like substance, growth promoter, antibiotic, anthelmintic, tranquilizer, or other agent that leaves a residue (9 CFR 381.1).

Given the statutory and regulatory barriers in place to prevent residues of antibiotics and other animal drugs, as well as pesticides, in food for human consumption above established tolerance limits, EPA assumes that it is highly improbable that antibiotics, other animal drugs, or pesticides are present routinely in detectable concentrations in the treated effluent of livestock or poultry processing plants. Obviously, the possibility of the slaughter of livestock or poultry containing drug or pesticide residues above tolerance limits exists. The financial self-interest of livestock and poultry producers suggests, however, that such occurrences would be infrequent and highly random. Thus, the probability of detection would be low, especially when pretreatment processes such as anaerobic lagoons with relatively long hydraulic detention times are used. Therefore, EPA has concluded that establishing effluent standards for antibiotics and other animal drugs and pesticides and requiring routine monitoring could impose an unnecessary burden on livestock and poultry processors.

7.1.2 Classical and Biological Pollutants

Classical and biological pollutants include conventional pollutants and pathogens. This section discusses each pollutant considered for regulation in alphabetical order.

Aeromonas

Aeromonas is a member of the family Vibrionaceae, which also includes Vibrios like *Vibrio cholerae*, the cause of cholera in humans. *Aeromonas* is not a common inhabitant of the intestinal tract of warm-blooded animals and normally is found in aquatic habitants. Its presence in meat and poultry processing wastewaters probably is the result of colonization in wastewater collection and treatment systems.

Biochemical Oxygen Demand

BOD is an estimate of the oxygen-consuming requirements of organic matter decomposition under aerobic conditions. When meat and poultry processing wastewaters are discharged to surface waters, the microorganisms present in the naturally occurring microbial ecosystem decompose the organic matter contained in the wastewaters. The decomposition process consumes oxygen and reduces the amount available for aquatic animals. Severe reductions in dissolved oxygen concentrations can lead to fish kills. Even moderate decreases in dissolved oxygen concentrations can adversely affect waterbodies through decreases in biodiversity, as manifested by the loss of some species of fish and other aquatic animals. Loss of biodiversity in aquatic plant communities due to anoxic conditions can also occur.

BOD is determined by measuring the depletion of dissolved oxygen resulting from aerobic microbial activity in a suitably diluted sample during incubation at 20 degrees celsius (°C) over a fixed period of time. Normally, this period is 5 days, and the results are reported as 5-day BOD, or BOD_5. If the bacteria responsible for nitrification are present in the sample, BOD_5 is a combined estimate of the oxygen required for both organic matter oxidation and the oxidation of ammonia to nitrate nitrogen (nitrification). Thus, BOD_5 includes both carbonaceous oxygen demand ($CBOD_5$) and nitrogenous oxygen demand (NOD). However, $CBOD_5$ can be determined separately by adding an agent that inhibits nitrification prior to incubation.

BOD_5 determinations include estimates of the amount of oxygen required for the degradation of both particulate and dissolved organic matter. First filtering the sample to remove particulate organic matter and then determining the BOD_5 of the filtrate, dissolved BOD_5, allows separation of these estimates. The difference between BOD_5 and dissolved BOD_5 ($DBOD_5$)is an estimate of the contribution of particulate matter to total BOD.

Chemical Oxygen Demand

COD is an estimator of the total organic matter content of both wastewaters and natural waters. It is the measure, using a strong oxidizing agent in an acidic medium, of the oxygen equivalent of the oxidizable organic matter present. COD is usually higher than BOD because COD includes slowly biodegradable and recalcitrant organic compounds not degraded microbially during the duration of the BOD test. For many types of wastewaters, the ratio between BOD and COD is relatively constant. When such a relatively constant ratio exists, COD can be used as a surrogate to estimate the impact of wastewater discharges on natural wastewaters. COD is most useful, however as a control parameter for wastewater treatment plant operation because it can be determined in 3 hours as opposed to the 5 days or more required by BOD. Thus, COD can be used to rapidly recognize deterioration in wastewater treatment plant performance and the need for corrective action.

Chloride

Chloride (Cl^-) is a common anion in wastewaters and natural waters. However, excessively high chloride concentrations in wastewater discharges can be harmful to animals and plants in non-marine surface waters and can disrupt ecosystem structure. It can also adversely affect biological wastewater treatment processes. Furthermore, excessively high chloride concentrations in surface waters can impair their use as source waters for potable water supplies. If sodium is the predominant cation present the water will have an unpleasant taste due to the corrosive action of chloride ions.

There are numerous sources of chloride in meat and poultry processing wastewaters; however, salt used in meat-curing processes is likely the most significant single source.

Cryptosporidium

Cryptosporidium parvum is an intestinal protozoan parasite responsible for the infectious disease cryptosporidiosis, which predominantly occurs in ruminants, particularly young calves. Other mammals, including pigs and humans, can also be infected. The disease is transmitted through oocysts shed in the feces of infected individuals. Clinical infection is most common in young animals and usually is self-limiting, with surviving individuals becoming carriers as adults. Other species of *Cryptosporidium* are responsible for infection in poultry but do not cause cryptosporidiosis in mammals, including humans. Thus, consideration of *Cryptosporidium* as a pollutant for possible regulation was limited to cattle processing wastewaters, especially veal processing wastewaters.

Hexane-Extractable Materials (Oil and Grease)

In meat and poultry processing wastewaters, oil and grease is primarily an estimate of the concentration of animal fats and oils lost during processing activities, but it may also include lubricating oils and greases. Oil and grease is not a specific substance. Rather, it is a group of substances determined on the basis of their common solubility in an organic extraction agent. Although a variety of extraction agents including trichlorotrifluoroethane, have been used to estimate oil and grease concentrations in wastewaters, n-hexane or a mixture of n-hexane and methyl-tert-butyl ether is commonly used, and oil and grease may be alternatively described as hexane-extractable materials (APHA, 1995).

Oil and grease in discharges of meat and poultry processing wastewaters is of concern for several reasons. One is the high BOD of animal fats and oils, which are readily biodegradable, and the impact on the dissolved oxygen status of receiving waters and related impacts on aquatic biota. In addition, a film of oil and grease on the surface of receiving waters can be unsightly and reduce natural re-aeration processes. Soluble and emulsified oil and grease can also inhibit the transport of oxygen and other gases necessary for plant and animal survival, also causing in aquatic ecosystem disruption.

Indicator Organisms

The total coliform, fecal coliform, and fecal streptococcus groups of bacteria share the common characteristic of containing species that normally are present in the enteric tract of all warm-blooded animals, including humans. Thus, these groups of bacteria are commonly used as indicators of fecal contamination of natural waters and the possible presence of enteric pathogenic bacteria, viruses, and parasites of enteric origin. They are used as indicators of the possible presence of enteric pathogens because of their normal presence in generally high densities in comparison to enteric pathogens, such as *Salmonella* and *Shigella*, and their relative ease of enumeration.

The total coliform group of bacteria consists of several genera of bacteria belonging to the family Enterobacteriaceae, but if also contains organisms not typical of enteric organisms, such as the species *Enterobacter aerogenes*. Thus, the presence of total coliforms is only an indicator of possible fecal contamination. Members of the fecal coliform group, on the other hand, are limited to those genera of the family Enterobacteriaceae that are limited to the enteric tract of warm-blooded animals. The species *Escherichia coli* is typically the principal component of the fecal coliform group. Because fecal streptococci are also normally present in the enteric tract of warm-blooded animals in relatively high numbers, the fecal streptococcus group of bacteria is also an indicator of fecal contamination of natural waters.

Because of the presence of manure and the common combination of processing and sanitary wastewaters for treatment, total coliforms, fecal coliforms, *E. coli*, and fecal streptococcus were considered as pollutants for possible regulation in meat and poultry processing wastewaters. The parameters as considered indicators of inadequate disinfection and the possible presence of pathogens in discharged effluents. In addition to potential human health impacts due to use of receiving surface waters for contact recreation and as source waters for public and private water supplies, pathogens possibly present in meat and poultry processing wastewaters can be infectious to wildlife.

Nitrogen

Several forms of nitrogen are pollutants of concern in meat and poultry processing wastewaters. Included are total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_4-N), and nitrite plus nitrate nitrogen (NO_2 + NO_3-N). Because protein is the principal component of meat and blood, meat and poultry processing wastewaters can contain relatively high concentrations of nitrogen. Another source of nitrogen in these wastewaters is fecal material, primarily in the forms of unabsorbed feed proteins and products of protein degradation.

TKN is an estimate of the sum of organic nitrogen and ammonia nitrogen, and it provides an estimate of organic nitrogen by difference when ammonia nitrogen is concurrently determined. Under both anaerobic and aerobic conditions, the readily biodegradable fraction of organic nitrogen is mineralized readily by microbial activity. The nitrogen not used for cell synthesis accumulates as ammonia nitrogen. The water quality impacts associated with organic nitrogen are related to this process of mineralization to ammonia nitrogen in natural waters and are discussed below.

As noted above, ammonia nitrogen in meat and poultry processing wastewaters is primarily the product of organic nitrogen mineralization. Cleaning and sanitizing agents, however, are also possible sources. Ammonia nitrogen is present in aqueous solutions as both ionized (ammonium) and un-ionized (ammonia) species. Ammonia nitrogen is a pollutant considered for regulation in meat and poultry processing wastewaters because its presence in wastewater discharges to surface waters has several negative environmental impacts. Both ammonia nitrogen and ammonium nitrogen can be directly toxic to fish and other aquatic organisms; ammonia (as nitrogen) is the more toxic. In addition, discharges of ammonia nitrogen can reduce ambient dissolved oxygen concentrations in receiving surface waters because of the microbially mediated oxidation of ammonia nitrogen to nitrite plus nitrate nitrogen. This demand is known as nitrogenous oxygen demand (NOD).

Ammonia nitrogen in wastewater discharges can also be responsible for the development of eutrophic conditions and the associated adverse impacts on ambient dissolved oxygen concentrations if nitrogen is the nutrient limiting primary productivity. Although phosphorus is typically the nutrient limiting primary productivity in fresh surface waters, nitrogen is typically the limiting nutrient in marine waters and the more saline segments of estuaries. Eutrophic conditions, an excess of primary productivity, are characterized by algae blooms, which cause shifts in ambient dissolved oxygen concentrations from supersaturation on sunny days to substantial deficits at night and on cloudy days, when photosynthesis does not occur. The decay of the biomass generated by excessive primary productivity also exerts a demand on ambient dissolved oxygen concentrations. With the depression of ambient dissolved oxygen concentrations, populations of fish and other aquatic organisms are adversely affected, possibly causing a change in ecosystem composition and a loss of biodiversity.

Nitrite plus nitrate nitrogen is rarely present in meat and poultry processing wastewaters before aerobic biological treatment, because the wastewaters lack the oxygen necessary for microbially mediated nitrification. Nitrite and nitrate salts used in further processing, however, are potential sources. Thus, the principal source of nitrite plus nitrate nitrogen following treatment is nitrification during aerobic biological treatment, which is often required, at least seasonally, to satisfy effluent limitations for the discharge of ammonia nitrogen to surface waters. Usually, nitrate nitrogen is the predominate form of oxidized nitrogen in these discharges, with nitrite nitrogen present in only trace amounts. High concentrations of nitrite nitrogen usually are indicative of incomplete nitrification and are accompanied by more than trace ammonia nitrogen concentrations.

Although nitrate nitrogen exerts an NOD in surface waters, the principal concern about oxidized forms of nitrogen in wastewater discharges is related to their role in the development of eutrophic conditions. The impacts of such conditions on fish populations, biodiversity, recreation, and potable water supply treatment costs were discussed above. An additional concern is their potential for increasing ambient surface water nitrate nitrogen concentrations above the national maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) in source waters used for public drinking water supplies.

Phosphorus

Total phosphorus and total orthophosphate phosphorus are both pollutants of concern in meat and poultry processing wastewaters. Phosphorus is a pollutant considered for regulation in meat and poultry processing wastewaters because of its role as the nutrient typically limiting primary productivity in freshwater ecosystems. In such aquatic ecosystems, an increase in ambient phosphorus concentration due to wastewater discharges above naturally occurring levels results in the excessive growth of algae and other phytoplankton, with the development of eutrophic conditions as the consequence. In turn, eutrophic conditions can cause fish kills, disruption of natural aquatic ecosystem structure, and loss of biodiversity. Additional impacts of eutrophication in fresh waters include impairment of recreational use and additional treatment cost for use of these waters as a source of potable water. In marine waters, phosphorus is not a pollutant of concern because of relatively high naturally occurring phosphorus concentrations. The impact of phosphorus in wastewater discharges into estuaries varies; in general, impacts decrease as salinity levels increase.

The sources of phosphorus in meat and poultry processing wastewaters are numerous, they include bone, soft tissue, blood, manure, detergents and sanitizers, and boiler water additives used to control corrosion. Both organic and inorganic forms of phosphorus are present, and the inorganic forms occur as both ortho- and polyphosphate phosphorus. Total orthophosphate phosphorus, also known as total reactive phosphorus, can be directly used by phytoplankton and higher adequate plants and are immediately available sources of phosphorus. Although polyphosphate forms of phosphorus undergo hydrolysis in aqueous solutions, hydrolysis is usually quite slow, as is mineralization of organically bound phosphorus. Thus, orthophosphate phosphorus is a potential pollutant of concern because of its immediate biological availability, whereas polyphosphates and organically bound phosphorus, which comprise the difference between total phosphorus and orthophosphate phosphorus, are pollutants of concern as sources of slowly released orthophosphate phosphorus.

Dissolved total phosphorus is simply the sum of ortho- and- polyphosphate phosphorus in solution, obtained by excluding suspended forms of phosphorus by filtration.

Salmonella

A number of pathogenic species of *Salmonella*, including *Salmonella enteritidis*, are common inhabitants of the enteric tracts of livestock and poultry and may be present in meat and poultry processing wastewaters. Because of salmonella's potential risk to public health through public and private water supplies, contact forms of recreation, and wildlife exposure to effluents discharged to natural waters, it was considered as a pollutant for possible regulation in meat and poultry processing wastewaters.

Solids

Meat and poultry processing wastewaters before and after treatment contain both suspended and dissolved solids, which are also known as nonfilterable and filterable residue. Suspended and dissolved solids concentrations are determined by filtering the solids with a standard glass fiber filter and then drying them to a constant weight. The solids retained on the filter are considered suspended solids, and the solids passing through the filter are considered dissolved solids. Dissolved solids concentrations can also be estimated indirectly by determining their conductance, the ability to carry an electric current. This ability depends on the presence and dissociation of inorganic compounds. Organic compounds in aqueous solutions generally do not dissociate and are poor conductors of electricity.

The principal constituents of suspended solids in treated meat and poultry processing wastewaters are soft and hard tissue particles not removed during treatment and biomass synthesized during treatment. Thus, suspended solids have both organic (volatile) and inorganic fractions. Dissolved solids consist primarily of dissolved inorganic compounds (mainly calcium, magnesium, iron, manganese, and sulfur compounds), but they can also contain colloidal organic material. The principal sources of dissolved solids in meat and poultry processing wastewaters are potable water supplies used for processing; salts used in processing, such as sodium chloride; and cleaning and sanitizing agents. Usually, the organic, and therefore potentially biodegradable, fraction of suspended solids is substantially higher than the inorganic fraction; the reverse is typically characteristic of dissolved solids. Total solids are the sum of suspended and dissolved solids with total volatile solids, or total volatile residue representing an estimate of the organic fraction of total solids.

Both suspended and dissolved solids in meat and poultry processing wastewaters were considered as pollutants for several reasons. Suspended solids that settle to form bottom deposits can create anaerobic conditions because of the oxygen demand exerted by microbial decomposition. They can alter habitat for fish, shellfish, and benthic organisms. Suspended solids also provide a medium for the transport of other sorbed pollutants, including nutrients, pathogens, metals, and toxic organic compounds such as pesticides, which accumulates and are stored in settled deposits. Settled suspended solids and other associated pollutants often have extended interaction with the water column through cycles of deposition, resuspension, and redeposition.

In addition, suspended solids in wastewater discharges can clog fish gills, reducing oxygen transport and increasing turbidity. In severe situations, clogging of fish gills can result in asphyxiation; in less severe situations, it can result in an increase in susceptibility to infection. Suspended solids also increase turbidity in receiving waters and reduce light penetration through the water column, thereby limiting the growth of rooted aquatic vegetation that serves as a critical habitat for fish, shellfish, and other aquatic organisms.

Dissolved solids were considered as pollutants for possible regulation, primarily because of their potential impact on the subsequent use of receiving waters as source waters for public and industrial water supplies. Reducing of dissolved solids concentrations in source waters to acceptable levels for public and industrial water supply use can be a costly process. Dissolved solids also have the potential to alter the chemistry of natural waters to a degree that adversely affects indigenous aquatic biota, especially in the immediate vicinity of the effluent discharge. An example is a possible influence on the toxicity of heavy metals and organic compounds to fish and other aquatic organisms, primarily because of the antagonistic effect of hardness.

Possible regulation of total volatile solids (total volatile residue) in meat and poultry processing wastewaters was considered because this parameter is also an estimator of organic matter and potential oxygen demand in receiving waters after treated effluent discharge.

Total Residual Chlorine

Chlorine, in the form of chlorine gas (Cl_2), calcium hypochlorite ($Ca(OCl)_2$), sodium hypochlorite (NaOCl), or chlorine dioxide (ClO_2), is commonly used to disinfect meat and poultry processing wastewaters before direct discharge to surface waters. Because free chlorine is directly toxic to aquatic organisms and can react with naturally occurring organic compounds in natural waters to form toxic compounds such as trihalomethane, total residual chlorine in meat and poultry processing wastewaters was considered as a pollutant for possible regulation.

Total Organic Carbon

Total organic carbon (TOC) is a measure of a variety of organic compounds in various oxidation states in water and wastewater. Some of these compounds can be oxidized further by biological or chemical processes and are captured in BOD or COD determinations. These tests, however, might not oxidize some organic carbon compounds. Thus, TOC might provide the most accurate estimate of organic matter content. TOC provides no information relative to potential oxygen demand; however, it can be used to estimate BOD and COD in a wastewater with a relatively constant composition, once correlations between TOC and BOD and COD are established. Like COD, TOC can be determined rapidly in contrast to BOD, which requires a 5-day incubation period.

7.1.3 Toxic and Other Nonconventional Pollutants

EPA considered 126 priority pollutants for regulation, including toxic metals and pesticides, as well as several nonconventional metals. This section discusses which metals and pesticides EPA considered for regulation.

Metals

A number of metals from a range of possible sources can be present in meat and poultry processing wastewaters. These possible sources include water supplies and distribution systems, processing equipment, cleaning and sanitizing agents, wastewater collection systems, and wastewater treatment equipment. In addition, metals such as arsenic, copper, and zinc are commonly added to livestock and poultry feeds as trace mineral supplements or growth stimulants, and that can be present in manures.

The following metals were considered as pollutants for possible regulation in meat and poultry processing wastewaters: antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, tin, titanium, vanadium, yttrium, and zinc. These metals were considered because of their potential toxicity to phytoplankton and zooplankton and to higher aquatic plant and animal species, including fish. They are also pollutants of concern, given the in potential for bioaccumulation and biomagnification in aquatic food chains and presence downstream in effluent receiving waters used as source waters for potable water supplies. Although metals are removed from wastewaters during conventional physicochemical and biological treatment processes through adsorption to biosolids removed by settling and filtration before discharge, these processes are not intentionally engineered to remove metals before effluent discharge.

Pesticides

With the exception of rodenticides in enclosed bait stations, pesticides are not used in meat and poultry processing facilities to prevent the risk of product contamination. They are, however, commonly topically applied to livestock and poultry in animal feeding operations for the control of ectoparasites. Although withdrawal periods are required before slaughter, residues can remain on feathers, hair, and skin at slaughter. Therefore, the following pesticides were considered as pollutants for possible regulation in meat processing wastewaters: carbaryl, cis-permethrin, dichlorvos, Malathion, and tetrachlorvinphos. Transpermithrin and carbaryl were considered as pollutants for possible regulation in poultry processing wastewaters.

These pesticides were considered because of their toxicity to aquatic ecosystems and their potential for bioaccumulation and biomagnification in aquatic food chains and presence downstream in effluent receiving waters used as source waters for potable water supplies. Although pesticides are removed from wastewaters during conventional physicochemical and biological treatment processes through adsorption to biosolids removed by settling and filtration before discharge, these processes are not intentionally engineered to remove pesticides before effluent discharge. For some pesticides, biodegradation may also occur during wastewater treatment.

7.2 SELECTION OF POLLUTANTS OF CONCERN

EPA determined pollutants of concern for the MPP industry by assessing Agency sampling data. To establish the pollutants of concern, EPA reviewed the analytical data from influent wastewater samples to determine which pollutants were detected at treatable levels. EPA set treatable levels at five times the baseline value to ensure that pollutants detected at only trace amounts would not be selected.

EPA obtained the pollutants of concern by establishing which parameters were detected at treatable levels in at least 10 percent of all the influent wastewater samples. Tables 7-2 and 7-3 list the MPP industry pollutants of concern. EPA did not sample at independent rendering facilities and transferred data from on-site rendering facilities.

Table 7-2. Pollutants of Concern for Meat Processing Facilities

Pollutant Group	Pollutant	CAS Number
Classicals or biologicals	*Aeromonas*	C2101
	Ammonia as nitrogen	7664417
	Biochemical oxygen demand (BOD)	C003
	BOD 5-day (carbonaceous)	C002
	Chemical oxygen demand	C004
	Chloride	16887006
	Cryptosporidium	137259508
	Dissolved biochemical oxygen demand	C003D
	Dissolved phosphorus	14265442D
	E. coli	C050
	Fecal coliform	C2106
	Fecal streptococcus	C2107
	Hexane extractable material	C036
	Nitrate/nitrite	C005
	Total coliform	E10606
	Total dissolved solids	C010
	Total Kjeldahl nitrogen	C021
	Total organic carbon	C012
	Total orthophosphate	C034
	Total phosphorus	14265442
	Total suspended solids	C009
	Volatile residue	C030
Metals	Chromium	7440473
	Copper	7440508
	Manganese	7439965
	Titanium	7440326
	Zinc	7440666
Pesticides	Cis-permethrin	61949766
	Trans-permethrin	61949777

[a] CAS Chemical Abstracts Services.

Table 7-3. Pollutants of Concern for Poultry Processing Facilities

Pollutant Group	Pollutant	CAS Number
Classicals or Biologicals	*Aeromonas*	C2101
	Ammonia as nitrogen	7664417
	Biochemical oxygen demand (BOD)	C003
	BOD 5-day (carbonaceous)	C002
	Chemical oxygen demand	C004
	Chloride	16887006
	Dissolved biochemical Oxygen demand	C003D
	Dissolved phosphorus	14265442D

Table 7-3. Pollutants of Concern for Poultry Processing Facilities (Continued)

Classicals or Biologicals	*E. coli*	C050
	Fecal coliform	C2106
	Fecal streptococcus	C2107
	Hexane extractable material	C036
	Nitrate/nitrite	C005
	Total coliform	E10606
	Total dissolved solids	C010
	Total Kjeldahl nitrogen	C021
	Total organic carbon	C012
	Total orthophosphate	C034
	Total phosphorus	14265442
	Total residual chlorine	7782505
	Total suspended solids	C009
	Volatile residue	C030
Metals	Copper	7440508
	Manganese	7439965
	Zinc	7440666
Pesticides	Carbaryl	63252

[a] CAS Chemical Abstracts Services.

Consequently, EPA is using all the pollutants of concern from Tables 7-2 and 7-3 for independent rendering facilities. EPA had planned to sample at an independent rendering facility after proposal. EPA subsequently decided, however that other data sources provided adequate information and instead evaluated information on three independent renderers provided by the industry.

At proposal, EPA had included *Salmonella* and carbaryl as pollutants of concern for the poultry and meat subcategories, respectively. However, based on new data from additional sampling episodes after the proposal and minor modifications to the use of preproposal sampling data, EPA is no longer considering *Salmonella* a pollutant of concern for the poultry subcategories and carbaryl a pollutant of concern for the meat subcategories.

7.3 SELECTION OF POLLUTANTS FOR REGULATION

7.3.1 Methodology for Selection of Regulated Pollutants

EPA selects the pollutants for regulation based on applicable Clean Water Act provisions regarding the pollutants subject to each statutory level and the pollutants of concern identified for each subcategory.

As presented above, EPA selected a subset of pollutants for which to establish numerical effluent limitations from the list of pollutants of concern for each regulated subcategory. In general, a chemical is considered a pollutant of concern if it is detected in the untreated process wastewater at five times the baseline value in more than 10 percent of the samples taken.

Monitoring for all pollutants of concern is not necessary to ensure that MPP wastewater pollution is adequately controlled because many of the pollutants originate from similar sources, have similar treatabilities, are removed by similar mechanisms, and are treated to similar levels. Therefore, monitoring for one pollutant as a surrogate or indicator of several others might be sufficient.

Regulated pollutants are pollutants for which EPA established numerical effluent limitations and standards. EPA selected a pollutant of concern for regulation in a subcategory if it meets all the following criteria:

- The chemical is not used as a treatment chemical in the selected technology option.
- The chemical is not considered a nonconventional bulk parameter.
- The chemical is not considered a volatile compound.
- The chemical is effectively treated by the selected treatment technology option.

- The chemical is detected in the untreated wastewater at treatable levels in a significant number of samples, typically five times the baseline value in more than 10 percent of the untreated wastewater samples.

- Control of the chemical through treatment processes would lead to control of a wide range of pollutants with similar properties; these chemicals are generally good indicators of overall wastewater treatment performance.

Based on the methodology described above, EPA is regulating pollutants in each subcategory that will ensure adequate control of a range of pollutants.

7.3.2 Selection of Regulated Pollutants for Existing and New Direct Dischargers

The current regulation requires facilities to maintain the pH at between 6.0 and 9.0 at all times. EPA is retaining this limitation and is codifying identical pH limitations for the previously unregulated poultry first and further processing subcategories. The pH must be monitored at the point of discharge from the wastewater treatment facility as indicated in the discharge permit.

In addition, EPA is establishing effluent limitations for MPP facilities for the following pollutants of concern: BOD, TSS, hexane extractable materials (oil and grease), fecal coliforms, ammonia as nitrogen, and total nitrogen (total Kjeldahl nitrogen plus nitrite plus nitrate nitrogen). The specific justifications for the pollutants to be regulated for each subcategory are provided below. In general, EPA selected these pollutants because they are representative of the characteristics of meat processing wastewaters generated in the industry and are key indicators of the performance of the treatment processes that serve as the basis for the effluent limitations.

A number of pollutants of concern evaluated by EPA are parameters that identify the quantity of material in an effluent that is likely to consume oxygen as it breaks down in surface waters after it has been discharged. These parameters are total organic carbon, BOD, carbonaceous BOD, COD, and dissolved BOD. Values for these pollutants of concern in meat and poultry processing wastewaters are typically very high because of the waste generated from killing, evisceration, further processing, and rendering processes. EPA is regulating BOD_5, which will be used as an indicator of the performance of biological treatment systems in removing all oxygen-demanding pollutants and the impact of treated effluent discharges to surface waters on dissolved oxygen concentrations. EPA had proposed adding COD to the BPT limitations for non-small facilities (based on subcategory-specific production thresholds) in Subcategories A through D and F through J to better reflect the design and operation of the existing BPT treatment technology (67 FR 8630). Commenters stated that biological treatment systems in place at meat products facilities are not designed or operated based on COD removal and that adding COD limitations would be financially burdensome. In addition, commenters stated that BOD or CBOD (carbonaceous BOD) would be a more appropriate measure for monitoring biological treatment system performance. EPA agrees that COD might not be an appropriate indicator of biological treatment technology performance at MPP facilities. EPA is not regulating COD or CBOD in the final rule because COD would not provide much useful information and CBOD would be somewhat redundant with the current BOD_5 limitations and standards.

TSS, total dissolved solids (TDS), and total volatile residue are parameters that measure the quantity of solids in a wastewater. Meat processing facilities typically produce wastewaters high in organic solids, including blood, carcass, feathers, and feces. These solids cause a high oxygen demand (both chemical and biochemical) and are high in nitrogen content. Because some nutrients bind to solids and solids often include oxygen-demanding organic material, limiting the loading of solids will prevent degradation of surface waters. EPA is regulating TSS as an indicator of the performance of biological treatment systems in removing solids. EPA considered regulating TDS; however, as organic matter is broken down in a biological wastewater treatment system, levels of TDS can increase. The treatment technology selected as the basis for the final rule does not reduce or control TDS. Therefore, EPA is not including TDS limits in the final regulations.

Wastewaters from meat processing facilities have high concentrations of the nutrients nitrogen and phosphorus associated primarily with blood, soft tissue, fecal material, and cleaning and sanitizing agents. In addition, facilities that employ advanced biological treatment systems to remove ammonia by biological nitrification, convert ammonia nitrogen to nitrite and nitrate nitrogen through microbially mediated oxidation. Because of the potential degrading impacts on surface waters associated with the discharge of nitrogen (e.g., eutrophication), EPA is regulating total nitrogen and ammonia nitrogen. In regulating total nitrogen, EPA will ensure that biological treatment systems used by facilities are effectively removing all forms of nitrogen, including TKN, nitrate plus nitrite, and ammonia nitrogen. EPA is also regulating ammonia nitrogen because of the significant oxygen demand it exerts, as well as its relatively high toxicity to aquatic life.

EPA did not select total phosphorus, orthophosphate, or dissolved phosphorus for the final regulation. Although they are present in the wastewaters from MPP facilities, the treatment technology selected as the basis for the final rule does not include phosphorus removal technology. EPA did consider technology options that would remove phosphorus through chemical-physical treatment (Option 2.5+P and Option 4), but those technology options did not achieve a level of phosphorus reduction that justified the additional cost of the technology. (See Section 13 for additional information.)In addition, for some subcategories the technology options that included chemical phosphorus removal were associated with severe economic impacts (facility closures), and therefore EPA does not consider those options economically achievable.

Oil and grease (as n-hexane-extractable material) is a parameter that measures oil and grease concentrations in effluents. Oil and grease, primarily in the form of animal fat, is present in relatively high concentrations in meat and poultry processing wastewaters. EPA has concluded that the control of oil and grease is necessary to ensure that treatment systems are effective in removing oil and grease. Excessive oil and grease concentrations can be associated with high BOD demand in a surface water. They present other nuisance problems as well. (See the discussion in Section 7.1.1.)

Chlorides measure the quantity of chloride ion dissolved in solution. In the meat processing industry, salts may be used in further processing and for cleaning and sanitizing purposes. The presence of chlorides in discharges to surface waters can adversely affect aquatic organisms because of their sensitivity to concentrations of salt. Although EPA determined that chlorides are a pollutant of concern, it is not regulating chlorides because biological systems are not specifically designed and operated to treat chlorides. In fact, EPA observed in some instances an increase in chlorides within the biological treatment system (from the influent to the effluent) at several facilities. As a result, EPA believes that a facility will not be able to manage a biological treatment process to consistently achieve effluent limitations for chlorides.

Total coliforms, fecal coliforms, *E. coli*, fecal streptococcus, *Salmonella*, and *Aeromonas* were considered pollutants of concern, because they provide information on the potential presence of bacterial and other pathogens in meat processing wastewaters. Pathogens are typically present in meat and poultry processing wastewaters because of the presence of fecal material. The reduction of pathogens is important to prevent impairment of surface water uses, such as use as a drinking water source or as a recreation water. EPA is regulating fecal coliforms as an indicator of the efficacy of treatment processes to control pathogens.

In many instances, EPA found meat processing facilities using chlorine to disinfect treated wastewaters. However, EPA has decided not to regulate total residual chlorine in the final rule, even though it is a pollutant of concern for the MPP industry. When chlorination is used for disinfection (e.g., to inactivate bacteria and pathogens), disinfectant residuals can result in the formation of by-products such as trihalomethanes, which can be a human health concern in drinking water. Although chlorination is the basis for the compliance costs for disinfection in the cost model (see Section 10), this regulation does not specify a technology-based process for disinfection, and these are effective methods besides chlorination with free chlorine (e.g., chloramines, ozone, ultraviolet radiation) that do not have the same potential for by-product formation. In addition, formation of disinfection by-products is a water quality issue, dependent on the characteristics and uses of the receiving water, and as such it should be controlled in individual NPDES permits on a facility-by-facility basis. In fact, for non-small facilities that responded to EPA's detailed survey, 63 percent of facilities in subcategories A through D and 48 percent of facilities in subcategory K already have total residual chlorine limits in their NPDES permits. An additional 5 percent of A through D facilities and 12 percent of K facilities have monitoring requirements for total residual chlorine without corresponding limits. Therefore, EPA concluded that the current system is working well in addressing residual chlorine issues. Furthermore, the potential for formation of trihalomethanes and other disinfection by-products is high when certain dissolved organic molecules are present, especially humics (forms of organic carbon created by decaying plant matter). The treatment processes used at meat and poultry products facilities to remove BOD and other parameters also reduce the concentrations of TOC in the discharged wastewater. If a chlorinated discharge enters U.S. waters that are high in organic carbon content, that is a local water quality issue best addressed in an individual NPDES permit.

Metals might be present in meat processing wastewaters for a variety of reasons. They are used as feed additives, they can be contained in sanitation products, or they can result from deterioration of meat-processing machinery and equipment. Many metals are toxic to algae, aquatic invertebrates, or fish. Metals can serve useful purposes in meat processing operations, but most metals retain their toxicity once they are discharged into receiving waters. Although EPA observed that many of the biological treatment systems used in the meat processing industry provide substantial reductions of most metals, biological systems are not specifically engineered to remove metals. As a result, EPA believes that a facility will not be able to manage a biological treatment process to consistently achieve effluent limitations. Therefore, EPA is not regulating metals.

Pesticides are used for controlling animal ectoparasites and might be present in wastewaters from initial animal wash and processing operations. Some pesticides are bioaccumulative and retain their toxicity once they are discharged into receiving waters. Although EPA observed that many of the biological treatment systems used in the meat processing industry provide adequate reductions of pesticides, most biological systems are not specifically engineered to remove pesticides. As a result, EPA believes that a facility will not be able to manage a biological treatment process to consistently achieve effluent limitations for pesticides. Therefore, EPA is not regulating pesticides.

7.4 REFERENCES

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SECTION 8

WASTEWATER TREATMENT TECHNOLOGIES AND POLLUTION PREVENTION PRACTICES

This section describes the unit processes that are currently in use or may be used to treat meat and poultry products (MPP) wastewaters. A variety of unit processes are used to provide primary, secondary, and tertiary wastewater treatment; however, because of the similarities in the physical and chemical characteristics of MPP wastewaters, EPA identified no practical difference in the types of treatment technologies between meat products and poultry products facilities (e.g., primary treatment for removal of solids, biological treatment for removal of organic and nutrient pollutants). In addition, the unit processes used in treating MPP wastewaters are similar to those normally used in treating domestic wastewaters (Eremektar et al., 1999; Johnston, 2001). In this section, the unit processes most commonly used or potentially transferable from other industries for the treatment of MPP wastewaters are described, and typical combinations of unit processes are outlined.

Wastewater treatment falls into three main categories: (1) primary treatment (e.g., removal of floating and settleable solids); (2) secondary treatment (e.g., removal of most organic matter); and (3) tertiary treatment (e.g., removal of nitrogen, phosphorus, or suspended solids or some combination thereof). MPP facilities that discharge directly to navigable waters under the authority of a National Pollutant Discharge Elimination System (NPDES) permit typically apply both primary and secondary treatment to generated wastewaters. As described in the MPP detailed surveys, many direct dischargers also apply tertiary treatment to wastewater discharged under the NPDES permit system. Table 8-1 identifies the types of wastewater treatment commonly found in the MPP industry.

Table 8-1. Distribution of Wastewater Treatment Units in MPP Industry

Treatment Category	Treatment Unit	Percent of Direct Discharging Facilities Having the Treatment Unit in Place
Primary treatment	Screen	98
	Oil and grease removal	83
	Dissolved air flotation	81
	Flow equalization	75
Secondary and tertiary treatment	Biological treatment [a]	100
	Filtration	23
	Disinfection	92

Source: EPA detailed survey data.
[a] Biological treatment includes any combination of the following: aerobic lagoon, anaerobic lagoon, facultative lagoon, any activated sludge process, and/or other biological treatment processes (e.g., trickling filter).

8.1 PRIMARY TREATMENT

Primary treatment involves removal of floating and settleable solids. In MPP wastewaters, the typical unit processes used for primary treatment are screening, catch basin, dissolved air flotation (DAF), and flow equalization. Chemicals are often added to improve the performance of the treatment units; for example, flocculant or polymer is added to DAF units. Primary treatment has two objectives in the MPP industry: (1) to reduce suspended solids and biochemical oxygen demand (BOD) loads to subsequent unit processes, and (2) to recover materials that can be converted into marketable products through rendering.

8.1.1 Screening

Screening is typically the first and most inexpensive form of primary treatment. It removes large solid particles from the waste stream that could otherwise damage or interfere with downstream equipment and treatment processes, including pumps, pump inlets, and pipelines (Nielsen, 1996). Several types of screens are used in wastewater treatment, including static or stationary, rotary drum, brushed, and vibrating. Static, vibrating, or rotary drum screens are most commonly used as primary treatment (USEPA, 1974, 1975). These screens use stainless steel wedge wire as the screen material and remove medium and coarse particles between 0.01 to 0.06 inch in diameter. Generally, all wastewater generated in MPP facilities is screened before discharge to subsequent treatment processes. The use of screens aids in recovering valuable by-products that are sometimes used as a raw material for the rendering industry and subsequent industries (Banks and Adebowale, 1991; USEPA, 1974, 1975). The use of secondary screens is becoming more prevalent in the industry. Secondary screening has the advantage of by-product recovery prior to adulteration by coagulants, and it reduces the volume of solids to be recovered in subsequent unit processes, such as DAF (Starkey and Wright, 1997).

The following subsections describe the main types of screens used at MPP facilities.

8.1.1.1 Static Screens

The primary function of a static screen (Figure 8-1) is to remove large solid particles (USEPA, 1974, 1975). For example, slaughterhouse raw wastewater can include coarse, suspended matter (larger than 1 mm mesh) that is insoluble, is slowly biodegradable, and accounts for 40 to 50 percent of the raw wastewater chemical oxygen demand (COD) (Johns, 1995). Screening can be accomplished in several ways. In older versions, only gravity drainage is involved. A concavely curved screen design that uses high-velocity pressure feeding and was originally developed for mineral classification has been adapted to meet MPP wastewater treatment needs. This design employs bar interference to the slurry, which slices off thin layers of the flow over the curved surface. The screen material is usually 316 stainless steel, although harder, wear-resistant stainless alloys can also be used for special purposes.

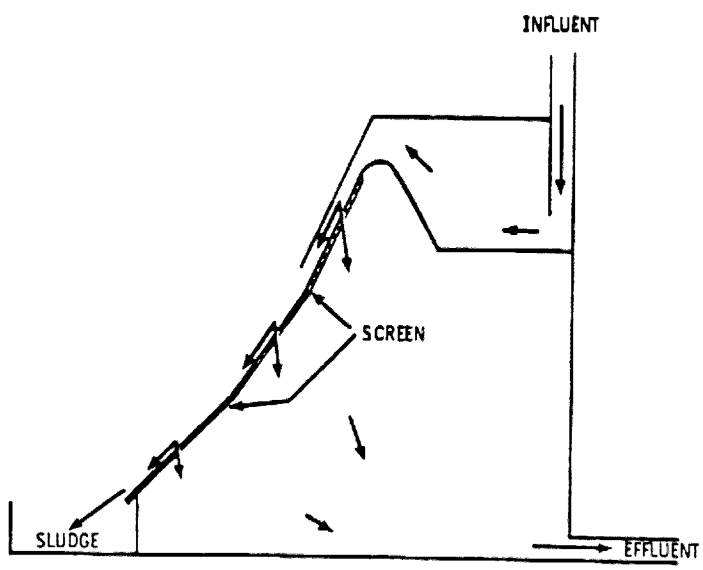

Figure 8-1. General schematic of a static screen (US EPA,1980).

Openings of 0.025 to 0.15 centimeter (0.01 to 0.06 inch) meet normal screening needs (USEPA, 1974, 1975).

In some poultry products facilities, "follow-up" stationary screens, consisting of two, three, and four units placed vertically in the effluent sewer before discharge to the municipal sewer, have successfully prevented feathers and solids from escaping from the drains in the flow-away screen room and other drains on the premises. These stationary "channel" screens are framed and are usually constructed of mesh or perforated stainless steel with ¼- to ½ -inch openings. The series arrangement permits removal of a single screen for cleaning and improves efficiency. The three-slope static screen is being used in a few poultry products facilities as primary treatment (USEPA, 1975). Static screens can be used in series to remove coarse particles before further screening by finer mesh screens.

8.1.1.2 Rotary Drum Screens

Rotary drum screens (Figure 8-2) are typically constructed of stainless steel mesh or wedge wire and are designed in one of two ways. In the first design the drum, driven by external rollers, receives the wastewater at one open end and discharges the solids at the other open end. The screen is inclined toward the exit end to facilitate movement of solids. The liquid passes outward through the screen (usually stainless steel screen cloth or perforated sheet) to a receiver and then to the sewer. To prevent clogging, the screen is usually sprayed continuously from a line of external spray nozzles (USEPA, 1974, 1975).

The second type of rotary screen is driven by an external pinion gear. Raw wastewater discharges into the interior of the screen, below the center, and solids are removed in a trough mounted lengthwise with a screw conveyor. The liquid exits from the screen into a box, where the

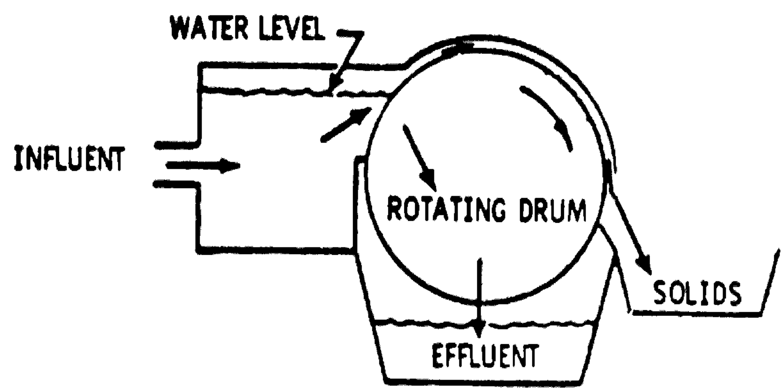

Figure 8-2. General schematic of a rotary drum screen (USEPA, 1980).

screen is partially submerged. The screen itself is typically 40 by 40 mesh, with openings of 0.4 millimeter. To assist in lifting the solids to the conveyor trough, perforated lift paddles are mounted lengthwise on the inside surface of the screen. Externally spraying the screen helps reduce blinding, and Teflon-coated screens reduce clogging by grease. Solid removals of up to 82 percent have been reported (USEPA, 1974, 1975).

8.1.1.3 Brushed Screens

Although most commonly used in sewage treatment, brushed screens can be adapted to remove solids from MPP wastewater. Brushed screens are constructed of a half-circular drum with a stainless steel perforated screen. Mesh size varies according to the type of solid being screened. As influent passes through the screen, rotary brushes sweep across, pushing solids off the screen and into a collection trough. If required, this design can be doubled to dry solid matter further by pushing solids onto a second screen that is pressed and then brushed into the collection trough (Nielsen, 1996).

8.1.1.4 Vibrating Screens

The effectiveness of a vibrating screen depends on rapid motion. Vibrating screens operate at between 99 and 1,800 revolutions per minute; the motion can be circular or straight, varying from 0.08 to 1.27 centimeters (1/32 to ½ inch) total travel. Speed and motion are selected by the screen manufacturer for the particular application (USEPA, 1974, 1975). Usually made of stainless steel, the vibrating screen allows effluent to pass through while propelling solids toward a collection outlet with the aid of gravity (Nielsen, 1996).

Of prime importance in the selection of a proper vibrating screen is the application of the proper cloth. The liquid capacities of vibrating screens are based on the percent of open area of the cloth. The cloth is selected with the proper combination of strength of wire and percent of open area. If the waste solids to be handled are heavy and abrasive, wire of greater thickness should be used to ensure long life. If the material is light or sticky however, the durability of the screening surface might be the least important factor. In such a case, a light wire might be desired to provide an increased percent of open area (USEPA, 1974, 1975).

Poultry products facilities use two types of vibrating screens. For offal recovery, vibrating screens usually have 20-mesh screening; for feather removal, as well as for in-plant primary treatment of combined wastewater, a 36- by 40-mesh screen cloth is used. On most applications a double-crimped, square-weave cloth is used because of its inherent strength and resistance to wire shifting. Vibrating screens with straight-line action are largely used for by-product recovery, while those with circular motion are frequently used for in-plant primary treatment (USEPA, 1975).

8.1.2 Catch Basins

Catch basins separate grease and finely suspended solids from wastewater by the process of gravity separation. The basic setup employs a minimum-turbulence flow-through tank in which solids heavier than water sink to the bottom and grease and fine solids rise to the surface. A basin is equipped with a skimmer and a scraper. The skimmer moves grease and scum into collecting troughs, and the scraper moves sludge into a hopper. From the trough and hopper, the grease, scum, and sludge are pumped to by-product recovery systems. Key factors affecting basin efficiency are the detention time and the rate of solid removal from the basin. Depending on influent concentration, recovery rates of between 60 and 70 percent can be achieved with a detention time of 20 to 40 minutes (Nielsen, 1996).

Typically, catch basins are rectangular and relatively shallow. The preferred length is 1.8 meters or 6 feet. The flow rate is the most important criterion for the design, and the most common sizing factor is determined by measuring the volume of flow during 1 peak hour with 30 to 40 minutes of detention. An equalization tank before the catch basin reduces size requirements significantly (USEPA, 1974, 1975). Depending on the influent characteristics, treatment costs range from $50 to $500 per million gallons treated (FMCITT, 2002).

Tanks can be constructed of concrete or steel. Usually two tanks with a common wall are built in case one becomes unavailable due to maintenance or repairs. Concrete tanks have the inherent advantages of low overall maintenance and permanence of structure. Some facilities, however, prefer to be able to modify their operation for future expansion, alterations, or even relocation. All-steel tanks have the advantage of being semi-portable, more easily field-erected, and more easily modified than concrete tanks. The all-steel tanks, however, require additional maintenance as a result of wear from abrasion and corrosion (USEPA, 1974, 1975).

A tank using all-steel walls and a concrete bottom is the best compromise between the all-steel tank and the all-concrete tank. The advantages are the same as those for steel; however, the all-steel tank requires a footing underneath and supporting members, whereas for the combined tank the concrete bottom forms the floor and supporting footings (USEPA, 1974, 1975).

8.1.3 Dissolved Air Flotation

DAF is used extensively in the primary treatment of MPP wastewaters to remove suspended solids. The principal advantage of DAF over gravity settling is its ability to remove very small or light particles (including grease) more completely and in a shorter time. Once particles reach the surface, they are removed by skimming (Metcalf and Eddy, 1991).

In DAF, the entire influent, some fraction of the influent, or some fraction of the recycled DAF effluent is saturated with air at a pressure of 40 to 50 pounds per square inch (psi) (250 to 300 kilograms per __ (kPa), and then introduced into the flotation tank (Martin and Martin, 1991). The method of operation might cause operating costs to differ slightly, but process performance is essentially equal among the three modes of operation (USEPA, 1974, 1975). With larger wastewater flows, only a fraction of the DAF effluent is saturated and recycled by introduction through a pressure control valve into the influent feed line. From 15 to 120 percent of the influent flow may be recycled in larger units (Metcalf and Eddy, 1991). Under atmospheric pressure in the flotation tank, the air desorbs from solution and forms a cloud of fine bubbles, which transport fine particulate matter to the surface of the liquid in the tank. A skimmer mechanism continually removes the floating solids, and a bottom sludge collector removes any solids that settle. Although unit shape is not important, a more even distribution of air bubbles allows for a shallower flotation tank. Optimum depth settings are between 4 and 9 feet (1.2 to 2.7 meters) (Martin and Martin, 1991).

Chemicals such as polymers and flocculants are often added prior to the DAF system to improve its performance. Typical removals of suspended solids by DAF systems vary between 40 and 65 percent without chemical addition and between 80 and 93 percent with chemical addition. Likewise, oil and grease removal by a DAF system improves from 60 to 80 percent without chemical addition to 85 to 99 percent with chemical addition (Martin and Martin, 1991). A DAF system has many advantages, including its low installation cost, compact design, ability to accept variable loading rates, and low level of maintenance (Nielsen, 1996). The mechanical equipment involved in the DAF system is fairly simple, requiring limited maintenance attention for such parts as pumps and mechanical drives (USEPA, 1974, 1975).

Although alternatives to DAF exist, including electro-flotation, reverse osmosis, and ion exchange, these processes have not been widely adopted by MPP facilities. Cost considerations and technical difficulties associated with these alternative technologies have prevented their incorporation (Johns, 1995). Cowan et al. (1992), however, summarized treatment and costs for extended trials, using a variety of ultrafiltration and reverse osmosis membranes at a number of slaughterhouses in South Africa. They reported that ultrafiltration and reverse osmosis treatment might be the method of choice for treating slaughterhouse wastewaters, both as a pretreatment step prior to discharge to a publicly owned treatment works (POTW) and as a means of reclaiming high-quality reusable water from the treated effluent.

8.1.4 Flow Equalization

Because most MPP facilities operate on a 5-day-per-week schedule, weekly variation of wastewater flow is common. In addition, each facility must be thoroughly cleaned and sanitized every 24 hours. Although wastewater flow is relatively constant during processing, a significant difference in flow occurs between the processing and cleanup periods, producing a substantial diurnal variation in flow and organic load on days of processing. To avoid the necessity of sizing subsequent treatment units to handle peak flows and loads, in-line flow equalization tanks are installed (Metcalf and Eddy, 1991; Reynolds, 1982). Flow equalization tanks can also be installed to store the effluent from the wastewater treatment plant before it is discharged to a

POTW or other effluent disposal destination. The end-of-treatment equalization ensures reduced variation in flow and waste load.

An equalization facility consists of a holding tank and pumping equipment designed to reduce the fluctuations of a waste stream. Such facilities can be economically advantageous, whether the industry is treating its own waste or discharging it into a city sewer after some pretreatment. The tank is characterized by a varying flow into the tank and a constant flow out. For MPP facilities, flow equalization basins usually are sized to provide a constant 24-hour flow rate on processing days, but they may also be sized to provide a constant daily flow rate, even on non-processing days. The major advantages of equalization basins are that the subsequent treatment units are small, because they can be designed for the 24-hour average flow rather than peak flows, and that secondary waste treatment systems operate much better when not subjected to shock loads or variations in feed (USEPA, 1974, 1975). To prevent settling of solids and to control odors, aeration and mixing of flow equalization basins are required. Methods of aeration and mixing include diffused air, diffused air with mechanical mixing, and mechanical aeration (Reynolds, 1982; Metcalf and Eddy, 1991).

8.1.5 Chemical Addition

Chemicals are often added to remove pollutants from wastewater. According to the MPP detailed survey responses, chemicals (e.g., polymers, coagulants, and flocculants such as aluminum or iron salts or synthetic organic polymers) are often added to MPP wastewaters prior to the DAF or clarifier to aggregate colloidal particles through destabilization by coagulation and flocculation to improve process performance. Essentially all the chemicals added are removed with the separated solids. When the solids are disposed of by rendering, the use of organic polymers is preferred to avoid high aluminum or iron concentrations in the rendered product produced. EPA noted during site visits to two independent rendering operations that sludges from DAF units that use chemical addition to promote solids separation are rendered; however, the chemical bond between the organic matter and the polymers requires that the sludges be processed (rendered) at higher temperatures (127°C or 260°F) and for longer retention times. Because the efficacy of aluminum and iron salts and organic polymers is pH-dependent, pH adjustment normally precedes the addition of these compounds to minimize chemical use (Ross and Valentine, 1992; USEPA, 1974, 1975).

8.2 SECONDARY BIOLOGICAL TREATMENT

MPP facilities that discharge directly to navigable waters under the authority of an NPDES permit at a minimum apply both primary and secondary treatment to generated wastewaters (see Table 8-1). The objective of secondary treatment is to reduce of BOD through the removal of the organic matter, primarily in the form of soluble organic compounds, that remains after primary treatment. Although secondary treatment of wastewater can be performed using a combination of physical and chemical unit processes, using biological processes has remained the preferred approach (Peavy, et al. 1986). Wastewater pollutant removal efficiencies of greater than 90 percent can be achieved with biological treatment (Kiepper, 2001). According to responses to the MPP detailed survey, common systems used for biological treatment of MPP wastewater include lagoons, activated sludge systems, extended aeration, oxidation ditches, and sequencing batch reactors. A sequence of anaerobic biological processes followed by aerobic biological processes is commonly employed by MPP facilities that use biological treatment. Kiepper (2001) suggests that approximately 25 percent of U.S. poultry facilities use biological treatment systems consisting of an anaerobic lagoon followed by an activated sludge system.

8.2.1 Anaerobic Treatment

Anaerobic wastewater treatment processes use the microbially mediated reduction of complex organic compounds to methane and carbon dioxide as the mechanism for reducing organic matter and BOD. Because methane and carbon dioxide are essentially insoluble in water, both desorb rapidly. This combination of gases, predominantly methane, is commonly referred to as biogas, and it can be released directly to the atmosphere, collected and flared, or used as a boiler fuel (Clanton, 1997). USEPA (1997) provides estimates of the emission factors (e.g., gram-CH_4 per head of cattle) for these gases. The efficiency of BOD removal by anaerobic treatment can be very high. Anaerobic wastewater treatment processes are more sensitive than aerobic wastewater treatment processes to temperature and loading rate changes.

The production of biogas usually occurs as a two-step process. In the first step, complex organic compounds are reduced microbially to simpler compounds, including hydrogen, short-chained volatile acids, alcohols, and carbon dioxide. Carbon dioxide is generated by the reduction of compounds containing oxygen. A wide variety of facultative and anaerobic microorganisms are responsible for the transformations that occur to obtain energy for maintenance, growth, and nutrients, including carbon for cell synthesis (Metcalf and Eddy, 1991; Nielsen, 1996; Peavy et al., 1986).

In the second step, the alcohols and short-chained volatile acids are reduced further to methane and carbon dioxide by a group of obligate anaerobic microorganisms referred to collectively as methanogens. The methanogens include a number of species of methane-forming bacteria with growth rates significantly lower than those of the facultative and anaerobic microorganisms responsible for the initial reduction of complex compounds into the substrates that are reduced to methane. The biogas produced by the microbial activity typically contains 30 to 40 percent carbon dioxide and 60 to 70 percent methane plus trace amounts of hydrogen sulfide and other gases (Metcalf and Eddy, 1991; Nielsen, 1996; Peavy, 1986; Clanton, 1997).

Because of the negligible energy requirements of anaerobic wastewater treatment processes, these processes are particularly attractive for the treatment of high-strength wastewaters such as MPP wastewaters. Even though anaerobic processes are not capable of producing dischargeable effluents, they can significantly reduce the amount of energy required for subsequent aerobic treatment to produce dischargeable effluents (Metcalf and Eddy, 1991; Nielsen, 1996; Peavy, 1986; Clanton 1997). Anaerobic treatment can also digest organic solid fractions of animal by-products from slaughterhouse facilities (Banks, 1994; Banks and Wang, 1999).

According to the MPP detailed survey, anaerobic lagoons are the most commonly used anaerobic unit process for treating MPP wastewaters. In addition to secondary treatment, anaerobic lagoons provide flow equalization. As noted previously, MPP operations normally occur on a 5-day-per-week-schedule, and lagoons reduce variation in daily flows to subsequent secondary and tertiary treatment processes. However, high-rate anaerobic processes have continued to attract attention as alternatives to anaerobic lagoons. Included are the anaerobic contact (AC), up-flow anaerobic sludge blanket (UASB), and anaerobic filter (AF) processes (Johns, 1995). These alternatives are especially appealing in situations where land for lagoon construction or expansion is not available.

8.2.1.1 Anaerobic Lagoons

A typical anaerobic lagoon is relatively deep, 10 to 17 feet (3 to 5 meters), with a detention time of 5 to 10 days. Many treatment systems comprise at least two lagoons in parallel or series and typical loading rates are between 15 and 20 pounds BOD_5 1,000 cubic feet. The influent wastewater flow is usually near the bottom of the lagoon and has a pH between 7.0 and 8.5. Anaerobic lagoons are not mixed, although some gas mixing occurs. A scum usually develops at the surface, serving several purposes: retarding heat loss, ensuring anaerobic conditions, and reducing emissions of odorous compounds (USEPA, 1974, 1975). Depending on the operating conditions, the BOD reductions by anaerobic lagoons can vary widely. Reductions up to 97 percent of BOD_5, up to 95 percent of suspended solids, and up to 96 percent of COD from the influent have been reported (John, 1995; USEPA, 1974, 1975).

Wastewater organic carbon anaerobic degradation products emitted from anaerobic lagoons include methane and carbon dioxide. Ammonium and hydrogen sulfide are also produced from the degradation of sulfur- and nitrogen-containing compounds found in meat products wastewater. Ammonium can be converted to ammonia in wastewater. The pH of the wastewater determines the emissions produced in the anaerobic lagoons. A pH of 8 or greater causes more ammonia to be emitted; a pH of 6 or lower produces more hydrogen sulfide and carbon dioxide emissions (Zhang, 2001).

Because odors emitted from anaerobic lagoons can be quite offensive, much effort has been put into maintaining oil and grease caps or developing covers for these ponds. Many operators maintain a cap of oil and grease on the anaerobic lagoons or anaerobic equalization tanks to reduce odors and inhibit oxygen transfer (thereby promoting anaerobic conditions). This oil and grease cap can be broken up and made ineffective with the influx of storm water or other highly variable flows to the anaerobic lagoons or anaerobic equalization tanks. Synthetic floating or biogas-inflated covers are used to prevent odors from escaping the lagoons, while simultaneously trapping biogas for collection and use as a fuel source. Covering lagoons also reduces heat loss, which increases microbial reaction rates. Surface area loading rates can thus be increased and lagoon volume reduced (Morris et al., 1998).

8.2.1.2 Alternative Anaerobic Treatment Technologies

Anaerobic Contact System

Mixed liquor solids from the completely mixed anaerobic reactor vessel are separated in a clarifier and returned to the reactor to maintain a high concentration of biomass (Stebor et al., 1990). The high biomass enables the system to maintain a long solids residence time (SRT) at a relatively short hydraulic retention time (HRT). The completely mixed, sealed reactors are normally heated to maintain a temperature of 35 °C (95 °F).

To provide a relatively short HRT, influent wastewater is mixed with solids removed from the effluent, usually by gravitational settling. Because of the low growth rates of anaerobic microorganisms, as much as 90 percent of the effluent solids may be recycled to maintain an adequate solids residence time. A degasifier that vents methane and carbon dioxide is usually included to minimize floating solids in the separation step (Eckenfelder, 1989). BOD loadings and HRTs range from 2.4 to 3.2 kilograms per cubic meter and from 3 to 12 hours, respectively (USEPA, 1974). Anaerobic contact systems are not common because of high capital cost. Nonetheless, these systems have several advantages over anaerobic lagoons, including the ability to reduce odor problems and reduced land requirements. Biogas produced can be used to maintain the reactor temperature.

Up-flow Anaerobic Sludge Blanket (UASB)

The UASB is another anaerobic wastewater treatment process. Influent wastewater flows upward through a sludge blanket of biologically formed granules, and treatment occurs when the wastewater comes in contact with the granules. The methane and carbon dioxide produced generate internal circulation and maintain the floating sludge blanket. Biogas is collected in a gas collection dome above the floating sludge blanket. Particles attached to gas bubbles that rise to the surface of the sludge blanket strike the bottom of degassing baffles, and the degassed particles drop down to the surface of the sludge blanket (Metcalf and Eddy, 1991). Residual solids and granules in the effluent are separated using gravity settling and returned to the sludge blanket. Settling may occur within the reactor or in a separate settling unit. Critical to this operation is the formation and maintenance of granules. Calcium has been used to promote granulation, and iron has been used to reduce unwanted filamentous growth (Eckenfelder, 1989).

The application of the UASB process to MPP wastewater has been a less successful endeavor, thus far, than other anaerobic processes. For example, in treating a slaughterhouse wastewater, it was difficult to generate the sludge granules, thus significantly lowering the level of BOD removal. High fat concentrations led to the loss of sludge (Johns, 1995).

Anaerobic Filter (AF)

The AF is a column filled with various types of media operating as an attached-growth or fixed-film reactor. Wastewater flows upward through the column. Because the microbial population is primarily attached to the media, mean cell residence times on the order of 100 days are possible. Thus, the AF provides the ability to treat wastewaters with COD concentrations as high as 20,000 milligrams per liter (mg/L), as well as resistance to shock loads. Several studies have shown that AFs operated at short HRTs can greatly reduce the organic content of process wastewater (Harper et al., 1999). Most development work on the AF has involved high-strength industrial and food-processing wastewaters.

For the MPP industry, removals of COD are reported from 80 to 85 percent when COD loadings are 2 to 3 kilograms per cubic meter per day (kg/m^3/day). When loadings are higher, performance suffers. Gas tends to have a relatively high methane content (72 to 85 percent). One facility reported BOD concentrations below 500 mg/L, at 33°C (91°F), with a COD loading of 2 to 3 kg/m^3/day. It is important to have effective pretreatment to remove oil and grease and suspended solids because a high oil and grease concentration can cause unstable operation of the system (Harper et al., 1999; Johns, 1995). Based on pilot-scale experiments, anaerobic packed-bed treatment has proven to be an effective alternative to DAF for pretreatment of poultry processing wastewater (Harper et al., 1999).

Anaerobic Sequence Batch Reactor (ASBR)

The ASBR is a variation of the anaerobic contact process that eliminates the need for complete mixing. This treatment is particularly applicable to MPP wastewaters because high protein concentrations eliminate the need for supplemental alkalinity. In addition, an ASBR easily addresses the high levels of solids typically found in MPP wastewaters. One study that used an ASBR system on process wastewater achieved BOD_5 removals ranging from 37 to 77 percent and COD removals ranging from 27 to 63 percent. The resulting biogas was 73 to 81 percent methane, although the high concentration of hydrogen sulfide (~1,800 ppm) in the biogas might necessitate at least partial removal of the hydrogen sulfide prior to use as a fuel (Morris et al., 1998).

8.2.2 Aerobic Treatment

In the treatment of MPP wastewaters, aerobic treatment might directly follow primary treatment. More typically, it follows some form of anaerobic treatment to reduce BOD and suspended solids concentrations to the levels required for discharge. Reduction of ammonia is also a typical role of aerobic processes in the treatment of MPP wastewaters. Many NPDES permits are written with seasonal limits for ammonia because the lower pH and lower temperature of the receiving waters during winter reduce the toxicity of ammonia by converting it to ammonium (Ohio EPA, 1999). Advantages of using aerobic wastewater treatment processes include low odor production, fast biological growth rate, no elevated operation temperature requirements, and quick adjustments to temperature and loading rate changes. The operating costs of aerobic systems, however, are higher than the costs of anaerobic systems, however, for processing livestock wastewater because of the relatively high space, maintenance, management, and energy requirements of artificial oxygenation. The microorganisms involved in the aerobic treatment process require free dissolved oxygen to reduce the biomass in the wastewater (Clanton, 1997).

Aerobic wastewater treatment processes can be broadly divided into suspended- and attached-growth processes. Aerobic lagoons and various forms of the activated-sludge process, such as conventional, extended aeration, oxidation ditches, and sequencing batch reactors

(SBRs), are examples of suspended-growth processes; trickling filters and rotating biological contactors (RBCs) are examples of attached-growth processes. Both use a diverse population of heterotrophic microorganisms that use molecular oxygen in the process of obtaining energy for cell maintenance and growth (Metcalf and Eddy, 1991).

The primary objective of aerobic wastewater treatment processes is transforming soluble and colloidal organic compounds into microbial biomass, with subsequent removal of the biomass by settling or mechanical separation as the primary mechanism for removal of organic matter and BOD. Some oxidation of organic carbon to carbon dioxide also occurs, providing energy for cell maintenance and growth. The degree of carbon oxidation depends on the SRT, also referred to as the mean cell residence time of the process, which determines the age of the microbial population. Processes with long SRTs operate in the endogenous respiration phase of the microbial growth curve and generate less settleable solids per unit of BOD removed. Attached growth processes usually operate at long SRTs (Metcalf and Eddy, 1991).

At SRTs sufficiently long to maintain an active population of nitrifying bacteria, oxidation of ammonia nitrogen to nitrate nitrogen (nitrification) also occurs. However, the rates of growth of the autotrophic bacteria responsible for nitrification, *Nitrosomas* and *Nitrobacter*, are substantially slower than the growth rates of the microorganisms responsible for BOD reduction (Metcalf and Eddy, 1991). Therefore, the amount of nitrification during aerobic treatment depends on the type of treatment system used and its operating conditions.

8.2.2.1 Activated Sludge

The activated sludge process (Figure 8-3) is one of the most commonly used biological wastewater treatment processes in the United States (Metcalf and Eddy, 1991). According to the MPP detailed survey, the most common forms of the activated sludge process used in the MPP industry include conventional, complete mix, extended aeration, oxidation ditch, and sequencing batch reactor. Other forms of the process that are sometimes used tapered aeration, step-feed aeration, modified aeration, contact stabilization, Kraus process, and high-purity oxygen. All of these forms share the common characteristics of short HRTs, usually no more than several hours, and SRTs on the order of 5 to 15 days. This differential is maintained by continually recycling a fraction of the settleable solids separated after aeration by clarification back to the aeration basin. These settled solids contain an active, adapted microbial population and are the source of the term "activated sludge." The microbial population is composed primarily of bacteria and protozoa, which aggregate to form flocs.

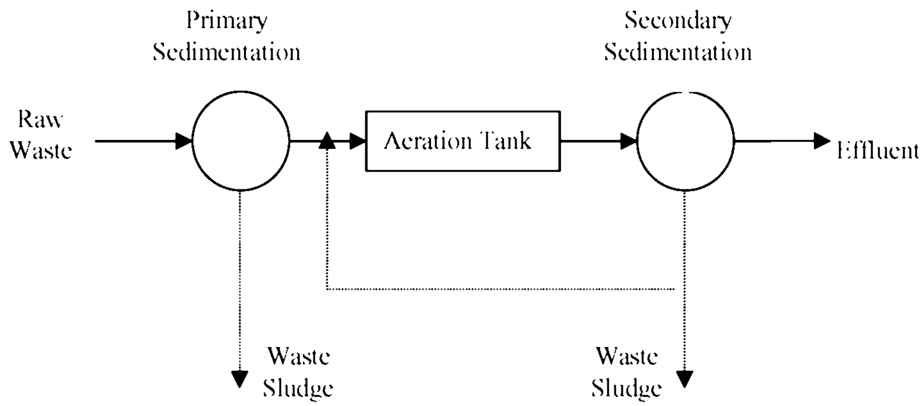

Figure 8-3. Activated Sludge Process (USEPA, 1974).

Floc formation is a critical factor in determining the efficacy of settling after aeration, which is the primary mechanism of BOD and suspended solids reduction. The fraction of activated sludge returned, known as the recycle ratio, determines the SRT of the process and serves as the basis for controlling process performance. Typically, about 20 percent of the settled solids are recycled to maintain the desired concentration of mixed liquor suspended solids (MLSS). The remaining sludge is removed from the system and may be stabilized by using aerobic or anaerobic digestion or by adding chemicals (lime stabilization), which can be followed by dewatering by filtration or centrifugation (USEPA, 1974, 1975).

The activated sludge process is capable of 95 percent reductions in BOD_5 and suspended solids (USEPA, 1974, 1975). In addition, reductions in ammonia nitrogen in excess of 95 percent are possible at temperatures above 10 °C (50 °F) and dissolved oxygen concentrations above 2 mg/L (Johns, 1995). Performance depend on maintaining an adequate SRT and mixed liquor suspended solids with good settling characteristics, which depend on floc formation. Excessive growth of filamentous organisms can impair the settleability of activated sludge. Excessive mixing can lead to the formation of pin flocs, which also have poor settling characteristics. Diffused air used for achieving the required aeration and mechanical systems used for obtaining necessary mixing result in significant energy use (Metcalf and Eddy, 1991).

Conventional

In the conventional activated-sludge process, the aeration tank is a plug flow reactor. A plug flow regime can be made with baffles in aeration tanks. Settled wastewater and recycled activated sludge enter the head end of the aeration tank and are mixed by diffused-air or mechanical aeration. Air application is generally uniform throughout the tank's length. During the aeration period, adsorption, flocculation, and oxidation of organic matter occur. Activated-sludge solids are separated in a secondary settling tank (Metcalf and Eddy, 1991).

Complete Mix

The complete mix activated-sludge process uses a complete mix tank as an aeration basin. The process is an application of the flow regime of a continuous-flow stirred tank reactor. Settled wastewater and recycled activated sludge are introduced, typically at several points in the aeration tank. The organic load on the aeration tank and the oxygen demand are uniform throughout the tank's length (Metcalf and Eddy, 1991).

Extended Aeration

Extended aeration is another variant of the activated-sludge process. The principal difference between extended aeration and the other variants of the activated sludge process is that extended aeration operates in the endogenous respiration phase of the microbial growth curve. Thus, lower organic loading rates and longer HRTs are required. Because of the longer HRTs, typically 18 to 36 hours, extended aeration has the ability to absorb shock loads. Other advantages include its generation of less excess solids from endogenous respiration and greater overall process stability (USEPA, 1974). However, the poor settling characteristics of the aeration basin effluent are a frequently encountered problem with extended aeration. In general, extended aeration treatment facilities are prefabricated package unit operations used for treating relatively low volume wastewater flows for small communities (Metcalf and Eddy, 1991). Extended aeration can be designed to provide a high degree of nitrification.

Oxidation Ditches

The oxidation ditch system represents a modification of the activated-sludge process in terms of its reactor configuration. The oxidation ditch consists of a ring- or oval-shaped channel equipped with mechanical aeration devices (Metcalf and Eddy, 1991). Aerators in the form of brush rotors, disc aerators, surface aerators, draft tune aerators, or fine pore diffusers with submersible pumps provide oxygen transfer, mixing, and circulation in the oxidation ditch. Wastewater enters the ditch, is aerated, and circulates at about 0.8 to 1.2 feet per second (ft/s). Oxidation ditches typically operate in an extended aeration mode with an HRT greater than 10 hours and an SRT of 10 to 50 days (USEPA, 1993). Oxidation ditches provide high removal of BOD and can be designed for nitrification and nitrogen and phosphorus removal (Sen et al., 1990).

Sequencing Batch Reactor

The sequencing batch reactor (SBR) is a fill-and-draw reactor system that uses one or more complete mix tanks in which all steps of the activated sludge process occur. SBR systems have four basic periods: fill (the receiving of raw wastewater), react (the time to complete desired reaction), settle (the time to separate the microorganisms from treated effluent), and idle (the time after discharging the tank and before refilling). These periods may be modified or eliminated, however, depending on effluent requirements. The time for a complete cycle is the total time between the beginning of fill and the end of idle (Martin and Martin, 1991). SBR systems provide high removal of BOD and suspended solids. In addition, these systems can be designed for nitrification and removal of nitrogen and phosphorus. Lo and Liao (1990) reported that SBR technology can be used successfully in the treatment of poultry processing wastewaters for the removal of 5-day BOD (BOD_5) and nitrogen. SBR offers the advantages of operational and loading flexibility, high removal efficiency, competitive capital costs, and reduced operator maintenance (Glenn et al., 1990).

8.2.2.2 Lagoons

Lagoons are widely used in the treatment of MPP wastewater. They are comparatively cheaper than other treatment processes, although they require larger land area. Lagoons can be anaerobic, aerobic, aerated, or facultative. Anaerobic lagoons are discussed in Section 8.2.1.1. Other types of lagoons are discussed in this section.

Aerobic lagoons

Aerobic lagoons, which are also known as aerobic stabilization ponds, are large, shallow, earthen basins that use algae in combination with other microorganisms for wastewater treatment. Low-rate ponds, which are designed to maintain aerobic conditions throughout the liquid column, may be up to 5 feet deep. High-rate ponds are usually shallower, with a maximum depth of 1.5 feet. They are designed to optimize the production of algal biomass as a mechanism for nutrient removal. In aerobic stabilization ponds, oxygen is supplied by a combination of natural surface aeration and photosynthesis. In the symbiotic relationship between the algae and other microorganisms present, the oxygen released by the algae during photosynthesis is used by the nonphotosynthetic microorganisms present in the aerobic degradation of organic matter, while the nutrients and carbon dioxide released by the nonphotosynthetic microorganisms are used by the algae (Martin and Martin, 1991).

Loading rates of aerobic stabilization ponds are in the range of 10 to 300 pounds of BOD per acre per day with an HRT of 3 to 10 days. Soluble BOD_5 reductions of up to 95 percent are possible with aerobic stabilization ponds (Martin and Martin, 1991). Aerobic stabilization ponds can be operated in parallel or in a series. To maximize performance, intermittent mixing is necessary. Without supplemental aeration, dissolved oxygen concentrations vary from supersaturation due to photosynthesis during daylight hours to values at or approaching zero at night, especially with high-rate ponds. In addition, without aeration, settled solids form an anaerobic zone at the bottom of the pond (Reynolds, 1982).

The low cost of aerobic stabilization ponds is offset, especially in colder climates, by seasonal variation in performance. In winter, limited sunlight due to cloud cover and shorter day length limits photosynthetic activity and oxygen release, as well as algae growth. In addition, ice cover limits natural surface aeration. Thus, aerobic stabilization ponds in colder climates can become anaerobic lagoons in winter months with a concurrent deterioration in effluent quality. They can also become a source of noxious odors in the following spring before predominately aerobic conditions become reestablished (Martin and Martin, 1991). Scaief (1975), however, reports no difference in overall treatment efficiency across all seasons for anaerobic-aerobic lagoon systems or anaerobic contact process followed by aerobic lagoons.

Aerated Lagoons

Aerated lagoons are earthen basins used in place of concrete or steel tanks for suspended-growth biological treatment of wastewater. Aerated lagoons are typically about 8 feet (2.4 meters) deep but can be as much as 15 feet (4.6 meters) deep. They can be lined to prevent seepage of wastewater to ground water. Although diffused air systems are used for aeration and mixing, fixed and floating mechanical aerators are more common.

Natural aeration occurs in diffused air systems by air diffusion at the water surface by wind- or thermal-induced mixing and by photosynthesis. Algae and cyanobacteria (blue-green algae) are the microorganisms responsible for most of the photosynthetic activity in a naturally aerated lagoon. Naturally aerated lagoons are approximately 1 to 2 feet deep, so that sunlight can penetrate the full lagoon depth to maintain photosynthetic activity throughout the day. Mechanically aerated lagoons do not have a depth requirement because oxygen is supplied artificially instead of by algal photosynthesis (Zhang, 2001).

Aerated lagoons can be operated as activated sludge units with the recycle of settled solids with relatively short HRTs, or as complete mix systems without settled solids recycle. Systems operated as activated sludge units have a conventional clarifier to recover settled solids for recycle. Aerated lagoons operated as complete mix systems without solids recycle might use a large, shallow, earthen basin in place of a more conventional clarifier for removing suspended solids. Typically, these basins are also used for the storage and stabilization of the settled solids. Usually, a detention time of no less than 6 to 12 hours is required.

One of the principal advantages of aerated lagoons is their relatively low capital cost; however, more land is required. With earthen settling basins, algae growth and odors, along with inconsistent effluent quality, can be problems.

Facultative Lagoons

Facultative lagoons are deeper than aerobic lagoons, varying in depth from 5 to 8 feet. Waste is treated by bacterial action occurring in an upper aerobic layer, a facultative middle layer, and a lower anaerobic layer. Aerobic bacteria degrade the waste in the upper layer, where oxygen is provided by natural surface aeration and algal photosynthesis. Settleable solids are deposited on the lagoon bottom and degraded by anaerobic bacteria. The facultative bacteria in the middle layer degrade the waste aerobically when dissolved oxygen is present and anaerobically otherwise. The facultative lagoons have more depth and smaller surface areas than aerated or aerobic lagoons. They still have good odor control capabilities, however, because of the presence of the upper aerobic layer, where odorous compounds such as sulfides produced by anaerobic degradation in the lower layer are oxidized before emission into the atmosphere. Biochemical reactions in facultative lagoons are a combination of aerobic and anaerobic degradation reactions (Zhang, 2001).

8.2.2.3 Alternate Aerobic Treatment Technologies

Trickling Filters

A trickling filter consists of a bed of highly permeable media to which microbial flora become attached, a distribution system to spread wastewater uniformly over the bed surface, and an under-drain system for collecting the treated wastewater and any microbial solids that have become detached from the media. As the wastewater percolates or trickles down through the media bed, the organic material present is absorbed into the film or slime layer of attached microorganisms. Within 0.1 to 0.2 millimeter of the surface of the slime layer, the organic matter absorbed is metabolized aerobically, providing energy and nutrients for cell maintenance and growth. As cell growth occurs, the thickness of the slime layer increases and oxygen diffusing into the slime layer is consumed before penetration to the media surface occurs. Anaerobic conditions develop near the media surface. In addition, organic matter and nutrients necessary for cell maintenance and growth are lacking because of utilization near the surface of the slime layer. Thus, endogenous conditions develop near the media surface and detachment occurs from hydraulic shear forces as the microorganisms at and near the media surface die. This process is known as "sloughing" and it can be a periodic or continual process depending on the organic and hydraulic loading rates. The hydraulic loading rate is usually adjusted to maintain continual sloughing and a constant slime layer thickness (Metcalf and Eddy, 1991).

The biological community in the trickling filter process includes aerobic, facultative, and anaerobic bacteria; fungi; and protozoans. The aerobic microbial population can include the nitrifying bacteria *Nitrosomonas* and *Nitrobacter*. It can also include algae and higher organisms such as worms, insect larvae, and snails, unlike activated sludge processes. Variations in these biological communities occur according to individual filter and operating conditions (Metcalf and Eddy, 1991).

Trickling filters have been classified as low-rate, intermediate-rate, high-rate, super high-rate, roughing, and two-stage, based on filter medium, hydraulic and BOD_5 loading rates, recirculation ratio, and depth (Metcalf and Eddy, 1991). Hydraulic loading rates range from 0.02 to 0.06 gallon per square foot per-day for low-rate filters to 0.8 to 3.2 gallons per square foot per day for roughing filters. Organic loading rates range from 5 to 25 pounds BOD_5 per 10^3 square foot per day to 100 to 500 pounds BOD_5 per 10^3 square foot per day. Low-rate and two-stage trickling filters can produce a nitrified effluent, while roughing filters provide no nitrification. Others might provide some degree of nitrification. Low-rate and intermediate-rate trickling filters traditionally have used rock or blast furnace slag as filter media; while high-rate filters employ only rock. Super high-rate filters use plastic media, while roughing filters may be constructed using plastic or redwood media; two-stage filters may use plastic or rock media (Metcalf and Eddy, 1991).

Trickling filters are secondary wastewater treatment unit processes and require primary treatment for removal of settleable solids and oil and grease to reduce the organic load and prevent plugging. Secondary clarification is also necessary. Lower energy requirements make trickling filters attractive alternatives to activated sludge processes. Mass-transfer limitations, however, limit the ability of trickling filters to treat high-strength wastewaters. To successfully treat such wastewaters, a two- or three-stage system is necessary. When staging of filters is used, a clarifier usually follows each stage. The overall BOD_5 removal efficiency can be as great as 95 percent (USEPA, 1974).

Rotating Biological Contactors

RBCs also employ an attached film or slime layer of microorganisms to adsorb and metabolize wastewater organic matter, providing energy and nutrients for cell maintenance and growth. RBCs consist of a series of closely spaced circular disks of polystyrene or polyvinyl chloride mounted on a longitudinal shaft. The disks are rotated alternately, exposing the attached microbial mass to the wastewater being treated for adsorption of organic matter and nutrients and then to the atmosphere for adsorption of oxygen. The rate of rotation controls oxygen diffusion into the attached microbial film and provides the shear force necessary for continual biomass sloughing (Metcalf and Eddy, 1991). Mass transfer limitations limit the ability of RBCs to treat high-strength wastewaters, such as MPP wastewaters. RBCs can be operated in series like multistage trickling filter systems; a tapered feed arrangement is possible. An example of such an arrangement would be three RBCs in parallel in stage one, followed by two RBCs in parallel in stage two, and one RBC in stage three.

As with trickling filters, hydraulic and organic loading rates are criteria used for design. Design values can be derived from pilot plant or full-scale performance evaluations or by using the theoretical or empirical approaches (Metcalf and Eddy, 1991). Typical hydraulic and organic loading rate design values for secondary treatment are 2 to 4 gal/ft^2/day and 2.0 to 3.5 pounds total $BOD_5/10^3$ square foot per day, respectively with effluent BOD_5 concentrations ranging from 15 to 30 mg/L. For secondary treatment combined with nitrification, typical hydraulic and organic loading rate design values for are 0.75 to 2 gal/ft^2/day and 1.5 to 3.0 pounds $BOD_5/10^3$ square foot per day, respectively, producing effluent BOD_5 concentrations between 7 and 15 mg/L and NH_3 concentrations of less than 2 mg/L (Metcalf and Eddy, 1991).

The major advantages of RBCs are (1) relatively low installation cost; (2) ability to combine secondary treatment with ammonia removal by nitrification, especially in multistage systems; and (3) resistance to shock loads. The major disadvantage is the need to enclose them especially in cold climates, to maintain high removal efficiencies, control odors, and minimize problems with temperature sensitivity (USEPA, 1974). Early RBC units experienced operating problems, including shaft and bearing failures, disk breakage, and odors. Design modifications have been made to address these problems, including increased submergence to reduce shaft and bearing loads (Metcalf and Eddy, 1991).

Although RBCs are used in both the United States and Canada for secondary treatment of domestic wastewaters, use for secondary treatment of high-strength industrial wastewaters such as MPP wastewaters has been limited. The energy requirements associated with activated-sludge processes might make RBCs more attractive for treating MPP wastewaters, especially following physical/chemical and anaerobic pretreatment. A BOD_5 reduction of 98 percent is achievable with a four-stage RBC (USEPA, 1974).

8.3 TERTIARY TREATMENT

Tertiary or advanced wastewater treatment is usually considered to be any treatment beyond conventional secondary treatment to remove suspended or dissolved substances. Tertiary wastewater treatment can have one or several objectives. One common objective is further reduction in suspended solids concentration after secondary clarification. Nitrogen and phosphorus removal also are common tertiary wastewaters treatment objectives. Existing wastewater treatment plants can be retrofit without the addition of new tanks or lagoons to incorporate biological nutrient removal (Randall et al., 1999). In addition, tertiary wastewater treatment can be used to remove soluble refractory, toxic, and dissolved inorganic substances. In the treatment of MPP wastewaters, tertiary wastewater treatment is most commonly used for further reductions in nutrients and suspended solids.

8.3.1 Nutrient Removal

In primary and secondary wastewater treatment processes, some reduction of nitrogen and phosphorus occurs by the separation of particulate matter during settling or cell synthesis. The

limited assimilative capacity of receiving waters, however, can require additional reductions in nitrogen and phosphorus concentrations before discharge. Both biological and physicochemical unit processes can be used to reduce nitrogen and phosphorus concentrations in wastewater. Biological processes are typically more cost effective than physicochemical processes. Moreover, retrofitting existing secondary treatment systems for biological nutrient removal can lead to reduced costs given the lower requirements for energy use and chemical addition (Randall and Mitta, 1998; Randall et al., 1999).

8.3.1.1 Nitrogen Removal

The removal of nitrogen from wastewaters biologically is a two-step process, beginning with nitrification and followed by denitrification. Nitrification, a microbially mediated process, is also a two-step process, beginning with the oxidation of ammonia to nitrite and followed by the oxidation of nitrite to nitrate. Bacteria of the genus *Nitrosomonas* are responsible for the oxidation of ammonia to nitrite; bacteria of the genus *Nitrobacter* are responsible for the subsequent oxidation of nitrite to nitrate (Metcalf and Eddy, 1991).

Following the nitrification process under anaerobic conditions, nitrite and nitrate are reduced microbially by denitrification, producing nitrogen gas as the principal end product. Small amounts of nitrous oxide and nitric oxide can also be produced, depending on environmental conditions. Because nitrogen, nitrous oxide, and nitric oxide are essentially insoluble in water, desorption occurs immediately. Although nitrification can occur in combination with secondary biological treatment, denitrification is usually a separate unit process following secondary clarification. Because the facultative and anaerobic microorganisms responsible for denitrification are heterotrophs, denitrification after secondary clarification requires the addition of a source of organic carbon for cell maintenance and growth. Methanol is probably the most commonly added source of organic carbon for denitrification, although raw wastewater (bypassed to the denitrification treatment tank), biosolids, and a variety of other substances also can be used (Metcalf and Eddy, 1991; USEPA, 1993).

The chemical transformations that occur during nitrification and denitrification are outlined below (Metcalf and Eddy, 1991):

Nitrification:

$NH_4^+ + 1.5\ O_2 \longrightarrow NO_2^- + 2H^+ + H_2O$ (*Nitrosomonas*)

$NO_2^- + 0.5\ O_2 \longrightarrow 2NO_3^-$ (*Nitrobacter*)

Denitrification (using methanol as carbon source):

$NO_3^- + 1.08\ CH_3OH + H^+ \longrightarrow 0.065\ C_5H_7O_2N + 0.47\ N_2 + 0.76\ CO_2 + 3 + 2.44\ H_2O$

Nitrification unit processes can be classified based on the degree of separation of the oxidation of carbonaceous and nitrogenous compounds to carbon dioxide and nitrate, respectively (Metcalf and Eddy, 1991). Combined carbon oxidation and nitrification can be achieved in all suspended-growth secondary wastewater treatment processes and with all attached-growth processes except roughing filters. Carbon oxidation and nitrification processes can also be separated, with carbon oxidation occurring first, using both suspended- and attached-growth processes in a variety of combinations. Both suspended- and attached-growth processes are used for denitrification, following combined carbon oxidation and nitrification.

Nitrification and denitrification can be combined in a single process. With this approach, wastewater organic matter is the source of organic carbon for denitrification. Thus, the cost of adding a supplemental source of organic carbon and providing re-aeration after denitrification is eliminated. Also eliminated is the need for intermediate clarifiers and return sludge systems. The proprietary four-stage Bardenpho process (Metcalf and Eddy, 1991) is a combined nitrification-denitrification process that uses both organic carbon in untreated wastewater and organic carbon released during endogenous respiration for denitrification. Separate aerobic and anoxic zones provide for nitrification and then denitrification.

Other processes include the Modified Ludzack-Ettinger (MLE), A^2/O, and University of Capetown (UCT) processes (USEPA, 1993). The A^2/O and UCT processes were developed to remove both nitrogen and phosphorus. SBR can also be used to achieve nitrification and denitrification (USEPA, 1993). Biological nitrogen and phosphorus removals can be enhanced in oxidation ditch systems by controlling aeration to maintain reliable aerobic, anoxic, and anaerobic volumes. For example, a BNR oxidation ditch process developed by Virginia Tech for retrofitting a domestic wastewater treatment facility was capable of (1) maintaining less than 0.5 mg/L total phosphorus and between 3 and 4 mg/L total nitrogen in the discharged effluent year-round and (2) significantly reducing operational costs by reducing the need for electrical energy, aeration, and chemical addition (Sen et al., 1990).

Nitrification is easily inhibited by a number of factors, such as toxic organic and inorganic compounds, pH, and temperature. In poorly buffered systems, the hydrogen ions released when ammonia is oxidized to nitrite or nitrate can reduce pH to an inhibitory level without the addition of a buffering agent.

A pH of at least 7.2 is generally recognized as necessary to maintain a maximum rate of nitrification (Grady and Lim, 1980). Based on the following theoretical stoichiometric relationships for the growth of *Nitrosomonas* and *Nitrobacter*, the alkalinity (HCO_3^-) used is 8.64 milligrams HCO_3^- per milligram of ammonia nitrogen oxidized to nitrate nitrogen. For *Nitrosomonas*, the equation is

$$55\ NH_4^+ + 76\ O_2 + 109\ HCO_3^- \rightarrow C_5H_7O_2N + 54\ NO_2^- + 57\ H_2O + 104\ H_2CO_3$$

and for *Nitrobacter*, the equation is

$$400\ NO_2^- + NH_4^+ + 4\ H_2CO_3 + HCO_3^- + 195\ O_2 \rightarrow C_5H_7O_2N + 3\ H_2O + 400\ NO_3^-$$

As noted above, one of the advantages of using wastewater organic matter as the source of organic carbon for denitrification is the elimination of the cost of an organic carbon source such as methanol. A second advantage is elimination of the need to add a source of bicarbonate alkalinity in poorly buffered systems to compensate for the utilization of alkalinity resulting from nitrification and the associated reduction in pH. As shown in the overall energy reaction for nitrification, two hydrogen ions are released for every ammonium ion oxidized to nitrate:

$$NH_4^+ + 2\ O_2 \rightarrow NO_3^-\ 2\ H^+\ H_2O$$

However, denitrification releases one hydroxyl ion for each nitrate ion reduced to nitrogen gas, as shown in the following overall energy reaction for denitrification using methanol as the source of organic carbon:

$$6\ NO_3^- + 5\ CH_3OH \rightarrow 5\ CO_2 + 3\ N_2 + 7\ H_2O + 6\ OH^-$$

In addition, hydrogen ions are required for cell synthesis during denitrification, as shown by the following relationship:

$$3\ NO_3^- + 14\ CH_3OH + CO_2 + 3\ H^+ \rightarrow 3\ C_5H_7O_2N + H_2O$$

Therefore, using wastewater organic matter as the source of organic carbon for denitrification in a combined nitrification/denitrification system usually eliminates the need for adding a source of alkalinity to prevent pH inhibition of nitrification. Very poorly buffered systems are the exception.

Using wastewater organic matter as the source of organic carbon for denitrification also reduces aeration requirements for BOD removal in suspended-growth systems. Based on half reactions for electron acceptors, 1/5 mole of NO_3^- is equivalent to 1/4 mole of O_2. Therefore, each unit mass of NO_3^- - N is equivalent to 2.86 units of O_2 in its ability to oxidize organic matter, if cell synthesis is ignored. Some organic matter, however, must be converted into cellular material and is not completely oxidized. Nevertheless, it does represent the removal of BOD through removal of excess suspended solids and an additional reduction in aeration requirements for BOD removal. Therefore, the actual reduction in BOD realized by using wastewater organic matter as the source of organic carbon for denitrification is marginally higher than 2.86 mass units of BOD per unit NO_3^- - N denitrified. The magnitude of this marginal increase depends on the SRT in the denitrification reactor; the magnitude decreases as SRT increases. Assuming an

SRT of 7.5 days, a ratio of BOD_5 in wastewater used as an organic carbon source for denitrification to NO_3^- - N of 3.5 should provide for essentially complete denitrification.

An added positive consequence of using wastewater organic matter as the source of organic carbon for denitrification is that sludge production per unit BOD removed is lower because denitrification is an anoxic process that occurs under anaerobic conditions. Typical cell yield under anaerobic conditions is 0.05 mg volatile suspended solids (VSS) per milligram BOD removed versus 0.6 milligram VSS per mg BOD removed under aerobic conditions (Metcalf and Eddy, 1991).

Both *Nitrosomonas* and *Nitrobacter* are autotrophic, mesophilic microorganisms with relatively low growth rates in comparison to heterotrophs, even under optimal conditions. Thus, maintaining an actively nitrifying microbial population might become harder and require excessively long SRTs in cold weather (Metcalf and Eddy, 1991; USEPA, 1993).

8.3.1.2 Phosphorus Removal

To achieve low effluent discharge limits, phosphorus can be removed from wastewater by using biological treatment and/or physicochemical methods. Biological treatment is cheaper than physicochemical methods and is particularly suitable for facilities with high flows.

Biological Treatment

Microorganisms used in secondary wastewater treatment require phosphorus for cell synthesis and energy transport. In the treatment of typical domestic wastewater, between 10 and 30 percent of influent phosphorus is removed by microbial assimilation, followed by clarification or filtration. However, phosphorus assimilation in excess of requirements for cell maintenance and growth, known as luxury uptake, can be induced by a sequence of anaerobic and aerobic conditions (Metcalf and Eddy, 1991).

Acinetobacter is one of the organisms primarily responsible for the luxury uptake of phosphorus in wastewater treatment. In response to volatile fatty acids present under anaerobic conditions, stored phosphorus is released. Luxury uptake and storage for subsequent use of phosphorus occurs, however, when anaerobic conditions are followed by aerobic conditions. Thus, removal of phosphorus by clarification or filtration following secondary treatment is increased because biosolids are already wasted (Metcalf and Eddy, 1991; Reddy, 1998; USEPA, 1987).

Several proprietary processes use luxury uptake to remove phosphorus from wastewater during suspended-growth secondary treatment. Included are the A/O, PhoStrip, and Bardenpho processes. In addition, SBRs can be operated to remove phosphorus. In the PhoStrip process, phosphorus is stripped from the biosolids generated using anaerobic conditions to stimulate release. The soluble phosphorus generated is then precipitated using lime. Both the A/O and PhoStrip processes are capable of producing final effluent total phosphorus concentrations of less than 2 mg/L. A modified version of the A/O process, the A^2/O process, along with the Bardnepho process and SBR is capable of combined biological removal of nitrogen and phosphorus (Metcalf and Eddy, 1991; Reddy, 1998; USEPA, 1987).

Physicochemical Process

Phosphorus can be removed from wastewater by precipitation using metal salts or lime. The metal salts most commonly used are aluminum sulfate (alum) and ferric chloride. Ferrous sulfate and ferrous chloride can also be used. Use of lime is less common because of the operating and maintenance problems associated with its use and the large volume of sludge produced. Polymers are often used in conjunction with metal salts to improve the degree of phosphorus removal. Ion exchange, discussed in Section 8.4.3.3, is also an option for phosphate phosphorus removal, but it is rarely used in wastewater treatment (Metcalf and Eddy, 1991).

Chemicals can be added to remove phosphorus (1) in raw wastewater prior to primary settling, (2) in primary clarifier effluent, (3) in mixed liquor with suspended-growth treatment processes, (4) in effluent from biological treatment processes prior to secondary clarification, or (5) after secondary clarification (Metcalf and Eddy, 1991). In Option 1 (pre-precipitation), precipitated phosphorus is removed with primary clarifier solids, whereas removal is done with secondary clarifier solids for Options 2 through 4 (co-precipitation). In Option 5, additional clarification or filtering facilities are required. In the treatment of MPP wastewaters, the addition of chemicals for phosphorus removal prior to DAF is a possible option (Metcalf and Eddy, 1991).

With alum addition, phosphorus is precipitated as aluminum phosphate ($AlPO_4$), and aluminum hydroxide ($Al(OH)_3$). With the addition of ferric chloride, the chemical species produced are ferric phosphate ($FePO_4$) and ferric hydroxide ($Fe[OH]_3$). Lime addition produces calcium phosphate ($Ca_5[PO_4]_3[OH]$), magnesium hydroxide ($Mg[OH]_2$), and calcium carbonate ($CaCO_3$). In the case of alum and iron, 1 mole theoretically will precipitate 1 mole of phosphate. However, competing reactions and the effects of alkalinity, pH, trace elements, and ligands found in wastewater make bench-scale or full-scale tests necessary to determine dosage rates. Because of coagulation and flocculation, suspended solids are also removed with the precipitated phosphorus species. With the addition of aluminum and iron salts, the addition of a base to maintain a pH in the range of 5 to 7 to optimize the efficacy of phosphorus precipitation might be necessary, depending on the wastewater's buffer capacity (Metcalf and Eddy, 1991; Reddy, 1998; USEPA, 1987).

When lime is used, it is usually calcium hydroxide ($Ca(OH)_2$). Because a reaction with natural bicarbonate alkalinity forms $CaCO_3$ as a precipitate, an increase to a pH of 10 or higher is necessary for the formation of $Ca_5(PO_4)_3(OH)$. After lime is used to precipitate phosphorus, recarbonation with carbon dioxide is necessary to lower pH (Metcalf and Eddy, 1991; Reddy, 1998; USEPA, 1987).

When chemical addition is used for phosphorus removal, additional benefits are realized. Because of coagulation and flocculation, effluent BOD and suspended solids concentrations are also reduced, especially when chemical addition occurs after secondary clarification (Metcalf and Eddy, 1991; Reddy, 1998; USEPA, 1987).

8.3.2 Residual Suspended Solids Removal

Simple clarification after secondary wastewater treatment might not reduce the concentration of suspended solids to the level necessary to comply with concentration or mass discharge permit limits or both. Granular-medium filtration usually is used to achieve further reductions in suspended solids concentrations. This practice also provides further reductions in BOD. Filtration is a solid-liquid separation in which the liquid passes through a porous material to remove as much fine material as possible (Reynolds, 1982).

Granular-Medium Filters

Metcalf and Eddy (1991) lists nine different types of commonly used granular-medium filters. They are classified as semi-continuous or continuous, depending on whether backwashing is a batch or a semi-continuous operation or a continuous operation. Within each classification, there are several different types, depending on bed depth, type of filtering medium, and stratification (or lack thereof) of the filter medium. Shallow, conventional, and deep bed filters are typically about 11 to 16, 30 to 36, and 72 inches, respectively, in depth. Sand or anthracite is used alone in mono-medium filter beds. Dual-medium beds can be composed of anthracite and sand, activated carbon and sand, resin beads and sand, or resin beads and anthracite. In multi-medium beds some combination of anthracites, sand, garnet or ilmenite, activated carbon, and resin beads is used. In stratified filter beds, the effective size of the filter medium increases with the direction of wastewater flow. Flow through the filter medium can be accomplished by gravity alone or under pressure with the use of rapid filters.

Several mechanisms are responsible for the removal of suspended solids in granular-medium filters. Included are straining, sedimentation, impaction, and interception. Chemical adsorption, physical adsorption, flocculation, and biological growth can also contribute to suspended solids removal (Metcalf and Eddy, 1991).

The operation of granular-medium filters has two phases: filtration and cleaning or re-generation. The second phase, commonly called backwashing, involves removing captured suspended solids when effluent suspended solids begin to increase or when head loss across the filter bed reaches an acceptable maximum value. With semi-continuous filtration, filtration and backwashing occur sequentially; with continuous filtration, the filtration and backwashing phases occur simultaneously Backwashing is usually accomplished by reversing flow through the filter medium with sufficient velocity to expand or fluidize the medium to dislodge accumulated suspended solids and transport them to the surface of the filter bed. Compressed air can be used in conjunction with the backwashing water to enhance removal of accumulated suspended solids. The backwashing water with the removed suspended solids typically is returned to a primary clarifier or a secondary biological treatment process unit (Metcalf and Eddy, 1991).

Filtration and backwashing occur simultaneously with continuous processes, and there is no suspended solids breakthrough or terminal head loss value. One type of continuous filter is the traveling bridge filter, which comprises a series of cells operated in parallel. Backwashing of individual cells occurs sequentially, while the other cells continue to filter influent. Deep bed filters, which are upflow filters, are backwashed by continually pumping sand from the bottom of the filter through a sand wash at the top of the filter. The clean sand is distributed on the top of the filter bed. Thus, sand flow is countercurrent to the flow of the wastewater being filtered (Metcalf and Eddy, 1991). In general, all types of granular-medium filters produce effluent with an average turbidity of 2 nephelometric turbidity units (NTU) or less from high-quality filter influent having a turbidity of 7 to 9 NTU. This level translates to a suspended solids concentration of 16 to 23 mg/L (Metcalf and Eddy, 1991). Lower quality filter influent requires chemical addition to achieve an effluent turbidity of 2 NTU or less. Chemicals commonly used include a variety of organic polymers, alum, and ferric chloride. They remove specific contaminants, including phosphorus, metal ions, and humic substances (Metcalf and Eddy, 1991).

Problems with the use of granular-medium filtration include turbidity breakthrough with semi-continuous filter even though terminal head loss has not been reached. Problems with both semi-continuous and continuous filters include buildup of emulsified grease, loss of filter medium; agglomeration of biological floc, dirt, and filter medium or the media's formation of mud balls and reduction of the effectiveness of filtration and backwashing; and development of cracks in the filter bed (Metcalf and Eddy, 1991).

8.3.3 Alternative Tertiary Treatment Technologies

8.3.3.1 Nitrogen Removal

In addition to the biological treatment discussed in Section 8.3.1.1, various physicochemical processes are used to remove nitrogen. The principal physical and chemical processes used for nitrogen removal are air stripping, breakpoint chlorination, and selective ion exchange. All these technologies, however, are reported to have limited use because of their cost, inconsistent performance, and operating and maintenance problems (Johns, 1995; Metcalf and Eddy, 1991). Air stripping and breakpoint chlorination are discussed in this section, and ion exchange is discussed in Section 8.3.3.3. Note that these three technologies remove nitrogen when the nitrogen is in the form of ammonia (air stripping, breakpoint chlorination, and ion exchange) or nitrate ions (ion exchange). Because raw meat-processing wastewater contains nitrogen primarily in organic form, the technologies might require additional upstream treatment to convert the organic nitrogen into ammonia or nitrate.

Air Stripping

Air stripping of ammonia is a physical process of transferring ammonia from wastewater into air by injecting the wastewater into air in a packed tower. To achieve a high degree of ammonia reduction, elevating the wastewater pH to at least 10.5, usually by adding lime, is necessary. The removal efficiencies of ammonia nitrogen can be as high as 98 percent with effluent ammonia concentrations of less than 1 mg/L (USEPA, 1974, 1975). Because of the high operation and maintenance costs associated with air stripping, the practical application of air stripping of ammonia is limited to special cases, such as those where a high pH is needed for other reasons (Metcalf and Eddy, 1991).

The high operation and maintenance costs for air stripping of ammonia can be attributed in part to the formation of calcium carbonate scale within the stripping tower and feed lines. Absorption of carbon dioxide from the air stream used for stripping leads to calcium carbonate scale formation. The scale varies in nature from soft to very hard. Because the solubility of ammonia increases as temperature decreases, the amount of air required for stripping ammonia increases significantly as temperature decreases for the same degree of removal. If ice formation occurs in the stripping tower, a removal efficiency is further reduced (Johns, 1995; Metcalf and Eddy, 1991).

Secondary environmental impacts also occur because air stripping of ammonia without subsequent scrubbing in an acid solution results in the emission of ammonia to the atmosphere. This emission can lead to unpleasant odors and air pollution. Particulate matter is also formed in the atmosphere, following the reaction of ammonia with sulfate. In addition, stripping towers can emit volatile organic compounds and cause noise (Peavy et al., 1986; Metcalf and Eddy, 1991).

Breakpoint Chlorination

Breakpoint chlorination involves the addition of chlorine to wastewater to oxidize ammonia to nitrogen gas and other stable compounds. This technology has been successfully used as a second, stand-by ammonia removal process for ammonia concentrations up to 50 mg/L (Green et al., 1981). Before chlorine reacts with ammonia, it first reacts with the oxidizable substances present, such as Fe^{+2}, Mn^{+2}, H_2S, and organic matter to produce chloride ions. After meeting the immediate demand of the oxidizable compounds, excess chlorine reacts with ammonia to form chloramines. With increased chlorine dosage, the chloramines formed are converted to nitrogen trichloride, nitrous oxide, and nitrogen gas. The destruction of chloramines occurs until the breakpoint chlorination point is achieved. After this point, free residual chlorine becomes available (Metcalf and Eddy, 1991). Therefore, the required chlorine dosage to destroy ammonia is achieved when breakpoint chlorination is reached. The overall reaction between chlorine and ammonia can be described by the following equation:

$$2NH_3 + 3HOCl \longrightarrow N_2 + 3H_2O + 3HCl$$

Stoichiometrically, the breakpoint reaction requires a weight ratio of 7.6 CL_2 to 1 NH_4^+-N, but in actual practice ratios of from 8:1 to 10:1 are common (Green et al., 1981). Process efficiencies consistently range between 95 and 99 percent. The process is easily adapted to complete automation, which helps ensure quality and operational control (Reynolds, 1982). The optimal pH for breakpoint chlorination is between 6 and 7. Because chlorine reacts with water, forming hydrochloric acid, a pH depression to below 6 might occur with poorly buffered wastewaters. Such a drop increases chlorine requirements and slows the rate of reaction.

One advantage of breakpoint chlorination for ammonia removal is its relative insensitivity to temperature. In addition capital costs are small relative to other ammonia removal processes, such as ammonia stripping and ion exchange (Green et al., 1981). However, many organic compounds react with chlorine to form toxic compounds, including trihalomethanes and other disinfection by-products, which can interfere with beneficial uses of receiving waters. Therefore, dechlorination is necessary. Both sulfur dioxide and carbon adsorption are used for dechorination; sulfur dioxide is the more common because of its lower cost. Another disadvantage of breakpoint chlorination for nitrogen removal is the potential for an undesirable increase in total dissolved solids (Metcalf and Eddy, 1991).

8.3.3.2 Residual Suspended Solids Removal

Microscreens can also be used to achieve supplemental removal of suspended solids. This practice also provides further reduction in BOD. Microscreens involve solid-liquid separation, a process in which liquid passes through a filter fabric to remove as much fine material as possible.

Microscreens

Microscreens are surface filtration devices used to remove a portion of the residual suspended solids from secondary effluents and from stabilization pond effluents. Microscreens are low-speed, continually backwashed, rotating-drum filters that operate under gravity conditions. Typical filter fabrics have openings of 23 or 35 micrometers and cover the periphery of the drum. Wastewater enters the open end of the drum and flows outward through the rotating screening cloth. The collected solids are backwashed into a trough located at the highest point in the drum and returned to primary or secondary treatment processes (Metcalf and Eddy, 1991).

Typical suspended solids removal is about 55 percent; the range is 10 to 80 percent. Some problems with microscreens are incomplete solids removal and an inability to handle fluctuations in suspended solids concentrations. Reducing drum rotational speed and decreasing frequency of backwashing can increase removal efficiency, but screening capacity is thereby reduced. Typical hydraulic loading rates and drum speeds are 75 to 150 gal/ft^2/min and 15 ft/min at a 3-inch head loss to 115 to 150 ft/min at a 6-inch head loss (Metcalf and Eddy, 1991).

8.3.3.3 Removal of Organic Compounds and Specific Ions

Various advanced wastewater treatment processes are used for removing organic compounds and target ions from wastewater. The carbon adsorption process has been widely used to remove organic compounds from different types of wastewater. To remove target ions from wastewater, ion exchange processes have been used. To prevent filter plugging and to ensure proper operation, granular activated carbon columns and ion exchange columns are usually preceded by filtration units.

Carbon Adsorption

Both granular and powdered activated carbon can be used to further reduce concentrations of organic compounds, including refractory compounds, after secondary biological treatment. With granulated activated carbon (GAC), the adsorption process occurs in steps. Initially, organic matter moves from the bulk liquid phase to the liquid-solid interface by advection and diffusion. Next, diffusion of the organic matter through the macropore system of the granulated activated carbon occurs at adsorption sites in micropores and submicropores. Although adsorption also occurs on the surface and in the macro- and mesopores of activated carbon granules, the surface areas of the micro- and submicropores greatly exceed the surface areas of the granule and the macro- and mesopores. With powdered activated carbon (PAC), adsorption occurs primarily on the surface of the carbon particles (Metcalf and Eddy, 1991; Weber, 1972).

When the rate of adsorption equals the rate of desorption, the adsorptive capacity of the carbon has been reached and regeneration is necessary. GAC is regenerated easily by oxidizing the adsorbed organic matter in a furnace. About 5 to 10 percent of GAC is destroyed in the regeneration process and must be replaced (Metcalf and Eddy, 1991). Also, the adsorptive capacity of regenerated GAC is slightly less than that of virgin GAC. A major problem with the use of PAC is that the regeneration methodology is not well defined.

A fixed-bed reactor is often used for wastewater treatment using GAC. Flow is downward through the carbon column, which is supported by an under-drain system. There might be provision for backwashing and surface washing to limit head loss due to the accumulation of particulate matter. Upflow and expanded bed columns are also used (Metcalf and Eddy, 1991). With biological wastewater treatment, PAC is usually added to the basin or to the secondary clarifier effluent. In the "PACT' process, the PAC is added directly to the aeration basin (Metcalf and Eddy, 1991).

Tertiary treatment using activated carbon can remove up to 98 percent of colloidal and dissolved organics measured as BOD_5 and COD in a wastewater stream. Effluent BOD_5 concentrations can be as low as 2 to 7 mg/L with effluent COD concentrations in the range of 10 to 20 mg/L (Metcalf and Eddy, 1991).

Use of activated carbon is common in water treatment to remove organic compounds from raw water supplies responsible for color, taste, and odor problems. In the treatment of MPP wastewaters, the use of carbon adsorption is generally limited to tertiary treatment prior to wastewater reuse as potable water.

Ion Exchange

Ion exchange is a unit process in which ions of a given species are displaced from an insoluble exchange material (resin) by ions of a different species in solution. This process is most commonly used to soften water by removing calcium and magnesium ions. It is also used in industrial wastewater treatment to recover valuable constituents, including precious metals and radioactive materials. It may be operated in batch or continuous mode. In a batch process, the resin is stirred with the water to be treated in the reactor until reaction is complete. The spent acid is removed by settling and is subsequently regenerated and reused. In a continuous process, the exchange material is placed in a bed or a packed column, and the water to be treated is passed through it. When the resin capacity is exhausted, the column is backwashed to remove trapped solids and then regenerated (Metcalf and Eddy, 1991). To maintain continuous operation, typically two or more columns are used, so that when one of the columns is off-line (backwashing or regenerating), the other column(s) are on-line (operational).

Although ion exchange is known to occur with a number of natural materials, a broad spectrum of synthetic exchange resins are available. Synthetic resins consist of networks of hydrocarbon radicals with attached soluble ionic functional groups. The hydrocarbon radicals are cross-linked in a three-dimensional matrix, with the degree of cross-linking imparting the ability to exclude ions larger than a given size. The nature of the attached functional groups largely determines resin behavior. There are four major classes of ion exchange resins: strongly acidic and weakly acidic cation exchange resins, and strongly basic and weakly basic anion resins. Strongly acidic resins contain functional groups derived from strong acids such as sulfuric acid (H_2SO_4) whereas functional groups of weakly acidic resins are derived from weak acids such as carbonic acid (H_2CO_3). Similarly, strongly basic resins contain functional groups derived from quaternary ammonium compounds, whereas functional groups of weekly basic resins are derived from weak base amines. The exchangeable counter ion of an acidic cation resin may be the hydrogen ion or some other monovalent cation, such as sodium. For a basic anion resin, the exchangeable counter ion may be the hydroxide ion or some other monovalent anion. The regenerant will be the corresponding acid, base, or simple salt (Weber, 1972).

The use of ion exchange in the treatment of MPP wastewaters is less common. The ion exchange technology may be used to remove ammonium ions from wastewater, nitrate ions from the nitrified wastewater, or phosphorus, or total dissolved solids from wastewater. The functional group to be used depends on the target ions (NH_4^+, NO_3^- , or other ions) to be removed.

To minimize head loss through ion exchange columns and possible resin fouling, ion exchange usually follows granular medium filtration and possibly carbon adsorption. In addition, special provisions are necessary for regeneration waste. Another waste stream requiring disposal is exhausted resin. Regeneration efficiency decreases with time, and replacement becomes necessary to maintain process performance.

8.4 DISINFECTION

Disinfection destroys remaining pathogenic microorganisms and is generally required for all MPP wastewaters being discharged to surface waters. Chlorine injection is the most commonly used method for wastewater disinfection; however, use of ultraviolet (UV) light for disinfection is not uncommon (USEPA, 2001). Ozone injection and combinations of UV and ozonation are also attractive disinfection alternatives.

8.4.1 Chlorination

The chemical reactions that occur when chlorine is added to wastewater have been described in the discussion of breakpoint chlorination for ammonia removal. For disinfection, the objective is to add chlorine at a rate that results in a free chlorine residual to ensure that pathogen kill occurs. As discussed previously, a free chlorine residual occurs only after reactions with readily oxidizable ions, organic matter, and ammonia are complete. Therefore, chlorine requirements for disinfection depend on wastewater characteristics at the time of disinfection. The degree of mixing and contact time in a chlorine contact chamber are critical factors in the process of disinfection using chlorine. The chlorine compounds most commonly used for wastewater disinfection are chlorine gas, calcium hypochlorite, sodium hypochlorite, and chlorine dioxide (Metcalf and Eddy, 1991). Chlorine dioxide is an unstable and explosive gas that requires special handling and safety precautions.

As also noted in the discussion of breakpoint chlorination for ammonia removal (Section 8.4.3.1), dechlorination is often necessary to reduce effluent toxicity. Sulfur dioxide addition is the most commonly used approach. Sulfur dioxide reacts with both free chlorine and chloramines with chloride ions, resulting primarily in the end production of chloride ions (Metcalf and Eddy, 1991).

8.4.2 Ozonation

Because ozone is chemically unstable, it decomposes to oxygen very rapidly after generation and thus must be generated on-site. The most efficient method of producing ozone is by electrical discharge. Ozone is generated from air or pure oxygen when a high voltage is applied across the gap of narrowly spaced electrodes. It is an extremely reactive oxidant, and it is generally believed that bacterial kill through ozonation occurs directly because of cell wall disintegration. Ozone is a more effective virucide than chlorine. Ozone does not produce dissolved solids and is not affected by ammonia concentrations or pH. In addition, no chemical residue is produced by using ozone because ozone decomposes rapidly to oxygen and water. Using ozone increases the dissolved oxygen concentration, controls odor, and provides removal of soluble refractory organics. One disadvantage of using ozone is that it must be generated on-site because of its chemical instability (Metcalf and Eddy, 1991).

8.4.3 Ultraviolet Light

Suspended or submerged lamps producing UV light are another option for wastewater disinfection, especially for the inactivation of the parasites *Cryptosporidium parvum* and *Giardia lamblia*. It is known that chlorine does not have an effect on *Cryptosporidium* and that high doses of ozone are required to complete inactivation (Brooks and Stone, 2001). Radiation emitted from the UV light is an effective bactericide and virucide that does not generate any toxic compound. Low-pressure mercury arc lamps are the principal means of generating the UV energy used for disinfection. Operationally, the lamps are either suspended outside the liquid to be treated or submerged in the liquid. Where the lamps are submerged, they are encased in quartz tubes to prevent cooling effects on the lamps. Radiation from low-pressure lamps with a wavelength of around 254 nanometers penetrates the cell wall of the microorganisms and is absorbed by cellular materials in a process that prevents replication or causes death of the cell (Stone and Brooks, 2001). Turbidity in the water absorbs UV energy and shields the microorganisms, and therefore it should be kept low for better results (Metcalf and Eddy, 1991). UV irradiation, whether at low or medium pressure, performs similarly in achieving a 4-log inactivation of *Cryptosporidium* (Stone and Brooks, 2001). UV irradiation in combination with ozonation can also be applied for the reuse of chiller water in poultry operations (Diaz and Law, 1997).

8.5 EFFLUENT DISPOSAL

The most common disposal methods for treated MPP wastewaters are discharge to adjacent surface waters under the authority of an NPDES permit or discharge to POTWs. Disposal by land application, however, is an alternative method that can eliminate the need for tertiary treatment of wastewater (Johns, 1995; Uhlman, 2001).

Land application by sprinkler or flood irrigation can be a feasible alternative to surface water discharge if the appropriate land is available and other prerequisites can be satisfied. These prerequisites include soils with moderately slow to moderately rapid permeability and soils with the ability to collect any surface runoff that occurs. In addition, the production of a marketable crop is necessary to provide a mechanism for the removal of nitrogen, phosphorus, and other nutrients from the soils to which wastewater has been applied (Uhlman, 2001).

In land application, wastewater disposal is performed using a combination of percolation and evapotranspiration with microbial degradation of organic compounds occurring in the soil profile. Both crop uptake (removal) and nitrification-denitrification are mechanisms of nitrogen reduction. Crop uptake, chemical precipitation, and adsorption to soil particles are mechanisms of phosphorus reduction. Water balances are managed to match crop water use and salt-leaching needs with irrigation to maintain water percolation to ground water within the system design (Uhlman, 2001). Nitrogen balances are also developed to match estimated nitrogen losses and crop uptake to minimize percolate nitrate losses to ground water. Spray and flood irrigation systems for wastewater disposal (Figure 8-4) can be designed with the objective of either wastewater disposal or wastewater reuse. If disposal is the objective, the application or hydraulic loading rate is controlled not by crop requirements but by the limiting design parameter, soil permeability or constituent loading. In many situations, nitrogen loading rate is the limiting design parameter to minimize leaching of nitrate nitrogen to ground water. Phosphorus loading rate is not usually a limiting design parameter because of the ability of soils to immobilize

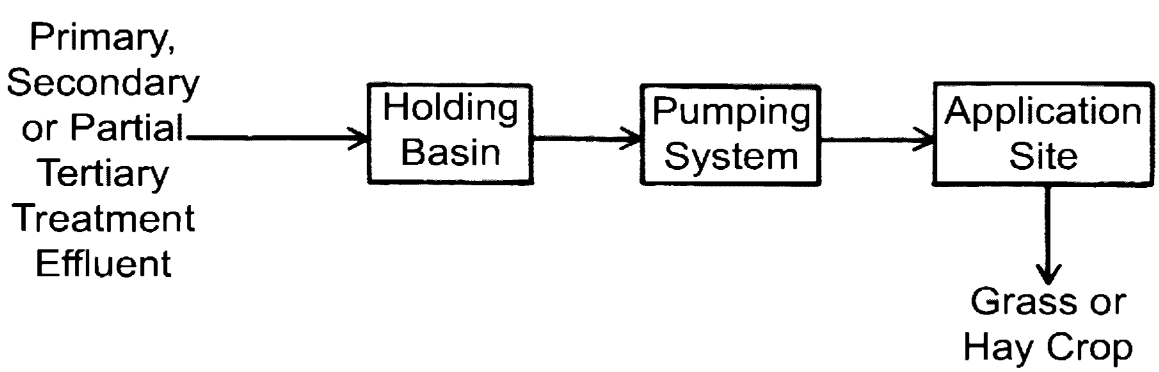

Figure 8-4. Spray/Flood Irrigation System (USEPA, 1974).

phosphorus. The ability of soils to adsorb phosphorus is finite, however, and saturation of the upper zone of the soil profile can occur (USEPA, 1974).

Wastewater can be applied to crops using solid set or center pivot sprinklers or flood irrigation. With flood irrigation, also known as ridge-and-furrow irrigation, wastewater is released into furrows between rows of growing crops. Fields irrigated using flood irrigation are graded to allow uniform irrigation of the entire field by gravity flow, with provision for capture and containment of any return flow. Intermittent application cycles, usually every 4 to 10 days, maintain aerobic conditions in the soil. In arid and semiarid areas, land application as a method for wastewater disposal is especially attractive because the low rates of precipitation allow higher hydraulic loading rates than in more humid regions. However, the accumulation of soluble salts (total dissolved solids) in the root zone of the soil profile can be problematic in arid and semi-arid regions because of the lack of precipitation, resulting in reduced leaching of these salts from the soil profile. Such salt accumulations are toxic to many plant species. Salt accumulations in the soil profile also occur when conventional irrigation practices are used in arid and semiarid climates. The typical approach used to deal with accumulations of soluble salts from irrigation is periodic hydraulic loadings to leach accumulated soluble salts from the root zone of the soil, although some ground water contamination might result. Reduction of total dissolved solids concentrations in MPP wastewaters prior to land application is another option, but the associated cost might make direct discharge to surface waters a more attractive option in arid and semiarid climates.

Wastewater treatment systems using sprinkler or flood irrigation as a method for MPP wastewater disposal should provide at least secondary treatment before using the wastewater for irrigation. Secondary treatment of wastewater reduces BOD and suspended solids loading rates and thereby reduces the potential of these parameters to act as limiting design factors. Secondary treatment also reduces the odor and vermin problems associated with flood irrigation or sprinkler application of less-treated wastewater. A holding basin is a necessary element to allow intermittent wastewater applications and to provide storage when climatic or soil conditions do not allow irrigation. Ideally, storage should be adequate to limit wastewater application to the active plant growth period of the year. Thus, storage of wastewater for at least 6 months in cold climates is desirable (Loehr et al., 1979). For a more complete discussion of wastewater disposal by land application, refer to Loehr et al. (1979) and Overcash and Pal (1979).

In the absence of proper system design and operation, land application as a method of wastewater disposal can adversely affect surface and ground water quality. Excessive organic loading rates can result in reduced soil permeability and generation of noxious odors due to the development of anaerobic conditions. Excessive nitrogen application rates can lead to nitrate leaching to ground water. Excessive phosphorus application rates can lead to surface or ground water contamination, or both, if the irrigated soils become saturated with phosphorus (Metcalf and Eddy, 1991).

Exposure to pathogens is also a concern, especially with spray irrigation systems, given the potential for pathogen transport in aerosols. Virus transmission through aerosols is the most serious concern because a single virus can cause infection. In contrast, infectious doses of bacterial pathogens range from at least 10^1 organisms for *Shigella* to as high as 10^8 organisms for enteropathogenic *E. coli* (Loehr et al., 1979). Using one or more of several recommended practices, however, can reduce the transmission of pathogens in aerosols. Those practices include (1) creating buffer zones with or without hedgerows, (2) using low-pressure nozzles aimed downward, (3) avoiding wastewater spraying under windy conditions, and (4) restricting irrigation to daylight hours (Johns, 1995).

Especially in colder climates, wastewater land application systems require storage facilities to avoid application to frozen, snow-covered, or saturated soil. Wastewater application under these conditions can result in surface runoff, transporting pollutants to adjacent surface waters. Refer to Loehr et al. (1979) for a detailed discussion of storage requirements for wastewater land application systems in various climates.

8.6 SOLIDS DISPOSAL

Typically, biosolids generated during the treatment of MPP wastewaters are aerobically digested before disposal by land application. Biosolids may be dewatered before land application. Rendering is a common disposal method for wastewater solids recovered by DAF before secondary treatment. Generally, the use of metal salts prior to DAF is avoided if rendering is used for the disposal of recovered solids because of the potential for unacceptably high concentrations of aluminum or iron in rendering products. Alternatives to rendering for the disposal of DAF solids are land application and land filling. High-quality by-products (e.g., blood) are often segregated from DAF solids and other MPP wastewater treatment plant (WWTP) sludges because some rendering operations (e.g., pet food manufacturing) require high-quality by-products as input.

EPA noted during site visits to two independent rendering operations that sludges from DAF units that use chemical additions to promote solids separation are rendered; however, the chemical bond between the organic matter and the polymers requires that the sludges be processed (rendered) at higher temperatures (260 °F) and longer retention times. EPA also observed during site visits that some independent renderers reject raw materials that have (1) a pH below 4 (with 3 being a general cutoff), (2) ferric chloride due to its corrosive nature, and (3) other contamination (e.g., pesticides).

8.7 POLLUTION PREVENTION AND WASTEWATER REDUCTION PRACTICES

8.7.1 Wastewater Minimization and Waste Load Reduction Practices at MPP Facilities

For many MPP facilities, wastewater flow minimization and waste load reduction practices have been incorporated into normal business practices to reduce production costs and maximize profits. As with other competitive industries, unessential consumption of water and energy, along with the additional costs of waste treatment, can mean the difference between profitability and operational losses. Although water reuse and by-product recovery are standard approaches for wastewater flow minimization and waste load reduction at MPP facilities, the extent of these practices and their effectiveness vary widely among individual facilities. Some large facilities have installed on-site advanced wastewater treatment systems that treat facility effluent, allowing this water to be reused for some applications within the facility. Other facilities have changed sanitation practices to reduce overall water use and effluence. For example, one independent renderer noted during an EPA site visit that his facility had fully converted from a wet cleaning method to a dry cleaning method in the product shipment area to minimize water pollution.

Industry sources have estimated that the implementation of the U.S. Department of Agriculture Food Safety and Inspection Service's (USDA FSIS) Hazard Analysis and Critical Control Points (HACCP) program has increased water usage by 20 to 25 percent. USDA FSIS disagrees with industry's assertion that implementation of HACCP has necessarily required greater use of water. Furthermore, USDA FSIS asserts that its regulatory performance standards provide for numerous water reuse opportunities (see 9 CFR 416.2(g)).

USDA FSIS promulgated the HACCP program on July 25, 1996 (61 FR 38806). The HACCP rule requires all MPP facilities to develop and implement a system of preventive controls to improve the safety of their products, with an emphasis on reducing microbial contamination from fecal material. The Sanitation Requirements for Official Meat and Poultry Establishments Rule (USDA, 1996; 64 FR 56400) also mandates that all MPP facilities develop and implement written standard operating procedures for sanitation.

As described below, opportunities remain for reducing potable water use and wastewater flow in MPP facilities through water conservation techniques and multiple use and reuse of water. In addition, opportunities exist to reduce waste loads to wastewater treatment facilities by physically collecting solid materials before using water to clean equipment and facilities. Gelman et al. (1989) and Berthouex et al. (1977) provide case studies of minimizing waste and water use at poultry processing and hog processing facilities, respectively. Both conclude that facilities can save costs through readily available process modifications that can significantly reduce water use, wastewater flow and loadings.

8.7.2 General Water Conservation and Waste Load Reduction Techniques

Reducing water use is important because facilities that institute a water use reduction program also reduce their raw wastewater load (Scaief, 1975). Numerous studies have demonstrated that water use in MPP facilities can be reduced significantly. For example, Carawan and Clemens (1994) reported a reduction in water use of 75 gallons per pig processed, a 33 percent reduction, after a water conservation program was implemented at a hog slaughtering and rendering operation. In addition, it has been demonstrated that substantial reductions in wastewater pollutant concentrations can be achieved by implementing waste load reduction practices. Reductions in BOD_5 in hog processing wastewater of 40 percent have been reported (Carawan and Clemens, 1994). However, both goals can be achieved only when management recognizes that a reduction in processing costs and an increase in profitability can be realized by reducing the costs of potable water and wastewater treatment. Thus, a management commitment to water conservation logically depends on the cost of potable water, and a management commitment to waste load reduction depends on the cost of wastewater treatment. When potable water is being obtained from private on-site wells, there is obviously less economic incentive to conserve water than when water is being purchased from a public utility or private water purveyor. In addition, wastewater treatment costs can be less visible for direct dischargers and less sensitive to pollutant concentrations.

The development of water conservation and waste load reduction programs in the MPP industry, as well as in other industries, begins with the development of general profiles of water use and wastewater pollutant concentrations over one or preferably several 24-hour periods to determine the relative significance of processing and cleanup activities. This step is usually accompanied or followed by measuring water use in individual phases of the processing process to identify opportunities for reducing water use. For example, measuring water flow to scalders and chillers in poultry processing to determine overflow rates can identify rates in excess of the FSIS requirements. Measuring and regulating water pressure for carcass washing to ensure that the FSIS requirements are not being exceeded is another example of how water use can be reduced in MPP operations. Measuring and regulating small flows such as those from hand-washing operations can also significantly reduce water use and wastewater volume.

The daily cleanup and sanitation of processing facilities and equipment contributes substantially to water use and wastewater pollutant load and probably presents the greatest opportunity for reductions. Typically, both water use and wastewater pollutant load can be reduced substantially by initially "dry cleaning" processing areas and equipment to collect meat scraps and other materials for disposal by rendering instead of the common practice of using water as a "broom." Although subsequent screening before wastewater treatment provides for recovery of larger particles, fine particulate matter and soluble proteins, fats, and carbohydrates are not recovered and are manifested as an increased pollutant load to the wastewater treatment plant. Gelman et al. (1989) have shown that BOD in cleanup wastewater in poultry processing can be reduced from 20 to 50 percent by initially dry cleaning processing areas and equipment. Concurrently, dry cleaning can increase the production of inedible rendered products. Dry cleaning of live animal holding areas can also reduce the amount of water required for the cleaning these facilities and the pollutant load in the wastewater generated. Responses to the MPP detailed survey indicate that dry cleaning is a much more common practice at meat processing facilities than at poultry processing facilities (47 percent for meat processing respondents versus 17 percent for poultry processing respondents).

To be successful, water conservation and waste load reduction plans must be implemented and performance monitored. Implementation requires employee training, which should be continual, and possibly the installation of new equipment such as hose nozzles and foot valves at hand wash stations that automatically shut off when not in use. Conversion to high-pressure, low-volume systems for carcass washing and general sanitation can also reduce water consumption. Continual monitoring of water use and waste loads, however, is a necessity to avoid slippage in performance.

8.7.3 Multiple Use and Reuse of Water

USDA FSIS guidelines do not preclude the multiple use and reuse of water in MPP facilities as practices to reduce potable water consumption and the discharge of treated wastewater. Although it is obvious that acceptable multiple use and reuse strategies must avoid contact with products intended for human consumption, a significant fraction of the water used in meat and poultry processing does not involve such contact.

The multiple use of water most commonly occurs in poultry processing. Witherow et al. (1978) report that water conservation through multiple use in poultry processing is rewarded by savings in processing cost and reduced requirements for wastewater treatment. Examples include using scalder overflow to flume feathers from mechanical de-feathering equipment and using chiller overflow to flume inedible viscera to screens for recovery before rendering. Combination UV irradiation and ozonation can be effective treatment for reused poultry chiller overflow (Diaz and Law, 1997). These are examples of countercurrent recycling, in which water reuse is countercurrent to product flow.

In contrast to multiple use, water reuse requires treatment as a prerequisite. The degree of treatment determines how the water can be reused. For example, reuse of wastewater after tertiary treatment to remove suspended solids along with double disinfection, such as chlorination followed by UV light, is permissible for purposes where there is no contact with industrial processes. Examples of this are evaporative condenser cooling and holding lot, parking lot, and wastewater treatment plant cleaning.

Further treatment to meet drinking water standards by using unit processes such as coagulation and flocculation followed by settling and then filtration and disinfection, expands the potential for reuse of wastewater treatment plant secondary effluent. Examples of permissible uses in hog processing include use on the kill floor up to the first carcass wash, flushing of large intestines (chitterlings), and cleaning of receiving pens and rendering facilities. Other possible uses of wastewater treated to meet drinking water standards include use for maintaining equipment (such as pump cooling) and use as boiler makeup water.

In the poultry processing industry, a number of unit process-level reuse strategies have also been explored. One example is the reuse of final chiller overflow, following diatomaceous earth filtration and disinfection, as scalder makeup water or for fluming of harvested giblets. As noted by Carawan (1994), it was demonstrated in the late 1970s that poultry processing wastewater treated to meet primary drinking water standards can be safe, when mixed with an equal amount of potable water, for use in poultry processing.

Based on data provided by the MPP detailed survey, EPA estimates that reuse of water in MPP facilities is relatively rare. About 8 percent of the poultry processing respondents to the survey indicated that they reuse water from the wastewater treatment plant in the de-feathering or evisceration areas. Other water reuse practices such as reusing effluent for screen washing or cleanup of outside areas are even less common as indicated by the detailed survey responses.

8.7.4 Specific Pollution Control Practices Identified by EPA in Previous Regulatory Proposals

The following relevant Best Available Technology Economically Achievable (BAT) in-plant pollution control practices were listed in EPA's *Development Document for Proposed Effluent Limitations Guidelines for the Poultry Segment of the Meat Product and Rendering Process Point Source Category* (USEPA, 1975):

- Control and minimize flow of freshwater at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines. Hand washers may require installation of press-to-operate valves. This also implies that screened wastewaters are recycled for feather fluming.
- Confine bleeding and provide for sufficient bleed time. Recover all collectable blood and transport it to rendering in tanks rather than by dumping it on top of feathers or offal.
- Use minimum USDA-approved quantities of water in the scalder and chillers.
- Shut off all unnecessary flow during worm breaks.
- Consider the reuse of chiller water as makeup water for the scalder. This might require preheating the chiller water with the scalder overflow water by using a simple heat exchanger.
- Use pretreated poultry processing wastewaters for condensing all cooking vapors in on-site rendering operations.
- Consider dry offal handling as an alternative to fluming. A number of plants have demonstrated the feasibility of dry offal handling in modern high-production poultry slaughtering operations.

- Consider steam scalding as an alternative to immersion scalding.
- Control water use in gizzard splitting and washing equipment.
- Provide for frequent and regular maintenance attention to by-product screening and handling systems. A backup screen might be required to prevent by-products from entering municipal or private waste treatment systems.
- Dry clean all floors and tables prior to washdown to reduce the waste load. This is particularly important in the bleeding, cutting, and further processing areas and all other areas where material spills tend to occur.
- Use high-pressure, low-volume spray nozzles or steam-augmented systems for plant washdown.
- Minimize the amount of chemicals and detergents to prevent emulsification or solubilization of solids in the wastewaters. For example, determine the minimum effective amount of chemical for use in the scald tank.
- Control inventories of raw materials used in further processing so that none of these materials are ever wasted to the sewer. Spent raw materials should be routed to rendering.
- Treat separately all overflow of cooking broth for grease and solids recovery.
- Reduce the wastewater from thawing operations.
- Make all employees aware of good water management practices, and encourage them to apply these practices.
- Treat offal truck drainage before sewering. One method is to steam sparge the collected drainage and then screen it.

- In-plant primary systems—catch basins, skimming tanks, air flotation, and the like—should provide for at least a 30-minute detention time of the wastewater. Frequent, regular maintenance attention should be provided.

The following BAT in-plant pollution control practices were listed in EPA's *Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Processor Segment of the Meat Products Point Source Category* (USEPA, 1974):

- Use water control systems and procedures to reduce water use considerably below that of Best Practicable Control Technology Currently Available (BPT) except for small processors.
- Reduce the wastewater from thawing operations.
- Provide for improved collection and greater reuse of cure and pickle solutions.
- Prepackage products (e.g., hams) before cooking to reduce grease contamination of smokehouse floors and walls.
- Revise equipment cleaning procedures to collect and reuse wasted materials, or to dispose of them through channels other than the sewer.
- Reuse or recycle noncontaminated water whenever possible.
- Initiate and continually enforce meticulous dry cleanup of floors before washing.
- Install properly designed catch basins and maintain them with frequent regular grease and solids removal.

It should be noted that the in-plant controls and modifications required to achieve the July 1, 1983, effluent limitations included water control systems and procedures to reduce water use to about 50 percent of the water used to meet BPT (USEPA, 1974).

8.7.5 Nonregulatory Approaches to Pollution Prevention

EPA is using nonregulatory approaches to facilitate reduction of wastewater generation in the MPP industry. Specifically, the Agency has formed partnerships with industry and state agencies to develop guidance materials and implement innovative practices for reducing waste.

Participants in developing this program include the American Meat Institute, the American Association of Meat Processors, USDA, several state agencies, EPA programs and regions, and other interested constituent groups. For example, EPA and its partners have developed best management practice guidance materials for the handling and disposal of rendering materials, and for chloride, nitrogen, and phosphorus discharges. The project team evaluated these management practices and developed measures of their effectiveness. The final tools will be deployed over the long term through the active leadership of the industry's trade associations. In addition, EPA partnered with the Iowa Waste Reduction Center (IWRC) and the Iowa Department of Natural Resources (IDNR) to pilot test the guide with five companies. IWRC and IDNR provided technical assistance and implementation consulting to the five companies. The pilot was completed in 2002, and EPA evaluated the pilot and incorporated the lessons learned into the final version of the *EMS Guide for Meat and Poultry Processors*. The final guide was completed in summer 2003 and is being marketed throughout the meat and poultry processing industry.

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SECTION 9

TECHNOLOGY OPTIONS

Based on the post-proposal evaluation of treatment in place (TIP) at meat and poultry products (MPP) facilities from data supplied in the MPP detailed surveys, site visits, and sampling episodes, EPA identified a number of potential technology options that are modifications of the options proposed as the basis for effluent limitations for the MPP industry. This section describes the technology options that EPA considered for the final rule.

Table 9-1 summarizes the treatment units that comprise the technology options EPA considered for the proposed and final rule. Options 2, 2+P, 2.5, 2.5+P, 3, 4, and 5 are applicable to non-small facilities, while Options 1 and 2 are applicable to small facilities. Small and non-small MPP facilities are defined in Section 2. It should be noted that after the proposed rule was published (67 FR 8582; February 25, 2002), EPA no longer considered Option 3 because of difficulty finding it in place at MPP facilities, and no longer considered Options 2+P and 5 because of the relatively high costs expected.

Table 9-1. Summary of Technology Options Considered for the MPP Industry

Treatment Units	Technology Options[a]							
	1[b]	2	2+P	2.5	2.5+P	3	4	5
BOD[c] Removal by Biological Treatment	X	X	X	X	X	X	X	X
Partial Nitrification	X							
Nitrification		X	X	X	X	X	X	X
Partial Denitrification				X	X			
Denitrification						X	X	X
Phosphorus Removal[d]			X		X		X	X
Filtration							X[e]	X
Disinfection	X	X	X	X	X	X	X	X

X: treatment unit is included in that option.
[a] For direct discharging facilities only.
[b] For small direct discharging facilities only.
[c] BOD–biochemical oxygen demand.
[d] Phosphorus removal by chemical precipitation.
[e] Applicable to poultry facilities only.

It should be noted that EPA develops effluent limitations guidelines (ELGs) and standards based on the performance of a combination of processes and treatment technologies but does not require their use. Instead, the specific processes and technologies used to treat MPP wastewaters are left to the discretion of the individual MPP facilities. After promulgation of the final rule, EPA would require compliance with the final numerical limitations and standards; MPP facilities would not be required to use specific processes or technologies. The options were developed based on information indicating that every facility in the MPP industry has some level of pretreatment. Pretreatment might encompass one or more of the following processes: screening, grit removal, dissolved air flotation (DAF) with or without chemical addition, equalization, and/or anaerobic lagoon treatment.

9.1 Option 1

Option 1 consists of biological treatment for biochemical oxygen demand (BOD) removal, partial nitrification, and disinfection (Figure 9-1). Partial nitrification is the process by which a portion of organic nitrogen and ammonia nitrogen are converted to nitrate plus nitrite nitrogen.

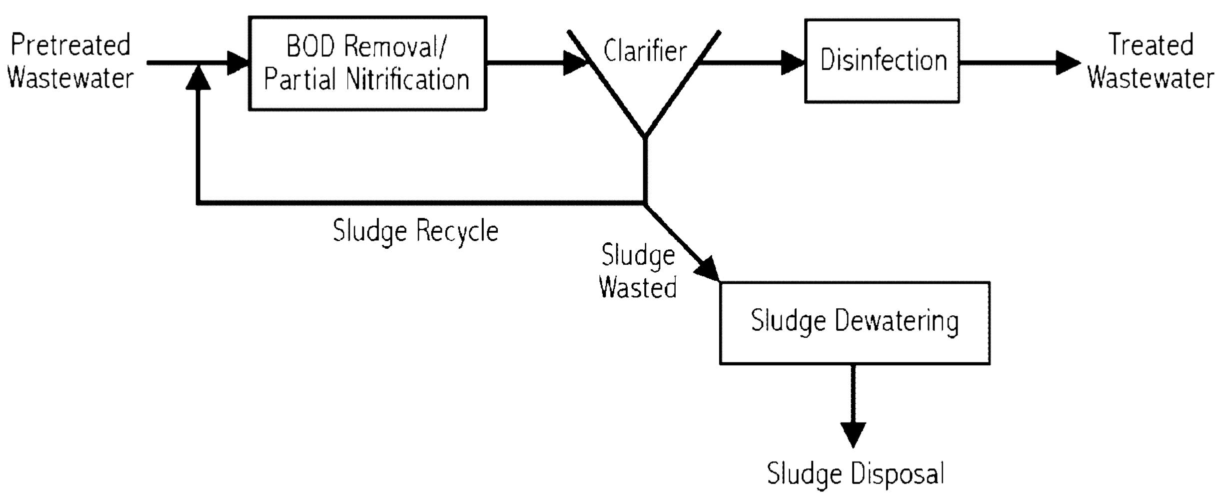

Figure 9-1. Treatment Unit Schematic for Technology Option 1 (Partial Nitrification)

9.2 Option 2

Option 2 is the same as Option 1 but has more complete nitrification rather than partial nitrification. Option 2 consists of BOD removal, nitrification, and disinfection (Figure 9-2). A facility with a nitrification system typically has an aerobic reactor in which BOD reduction and nitrification take place. The pretreated wastewater enters the aerobic reactor, where BOD removal and total Kjedahl nitrogen (TKN) removal (nitrification) occur. Nitrification in the aerobic reactor converts TKN in the wastewater to nitrate/nitrite. The wastewater from the aerobic reactor then flows into the clarifier(s), where the biomass is separated from the wastewater. One portion of the biomass that is separated is then recycled to the aerobic reactor, while the other portion is wasted (removed for further processing and ultimate disposal).

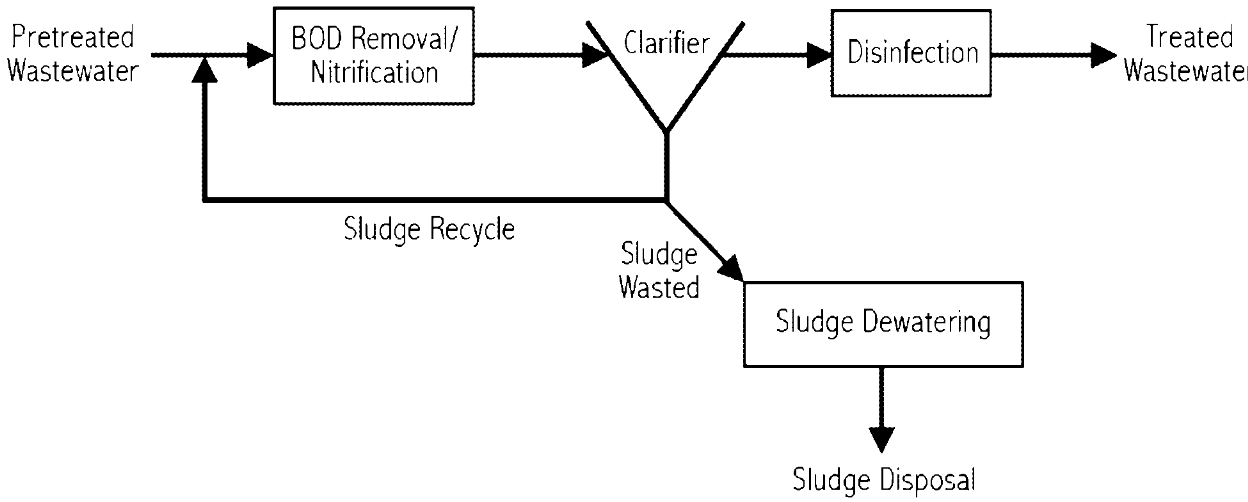

Figure 9-2. Treatment Unit Schematic for Technology Option 2 (Nitrification)

9.3 Option 2+P

This option is the same as Option 2 but also includes phosphorus removal. Therefore, Option 2+P consists of BOD removal, nitrification, phosphorus removal, and disinfection (Figure 9-3). A facility with a nitrification system typically has an aerobic reactor in which BOD reduction and nitrification take place. The influent wastewater enters the aerobic reactor, where

BOD removal and TKN removal (nitrification) occur. Nitrification in an aerobic reactor converts TKN in the wastewater to nitrate/nitrite. The pretreated wastewater then flows through the mix tanks into the clarifier(s), where the biomass is separated from the wastewater. One portion of the separated biomass is recycled to an aerobic reactor while the other portion is wasted. A chemical such as alum is fed at or before the mix tanks for phosphorus removal.

Phosphorus removal by chemical precipitation is achieved by adding chemicals to precipitate the phosphate present in the wastewater. Chemicals may be added to the primary, secondary, or tertiary processes, or at multiple locations in a plant. Chemicals used for phosphorus precipitation include metal salts such as alum (aluminum sulfate), ferric chloride, and lime.

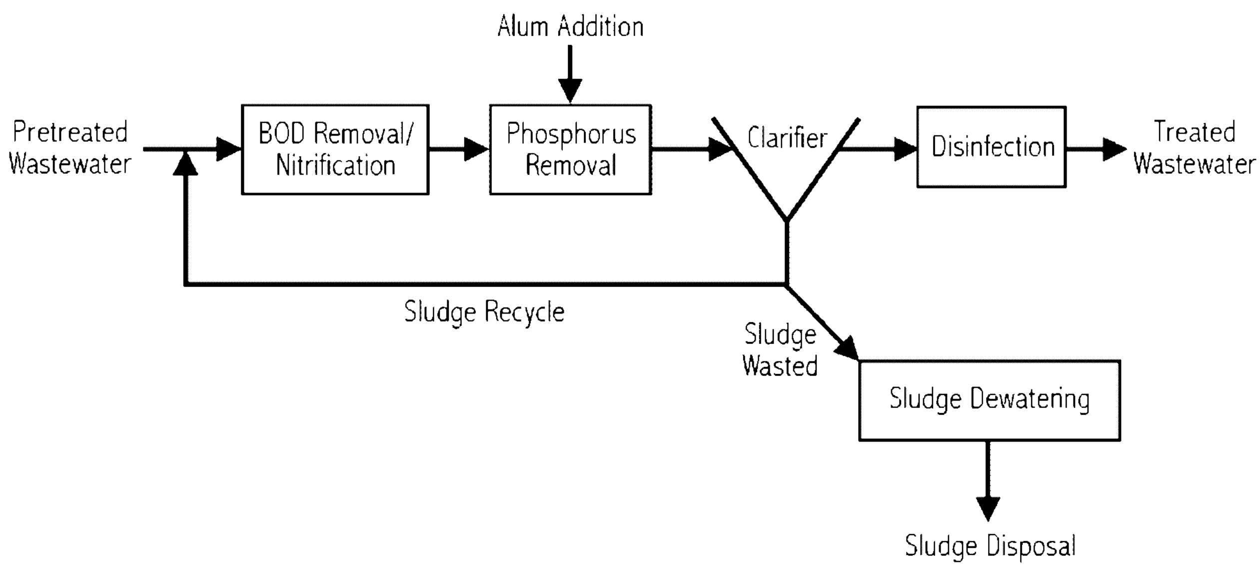

Figure 9-3. Treatment Unit Schematic for Technology Option 2+P (Nitrification + Phosphorus Removal)

9.4 Option 2.5

This option is the same as Option 2 but also includes partial denitrfication. Therefore, Option 2.5 consists of BOD removal, nitrification, partial denitrification, and disinfection

(Figure 9-4). A facility with a wastewater treatment plant designed for nitrification and partial denitrification typically has an aerobic reactor where BOD removal and nitrification take place. The nitrate/nitrite produced in the aerobic reactor is recycled to an anoxic reactor for denitrification. During the denitrification process, a significant amount of BOD is consumed, reducing the BOD load on the aerobic reactor. The wastewater from the aerobic reactor flows into the clarifier(s), where the biomass is then separated from the wastewater. One portion of the biomass that is separated is recycled to the anoxic reactor while the other portion is wasted.

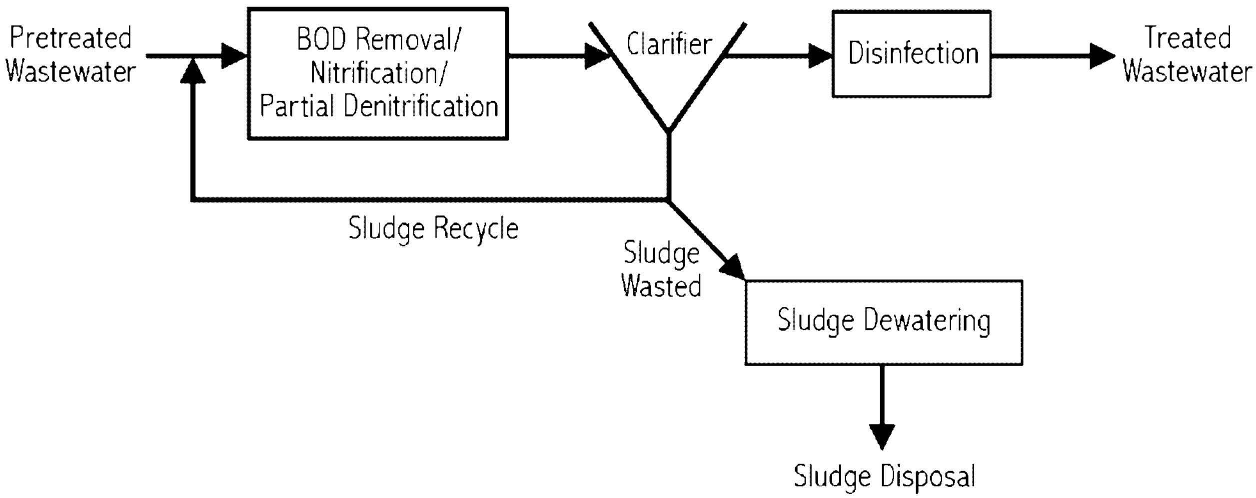

Figure 9-4. Treatment Unit Schematic for Technology Option 2.5 (Nitrification + Partial Denitrification)

Denitrification reduces nitrate plus nitrite to nitrogen gas and removes the nitrogen from the water. Experience has shown that significant biological nitrogen removal activity does not occur in strictly aerobic systems. Rather, its activity is promoted by incorporating an unaerated zone into the process design. For denitrification, an anoxic stage (nitrate present, no oxygen) is included. The reactor configuration typically includes an anoxic/unaerated stage ahead of an aerobic reactor. The nitrates produced in the aerobic reactor are recycled to the anoxic tank for denitrification. Typically, the process consists of a single-stage, two-tank system (e.g., anoxic/aerobic). In some cases, however, a facility with high influent TKN concentrations might use a two-stage four-tank system (two anoxic tanks, two aerobic reactors) to achieve partial denitrification. The reactors are followed by a secondary clarifier used to concentrate the sludge and return the sludge to the anoxic tank.

Denitrification is a two-step biological process called dissimilation. Nitrate is converted to nitrite, which is reduced to nitrogen gas. A range of bacteria, including *Pseudomonas*, *Micrococcus*, *Achromobacter,* and *Bacillus*, assist with denitrification. These bacteria can use either oxygen or nitrate to oxidize organic material. Because oxygen is more energetically favorable than nitrate, denitrification must be conducted in the absence of oxygen (anoxic conditions) to ensure that nitrate, rather than oxygen, is used in the oxidation of the organic material. For denitrification to occur, a carbon source must be available for oxidation. Carbonaceous material in the raw wastewater is often used as a carbon source. If the carbonaceous material in the wastewater is not available, however, an external carbon source such as methanol might have to be added to the denitrification system.

9.5 Option 2.5+P

This option is the same as Option 2.5 but also includes phosphorus removal. Therefore, Option 2.5+P consists of BOD removal, nitrification, partial denitrification, phosphorus removal, and disinfection (Figure 9-5). A facility with a wastewater treatment plant designed for nitrification typically has an aerobic reactor where BOD removal and nitrification take place. The nitrate/nitrite produced in the aerobic reactor is recycled to an anoxic reactor for denitrification. During the denitrification process, a significant amount of BOD is consumed, reducing the BOD load on the aerobic reactor. The wastewater from the aerobic reactor flows through the mix tanks into the clarifier(s), where the biomass is then separated from thewastewater. One portion of the biomass that is separated is recycled to the anoxic reactor, while the other portion is wasted. A chemical such as alum is fed at or before the mix tanks for phosphorus removal.

Phosphorus is removed by chemical precipitation by adding chemicals to precipitate the phosphate present in wastewater. Chemicals may be added to primary, secondary, or tertiary processes, or at multiple locations in a plant. Chemicals used for phosphorus precipitation include metal salts such as alum (aluminum sulfate), ferric chloride, and lime.

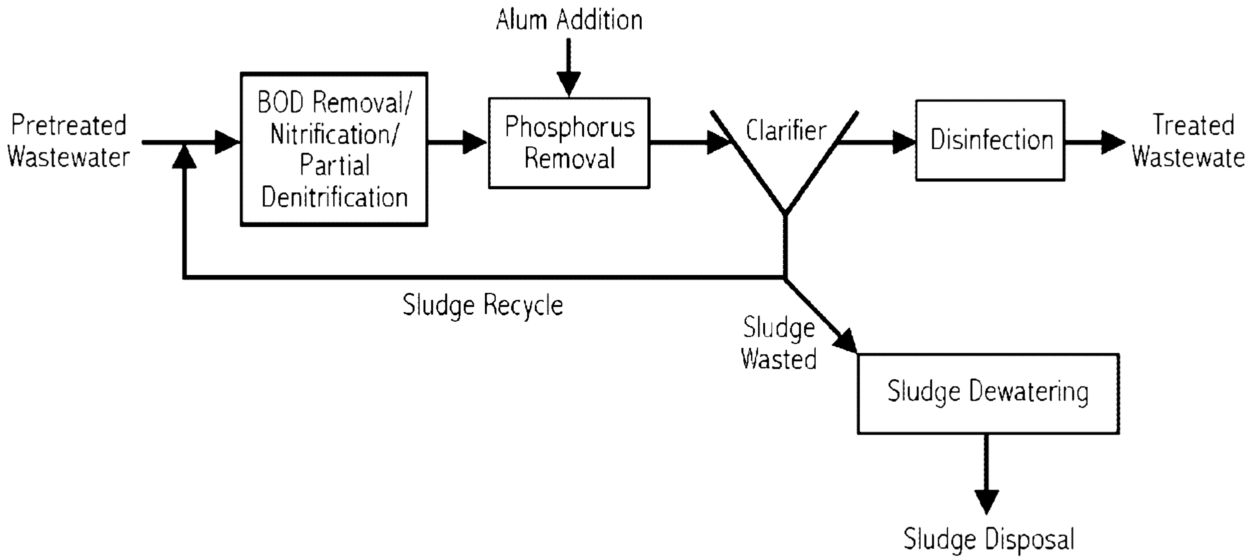

Figure 9-5. Treatment Unit Schematic for Technology Option 2.5+P (Nitrification + Partial Denitrification + Phosphorus Removal)

9.6 Option 3

Option 3 is the same as Option 2.5 but includes more complete denitrification instead of partial denitrification. Therefore, Option 3 consists of BOD removal, nitrification, denitrification, and disinfection (Figure 9-6). A facility that meets the requirements for Option 3 typically has a wastewater treatment plant designed for nitrification with an aerobic reactor in place along with anoxic tanks, mixers before the existing aeration tank, recycle pumps for recycling nitrate/nitrite from the existing aeration tanks to the anoxic reactor, intermediate process pumps for pumping wastewater through the treatment plant, additional anoxic tanks with mixers after the existing aeration tanks, additional aeration tanks, an aeration system for the second aerobic reactor, a methanol feed system, and mix tanks.

In the first aerobic reactor (aerobic reactor 1), BOD removal and nitrification take place. The nitrate/nitrite produced in aerobic reactor 1 is recycled to the first anoxic reactor (anoxic reactor 2) for denitrification. During denitrification, a significant amount of BOD is consumed, reducing the BOD load on aerobic reactor 1. The wastewater from this aerobic reactor flows into the second anoxic reactor (anoxic reactor 3), where methanol is added to denitrify the remaining nitrate/nitrite in the wastewater. In the second aerobic reactor (aerobic reactor 4), nitrogen gas (formed by denitrification) attached to the solids in the wastewater is stripped off. Any residual BOD in the wastewater is also removed. The wastewater then flows through the mix tanks into the clarifier(s) where the biomass is separated from the wastewater. One portion of the biomass separated is recycled to anoxic reactor 2, while the other portion is wasted.

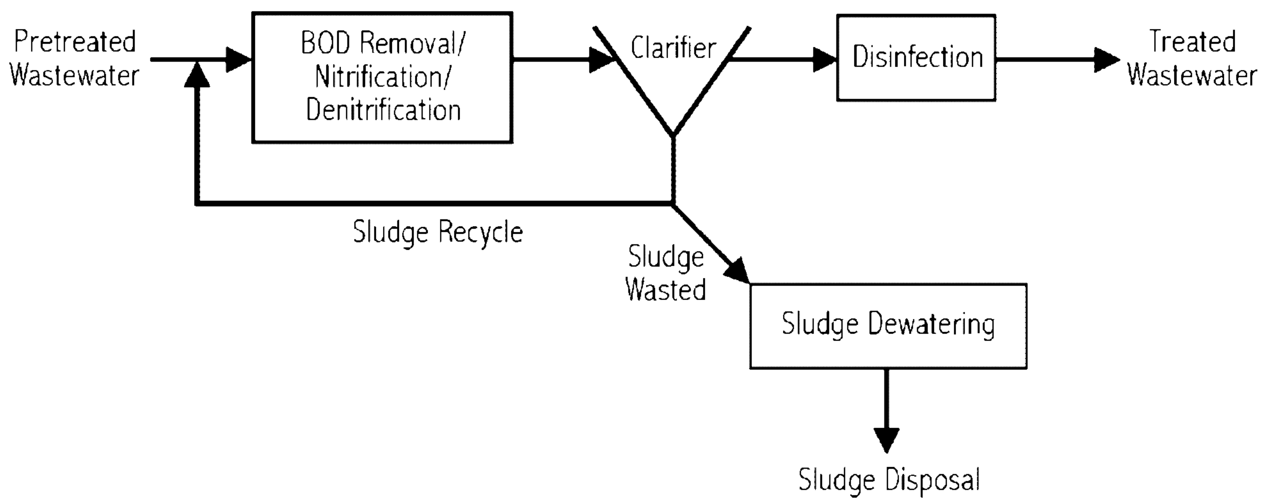

Figure 9-6. Treatment Unit Schematic for Technology Option 3 (Nitrification + Denitrification)

9.7 Option 4

This option is the same as Option 2.5+P but includes more complete denitrification instead of partial denitrification. Therefore, Option 4 consists of BOD removal, nitrification, denitrification, phosphorus removal, and disinfection (Figure 9-7). A facility that meets the requirements for Option 4 typically has a wastewater treatment plant designed for nitrification with an aerobic reactor in place along with anoxic tanks, mixers before the existing aeration tank, recycle pumps for recycling nitrate/nitrite from the existing aeration tanks to the anoxic reactor, intermediate process pumps for pumping wastewater through the treatment plant, additional anoxic tanks with mixers after the existing aeration tanks, additional aeration tanks, an aeration system for the second aerobic reactor, a methanol feed system, an alum feed system, and mix tanks. The single-stage, two-tank system for nitrification and partial denitrification discussed under Option 2.5+P cannot achieve low effluent nitrate plus nitrite concentrations. Usually, a two-stage four tank system with methanol addition is required to achieve low effluent nitrate concentrations. A two-stage system consists of anoxic reactor 1, aerobic reactor 2, anoxic reactor 3, and aerobic reactor 4. Nitrates produced in aerobic reactor 2 are recycled to anoxic reactor 1, where most of the nitrates are denitrified. The remaining nitrates are denitrified in anoxic reactor 3 with methanol addition. The final aeration basin is used to strip off nitrogen gas from the solids for easy settling and to remove residual BOD. The reactors are followed by a secondary clarifier, which is used to concentrate the sludge and return it to the anoxic tank. A chemical such as alum is fed at or before the mix tanks for phosphorus removal.

9.8 Option 5

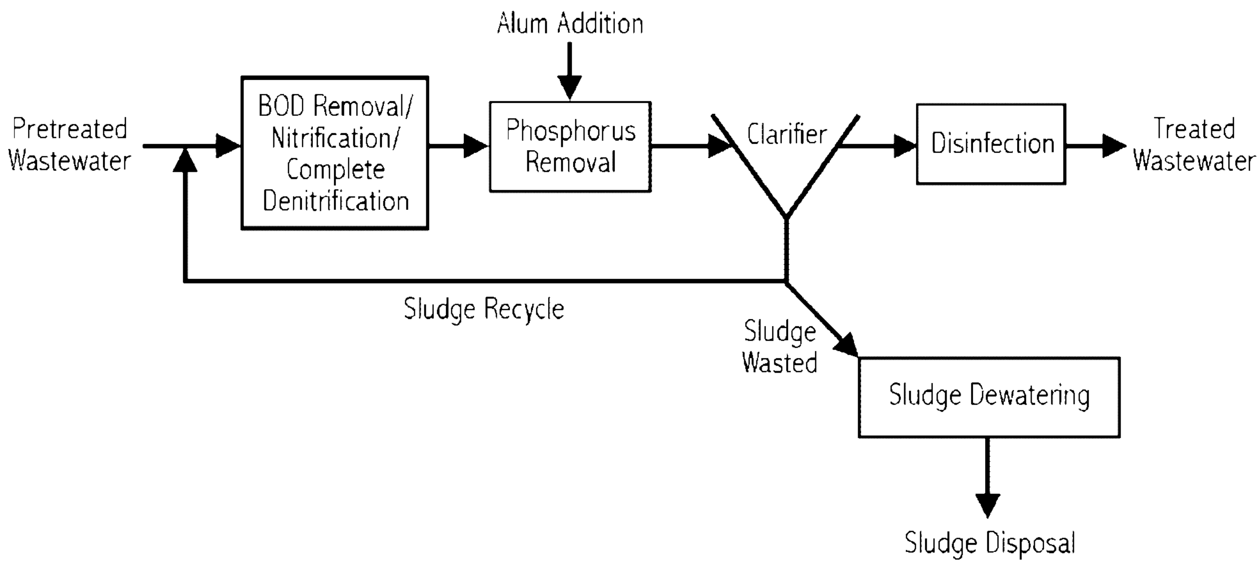

Figure 9-7. Treatment Unit Schematic for Technology Option 4
(Nitrification + Complete Denitrification + Phosphorus Removal)

This option is the same as Option 4 but includes filtration. Therefore, Option 5 consists of BOD removal, nitrification, denitrification, phosphorus removal, filtration, and disinfection (Figure 9-8). A facility that meets the requirements for Option 5 typically has a wastewater treatment plant designed for nitrification with an aerobic reactor in place along with anoxic tanks, mixers before the existing aeration tank, recycle pumps for recycling nitrate/nitrite from the existing aeration tanks to the anoxic reactor, intermediate process pumps for pumping wastewater through the treatment plant, additional anoxic tanks with mixers after the existing aeration tanks, additional aeration tanks, an aeration system for the second aerobic reactor, a methanol feed system, an alum feed system, and mix tanks. The single-stage two-tank system for nitrification and partial denitrification discussed under Option 2.5+P cannot achieve low effluent nitrate + nitrite concentrations. Usually, a two-stage four-tank system with methanol addition is required to achieve low effluent nitrate concentrations. A two-stage system consists of anoxic reactor 1, aerobic reactor 2, anoxic reactor 3, and aerobic reactor 4. Nitrates produced in aerobic reactor 2 are recycled to anoxic reactor 1, where most of the nitrates are denitrified. The remaining nitrates are denitrified in anoxic reactor 3 with methanol addition. The final aeration basin is used to strip off nitrogen gas from the solids for easy settling and to remove residual BOD. The reactors are followed by a secondary clarifier which is used to concentrate the sludge and return it to the anoxic tank. A chemical such as alum is fed at or before the mix tanks for phosphorus removal. After phosphorus removal, the wastewater flows through a filter to further reduce the concentration of suspended solids, as well as BOD. The wastewater is then disinfected before it is discharged into the receiving water.

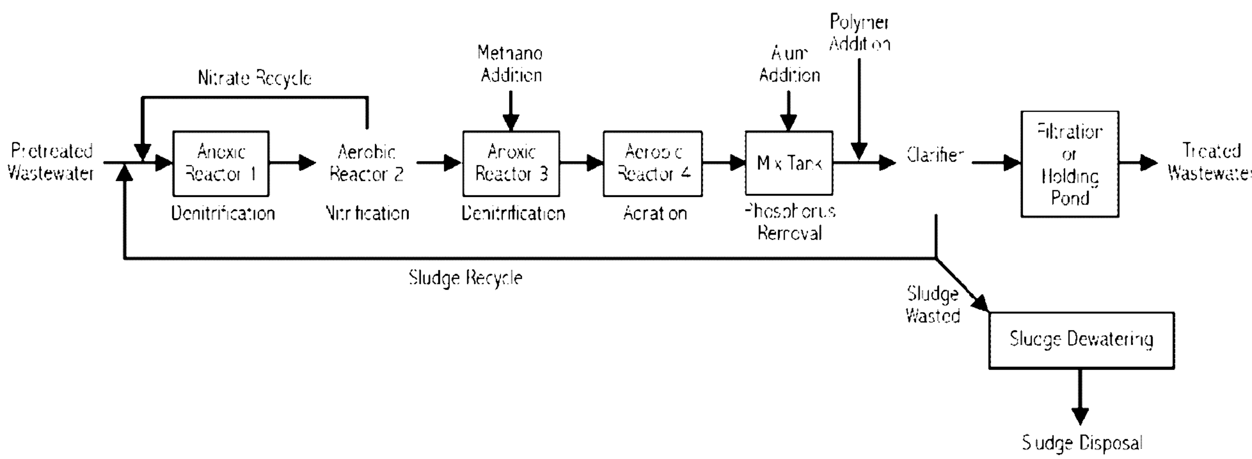

Figure 9-8. Treatment Unit Schematic for Technology Option 5
(Nitrification + Complete Denitrification + Phosphorus Removal + Filtration)