CHARACTERIZATION OF POULTRY PROCESSING OPERATIONS, WASTEWATER GENERATION, AND WASTEWATER TREATMENT USING MAIL SURVEY AND NUTRIENT DISCHARGE MONITORING METHODS

by

BRIAN HARRY KIEPPER

(Under the Direction of Aaron Estes Reynolds)

ABSTRACT

Periodic evaluation of wastewater characteristics and treatment practices within U.S. poultry processing plants is needed due to the industry's rapid expansion. U.S. poultry processing plants slaughtered over 9.01 billion birds in 2002. Total wastewater generation by U.S. slaughter plants is now between 45 and 90 billion gallons annually. Two separate methods were used to characterize poultry slaughter and further processing plant operations, wastewater generation, and wastewater treatment practices. The first method, a self-administered mail survey questionnaire, was completed by 58 U.S. poultry processing facilities. Completed surveys were received from 46 chicken and five turkey slaughter plants. Further processing plants submitted five surveys along with two stand-alone rendering facilities. The second method involved the monitoring of phosphorus and nitrogen discharges at four locations within six plants. Each sample was analyzed for total phosphorus (P) and total Kjeldahl nitrogen (TKN). Results show statistically similar trends in nutrient discharges from slaughter plants.

INDEX WORDS: Poultry processing, Wastewater treatment, Mail Survey, Nitrogen, Phosphorus, Water conservation, Industrial water use

CHARACTERIZATION OF POULTRY PROCESSING OPERATIONS, WASTEWATER GENERATION, AND WASTEWATER TREATMENT USING MAIL SURVEY AND NUTRIENT DISCHARGE MONITORING METHODS

by

BRIAN HARRY KIEPPER

B.S., Tennessee Technological University, 1985

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2003

CHARACTERIZATION OF POULTRY PROCESSING OPERATIONS, WASTEWATER GENERATION, AND WASTEWATER TREATMENT USING MAIL SURVEY AND NUTRIENT DISCHARGE MONITORING METHODS

by

BRIAN HARRY KIEPPER

Approved:

Major Professor: A. Estes Reynolds

Committee: William C. Merka
E. William Tollner

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2003

DEDICATION

This thesis and the work it encompasses is dedicated to my mother, Audrey Jean Kiepper; devoted daughter, dedicated nurse, and loving single parent. Your example of parental devotion to your son inspires me as a father to my sons every day. Mom, I love you.

ACKNOWLEDGEMENTS

Completing graduate work resulting in the culmination of a thesis is rarely, if ever, accomplished alone. This thesis and the body of work it encompasses is no exception.

First, I would like to thank Dr. Estes Reynolds for serving as my major professor and for his consistent advise and motivation throughout these last three years of balancing my full-time work with part-time graduate school. I would also like to thank Dr. Bill Tollner for serving as a valuable member of my committee.

I would like to thank Dr. Dale Threadgill, Head of the Department of Biological & Agricultural Engineering, for overseeing a department of faculty and staff that nurture a work environment at the University of Georgia that encourages and motivates employees to set and reach both their career and educational goals.

A special thank you goes to Dr. Jackie Sellers, who as my direct supervisor provided me the opportunity to attend class and complete research while fulfilling my responsibilities to the Engineering Outreach Service at UGA, and as a friend encouraged me with his insight and made me laugh daily with his humor. His positive attitude in the face of life's daily difficulties is an inspiration to all that know him.

Another very special thank you goes to Dr. Bill Merka who has been my teacher, mentor and friend since the first day I stepped onto the UGA campus. It is his knowledge and devotion to a career in my chosen field that is the true inspiration for the work this thesis encompasses. From the day we first plunged under a poultry house together until today, over five years later, I continue to learn from him.

Finally, I wish to thank my wife of ten years, Ginny, and my sons, Bryce and Brant, for their patience, support, and love. You are the reason I rise each morning ready to face another day, and the reason I can smile as I go to bed each night. I am truly blessed by each of you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Thesis Rationale

Rationale for this study centers on the need for periodic scientific review of wastewater characteristics and treatment practices within the U.S. poultry meat processing industry. The need for this review stems from the rapid growth of the poultry industry that started in the 1940s and continues today at an annual rate of approximately five percent. The structure of the poultry industry has changed significantly over the last 40 years due to the emergence of the vertically integrated production system in the late 1950s along with the significant increase in U.S. consumption and export of poultry meat. The poultry meat processing industry has responded to this growing demand with larger plants, faster processing line speeds, and more employees. A typical chicken processing plant in 1992 produced approximately five times more output than a plant in 1967. Traditionally, poultry slaughter facilities produced mostly whole birds. In contrast, slaughter plants today generate a product mix of whole birds, cut-up parts, deboned meat, and other further processed convenience products (Ollinger *et al.,* 2000).

Since 1972, following the implementation of the Clean Water Act and subsequent creation of the United States Environmental Protection Agency (USEPA), poultry meat processors have been required to continually improve the treatment of their wastewater prior to effluent discharge. At the same time, poultry plant water use has risen in response to United States Department of Agriculture (USDA) food safety protocols such as the Hazard Analysis Critical Control Point (HACCP) and Zero Tolerance for fecal material programs (Cates *et al.*, 2001). This increased generation of wastewater requires more efficient removal of by-products and pollutants that will allow for effluent discharge within environmental regulatory limits.

This study first establishes current processing operations and wastewater treatment practices of U.S. poultry meat processing plants by use of a mail survey. The study then identifies wastewater stream characteristics and specific poultry meat processing operations that contribute the highest nutrient loading by use of wastewater monitoring of nitrogen and phosphorus discharges. Finally, the two study methods' advantages and disadvantages are analyzed.

U.S. Poultry Meat Industry

The operations of the poultry meat industry can be divided into two major categories: production and processing. Poultry production includes all the functions involved in raising flocks of live birds: breeding, hatching, grow-out, feed manufacture, and production waste handling. Processing is defined as the functions involved in converting a live bird into meat products and by-products: slaughtering, further processing, rendering, and processing waste handling.

Production Levels

Beginning in the mid-1920s, the U.S. has seen a significant rise in the production of commercially raised poultry that continues today (Romans *et al.*, 1994). From 1960 to 1998 the U.S. annual rate of young chickens or 'broilers' slaughtered increased 510 percent from 1.534 billion to 7.838 billion birds (Ollinger *et al*., 2000). The initial expansion of the poultry industry took place in the 'Delmarva' section of Delaware, Maryland and Virginia (USDA-FSIS, 1991). Since the late 1940s, southeastern poultry firms have dominated U.S. poultry meat production and processing. In 1992, 65.4 percent of broiler slaughter was completed in the Southeast region (AL, AR, GA, FL, LA, MS, NC, SC, TN), the Central Atlantic region accounted for 15.1 percent (DE, MD, VA, WV), Southwestern states made up 10.8 percent (TX, OK, AZ, NM, CA), while the remainder of the country accounted for 8.7 percent (Ollinger *et al*., 2000). In 2002, the USDA's National Agricultural Statistics Service (NASS) reported that U.S. poultry processing plants slaughtered 9.011 billion birds with a combined live weight of 52.043 billion pounds.

Since 1930 rapid advances in the management, disease control, genetics, production techniques, processing technologies, and marketing of U.S. poultry have resulted in a highly efficient meat producing industry. The growth of the poultry industry worldwide has been attributed to poultry's ability to adapt to most areas of the world, their affinity for rapid growth and generations rates, as well as their low cost per animal unit. Today, due to poultry's ability to be hatched year around and rearing available in climate controlled confinement, birds can be raised in flocks of several thousands rather than as individual animals as in cattle or swine. These qualities have allowed for the development of a highly integrated, mass production industry that is dominated by large poultry production companies (Mountney and Parkhurst, 1995).

World War II had the single greatest impact on the increase in U.S. poultry consumption. Due to poultry's secondary status in American diets prior to the war, it was not rationed like other meats. Consequently during the early 1940s, poultry quickly became the primary meat consumed in the U.S. Beef and pork again supplanted poultry in American diets after the war ended, but poultry was now a commonly accepted food item (Ollinger *et al.*, 2000).

Table 1.1 shows that U.S. per capita consumption of chicken has grown over the last 40 years to the point that it now exceeds the consumption rate of beef. Table 1.2 shows that there has also been a dramatic increase in the annual rate of poultry products exported over the same period of time.

Table 1.1. Annual U.S. per capita consumption of chicken, turkey, and beef in pounds.

Product	1960	1963	1967	1972	1977	1982	1987	1992	1997	1999
Chicken[1]	27.8	30.8	32.4	41.7	40.2	47.0	57.4	67.8	72.7	78.8
Turkey	6.3	6.9	8.7	9.0	8.8	10.6	14.7	17.9	17.6	17.8
Beef	64.2	69.9	78.8	85.1	91.5	76.9	73.7	66.3	66.9	65.4

[1] Includes broilers and mature hens.
Source: Ollinger *et al.,* 2000.

Table 1.2. Annual U.S. net exports of chicken and turkey in million pounds.

Product	1960	1963	1967	1972	1977	1982	1987	1992	1997	1999
Chicken[1]	137	157	88	100	349	524	767	1,530	5,043	4,421
Turkey	24	31	49	36	54	51	33	202	605	400

[1] Includes broilers and mature hens.
Source: Ollinger *et al.,* 2000.

Vertical Integration

The U.S. poultry industry's vertically integrated system in existence today emerged during the late 1950s with the opening of the J.D. Jewel, Inc., plant in Gainesville, Georgia. In this integrated structure, a single poultry firm owns the animals, hatchery, feed mill, slaughter plant and rendering operation in a local area (Lasley and Baker, 1984). Contractual arrangements are made with local farmers to grow out chicks for slaughter after a specified time period. The major advantage of this system is its ability to produce a steady supply of consistent quality live chickens for slaughter (Ollinger *et al*., 2000). It was the development of this vertically integrated system, along with improvements in breeding and processing technologies, that enabled poultry companies to realize the economies of scale that exist today (Bugos, 1992).

One of the key developments within the integrated poultry industry that led to its rapid development was in genetic selection for increased feed efficiency. Prior to these developments in breeding, the poultry meat market was dominated by surplus cockerels and spent laying hens. Hodgson (1959) reported that "overshadowing all other developments in the production of poultry meat has been the evolution of the fast growing broiler bird through breeding experiments". In 1934 a study showed that 14 weeks and 4.0 to 4.5 pounds of feed per pound of weight gain were required to produce a market ready 3.5 pound chicken. By 1961, only eight weeks and 2.0 to 2.4 pounds of feed per pound of weight gain were needed (Combs, 1961). Today broilers weighing 4.5 pounds are produced in 43 to 45 days utilizing 1.8 to 2.0 pounds of feed per pound of weight gain (Mountney and Parkhurst, 1995).

U.S. Poultry Processing

Poultry are processed at plants designed to accept live birds and convert them to whole bird carcasses ready for packaging or for further processing. During the past 30 years, the average slaughter plant has increased in capacity from approximately 60,000 to 200,000 birds per day. In 1972 approximately 25 percent of chicken and turkey slaughter plants employed over 400 employees. By 1992, plants employing over 400 people accounted for over 80 percent of poultry slaughter facilities. The continued shift towards large processing plants indicates that economies of scale are important (Ollinger *et al.*, 2000).

Another major impact to the poultry processing industry has been in consolidation of poultry firms. To measure the rate of consolidation, a method called the ‘four-firm concentration ratio’ is commonly used. The four-firm concentration ratio measures the percent share of the poultry industry output held by the four largest producers and is widely used as an indicator of structural change. In 1963 the four largest poultry firms controlled 14 percent of chicken slaughter plants and 23 percent of turkey plants. By 1992, those percentages had increased to 41 percent for chicken plants and 45 percent for turkey facilities (Ollinger *et al*., 2000).

By 1968, the basic automated poultry slaughtering process in use today was established (Bugos, 1992). Due to the dominance of broilers, which account for almost 95 percent of the total number of poultry slaughtered in the U.S., the brief description of poultry processing that follows covers the general practices in this category. Processing practices for other poultry species or for specialized religious practices will differ somewhat than described here. For the purposes of this document, the processing steps are divided into five major categories: First Processing, Second Processing, Third Processing, Cook Plants, and Rendering.

First Processing – Poultry Slaughter

First processing begins when live birds enter the plant and are stunned, killed and bled. Feathers and viscera are then removed under USDA inspection. The carcasses are chilled in an ice bath and washed, refrigerated, and either packaged or sent to further processing.

Processing of broilers begins with their delivery to the processing plant in cages on flatbed trucks. The birds are mechanically shaken from the cages onto a conveyor belt that transports them into the hanging room. In the hanging room the birds are manually removed from the conveyor belt and hung by their feet onto a shackle line to minimize struggling (Drewniak *et al.,* 1955; Kotula *et al.,* 1961). To meet USDA humane slaughter regulations the chickens are electrically stunned prior to killing (Stadelman *et al*., 1988). Stunning not only immobilizes the birds for efficient killing, but also relaxes the muscles that hold the feathers (Mountney and Parkhurst, 1995). Once stunned, mechanical devices are used to kill the birds by cutting their throats in a way that allows the blood to drain to the floor where it is collected (Davis and Coe, 1954). Most processors allow from 90 to 180 seconds for blood to drain from the birds prior to scalding (Stadelman *et al.,* 1988).

Blood constitutes about 10 percent of the total body weight of broilers. However, only 3 to 5 percent drains from the carcass after cutting (Kotula and Helbacka, 1966; Newell and Shaffer, 1950a, 1950b). The USDA (2003) reported that the average live weight of broilers processed in 2002 was 5.12 pounds. Thus a typical plant processing 200,000 birds per day will collect 30,720 to 51,200 pounds of blood. Assuming the specific gravity of blood to be that of water, a typical plant will collect 3,683 to 6,139 gallons of blood per day.

Once the chickens are bled out they are usually submerged into hot water or ‘scalded’ to enhance the removal of feathers. The speed at which feathers are loosened by scalding depends upon the temperature of the water and the period of immersion (Romans *et al.,* 1994). Although Poole *et al.* (1954) reported that scalding temperature is more important than immersion time.

Scalded carcasses are then defeathered. One of the most important developments in the modern poultry processing industry was the invention of the rubber-picking finger. By the mid-1940s rubber fingered picking machines had been perfected to the point that they had replaced much of the manual labor formally used to remove feathers by hand (Mountney and Parkhurst, 1995). The removed feathers are transported by water in a flume to the offal collection area.

Offal is defined as all of the parts of processed poultry that are not part of the carcass as it leaves the first processing step. Feathers account for approximately 7.0 percent of a chicken's live weight and a typical plant processing 200,000 birds per day will collect approximately 72,000 pounds of feathers (Mountney and Parkhurst, 1995).

Once defeathered the carcasses are washed and enter the evisceration area. To meet food safety regulations, the defeathered carcasses are removed from the initial shackle line and placed on a separate evisceration shackle line. Using various mechanical devices and manual techniques, the viscera of each carcass is then removed, processed to harvest additional products, and USDA inspected based on individual plant applications. Once removed, the viscera of each bird is generally left hanging outside the body, but still attached to aid in the inspection process (Childs and Walters, 1962; Mountney and Parkhurst, 1995). Once the viscera are inspected, many plants remove the heart, gizzard, liver, and neck as edible giblets. The edible giblets are processed separately from the carcasses for separate sale or placement in bags for insertion into whole birds. The remaining offal is dissected from the carcass and conveyed by water flume or vacuum system to the offal recovery area. Offal accounts for 17.5 to 18.5 percent of a chicken's live weight (Mountney and Parkhurst, 1995). A typical plant processing 200,000 birds per day will collect approximately 179,200 to 189,440 pounds of by-product.

The carcasses are now thoroughly washed both inside and out prior to chilling. The USDA requires that carcasses be chilled to at least 40^{o}F (4.4^{o}C) internal temperature (Mountney and Parkhurst, 1995). Research in the late 1950s and early 1960s revealed that slurries of agitated ice and water in vats were the most effective method of chilling (Klose *et al.*, 1960; Mickelberry *et al.*, 1962; Tarver *et al.*, 1956). Many U.S. poultry processing plants use a prechiller that also acts as a washing step, which the USDA requires to be maintained at a temperature less than 65^{o}F (18.3^{o}C). A second chiller with a maximum temperature of 35^{o}F (2^{o}C) brings carcasses to the final desired internal temperature of 40^{o}F (4.4^{o}C). USDA regulations require a minimum fresh water replacement rate of 0.5 gallon per broiler entering a chiller (McKee, 2001).

Due to the more recent inceptions of the HACCP and Zero Tolerance food safety programs in the U.S., many poultry processing plants have installed final inside and outside high-pressure bird washing stations for post-chilled carcasses (Pearson and Dutson, 1995). This final washing step has led to a one to two gallons per bird increase in plant water use. The washed and chilled carcasses are now ready for packaging or transport to further processing operations.

Poultry By-products

Products produced from the slaughter of poultry fall into two basic categories: edible and inedible (Ockerman and Hansen, 2000). The maximum percent yield of edible or 'dressed' product from the various poultry species ranges from a high of 77 percent for turkeys to a low of 58 percent for ducks. Chicken dressed percentage yields averages 70 percent (Hedrick *et al.*, 1994; Mountney, 1966). This means that 23 to 42 percent of processed poultry is classified as inedible animal by-product and thus must be utilized or disposed of outside of the human edible market. Using the 2002 total live weight for broilers of 44.623 billion pounds (USDA 2003), U.S. young chicken processors produced approximately 12.7 billion pounds of inedible offal.

By definition, poultry organs and other parts that are normally acceptable for human consumption (liver, heart, gizzard, neck) are considered 'edible offal', with the remaining by-product material classified as 'inedible offal' (Romans *et al.*, 1994). However, the general term of 'offal' usually refers to the inedible poultry by-products that are normally not acceptable for human consumption (feathers, heads, lungs, intestinal tracts and their contents). In this document, use of the term 'offal' will represent inedible poultry by-products. The majority of offal is utilized in a process known as 'rendering'.

Second Processing

Second processing is defined here as any process in which a chilled poultry carcass is separated into parts and/or meat is separated from bone. Operations in this category include cut-up, tray packing, deboning, MSC (mechanically separated chicken), MDM (mechanically deboned meat), and portion control.

In general a dressed poultry carcass can be divided into five major parts: wings, thighs, drumsticks, breasts, and back (Romans *et al.*, 1994). Today, uniform cut-up parts destined for retail sale are often placed on trays and over wrapped with plastic film or 'tray packed' at the processing plant. Individual portions are not only cut up and packaged, but each individual package is often weighed, priced, and printed with the store's label and bar code for automated check out (Mountney and Parkhurst, 1995).

Deboning of poultry parts is accomplished either by hand or mechanical device. Meat that is deboned by hand has a greater value that meat obtained mechanically, but it also has a higher cost of processing (Baker and Bruce, 1989). Hand deboned meat is also more versatile than mechanically separated meat and can be used in more products because it retains more of the characteristics of the whole bird (Froning, 1979). Hand deboning remains a popular method in U.S. poultry processing plants and is responsible for employee numbers at large plants exceeding 1000 workers. Normally only the breast and thighs are hand deboned due to the high value of the resulting cuts of meat in a whole muscle form (Stadelman *et al.*, 1988). MDM has the advantage of drastically lower labor costs, but the recovered meat has a paste-like texture that limits the manner in which it can be used (Baker and Bruce, 1989). The major concern of MDM is the possibility of bone fragments in the final product (Froning *et al.*, 1979; Froning *et al.*, 1981).

The increased demand from the restaurants and institutional food service sectors for uniform deboned products with strict specifications has led to the development of specialized techniques in portion control. Many plants utilize manual portion control, but mechanical advances such as computer driven water knifes have increased the accuracy and production per unit cost of producing these specialized products. The waste stream of second processing plants is made up almost exclusively of bone, meat, fat and skin. The recovered solids from second processing wastewater is usually collected and processed by a renderer.

Third Processing

Third processing is defined here to include all the processes that manipulate deboned poultry meat into value-added, convenience foods for consumers. Poultry convenience foods are products in which services and additional ingredients have been added to the raw meat that reduces the amount of preparation time required by the consumer (Harp and Durham, 1963). In 1964, J.D. Jewell, Inc. of Gainesville, Georgia, introduced one of the first true convenience products when they merchandized cooked diced chicken meat packaged in waxed cardboard cartons containing five ounce poly bags and designed for use in salads and other dishes (Mountney and Parkhurst, 1995).

The third processing category includes batter and breading, curing and smoking, marination, bar-b-que, parfrying, fully cooked RTE (ready to eat) products, and IQF (instant quick frozen). As an example, coatings are used to enhance poultry product appearance, increase palatability, improve yield, lower unit costs and act as a moisture barrier (Mead, 1989; Vickers and Bourne, 1976; Zwiercon, 1974). Each year an increasing amount of poultry meat is being converted into convenience food forms, either alone or in combination with a wide variety of other ingredients. The USDA regulates the production and labeling of these manufactured products (USDA, 1981). Due to the use of non-poultry meat ingredients, the wastewater generated by plants in this third processing category is similar to bakery wastewater, with large volumes of highly water soluble carbohydrate materials such as flour, sugar and spices.

Cook Plants

Cook plants process the raw whole poultry carcasses of mature or ‘spent’ breeding and egg laying chickens into fat, broth and meat. During the cooking process, fat is recovered, processed, and packaged for sale. Following cooking, the meat is separated from bone, chopped and frozen prior to packaging. The water used during the cooking process is collected as broth and pumped to evaporation systems where it is condensed and packaged for sale.

Most of the fat, broth and meat collected by cook plants are sold to other food processors as ingredients in soups, stews and other convenience food products (Mountney and Parkhurst, 1995). The majority of poultry processed in cook plants are large mature broiler breeder hens and smaller ‘spent’ egg laying hens. As a group these chickens accounted for fewer than two percent of the total birds slaughtered in 2002 (USDA, 2003). Mature broiler breeder hens are the parents of production broiler flocks that are at the end of their productive egg laying lives. They are larger and have a better meat yield than young broilers, with an average slaughtered live weight of 7.89 pounds in 2002. A stronger flavor and a tougher texture then young birds characterize their meat. Spent egg laying hens are usually about 18 months old; small, and with relatively poor conformation and meat yield (Rankin, 2000). During 2002, 96.45 million spent hens were processed with an average live weight at slaughter of 3.40 pounds (USDA, 2003). The waste stream generated in cook plants is similar to second processing, with the exception that the poultry meat is cooked and is dominated by bones and small pieces of poultry meat, fat and skin.

Further Processing

Further processing can be defined as the conversion of raw poultry carcasses into convenient-to-use, value-added forms such as cut portions, battered pieces, parfried breaded pieces, cold cuts, burger patties, and hot dogs (Baker and Bruce, 1989). Over the last four decades, there has been a significant demand shift in the U.S. marketplace from the desire for whole birds to more poultry products that are further processed for increased consumer convenience. This significant shift is evident from whole bird consumption patterns. In 1962, whole birds accounted for 87 percent of the broiler processing market. By 1997, only 13 percent of the broilers processed were sold as whole birds. This shift away from whole bird consumption to convenience products is seen as one of the major forces driving broiler production rates up by approximately five percent each year (Ollinger *et al.*, 2000).

To meet consumer demand for greater portion size, the average weight of each bird has also increased. From 1960 to 1998, the average live weight of processed broilers increased from 3.36 to 4.86 pounds (Ollinger *et al.,* 2000), and by 2002 the average weight reached 5.12 pounds (USDA, 2003). The average live weight of slaughtered turkeys increased from 15.06 pounds in 1960 to 24.63 in 1998 (Ollinger *et al.,* 2000), and by 2002 the average weight reached 26.76 pounds (USDA, 2003).

Rendering

The process of rendering inedible animal products has changed little over the years and basically consists of cooking raw offal materials to remove fat and moisture from the protein and bone (Grummer, 1992). Rendering serves two purposes: it separates offal into its fat and protein components, and it cooks the animal tissue. The separated materials have a greater value than the raw offal material. Also, cooking significantly increases the stability or 'shelf life' of the fat and protein by reducing the moisture content and killing the microbes present in the raw offal (Romans *et al.,* 1994). In general, raw offal contains 50 percent moisture, 25 percent fat, and 25 percent protein and bone. In 1987, poultry processors supplied the U.S. rendering industry with seven billion pounds of raw offal, which represented 19.5 percent of their total raw material (John, 1991). Rendering can be categorized into three basic types: batch, continuous, or continuous at low-temperature. Batch and continuous rendering are often referred to as 'dry-rendering', while continuous processing at low temperature is often called 'wet rendering'.

During batch rendering, the raw material is first ground and then placed in steam-jacketed vessels for cooking. Cooking times vary from 20 minutes to three hours at temperatures ranging from 240 to 290^{o}F. Cooking both removes moisture and releases fats that are drained from the remaining solid mass. Time and temperature of the cooking process are critical. Sufficient moisture must be removed prior to the next stage of 'pressing'. However, at the same time the protein based solids must not be overcooked. Excessive denaturing of the protein by overcooking will reduce the value of the finished product as an animal feed stock (Grummer, 1992).

Continuous rendering differs from batch processing only in that the raw material is continually fed and removed from the cooking vessel. Continuous cooking times are usually in the range of 45 to 80 minutes at temperatures range from 240 to 445°F. Continuous wet rendering involves heating the raw material at low temperatures (158°F). The low temperature allows the moisture to remain in the raw material while approximately half the water is removed. The role of heating is to break the tissue cells open so that the fat within the tissues is released. Following draining and pressing to remove fat and moisture, the wet pressed cake is dried at elevated temperatures to obtain adequate heat treatment of the protein (Grummer, 1992).

Four major products are produced as a result of poultry offal rendering: fat in the form of oil and grease, feather meal, poultry meal, and blood meal. Immediately after the conclusion of the cooking of raw offal, poultry oil is removed from the solids usually using a screw press. The resulting oil is very high in energy and strongly enhances the palatability of pet food. On the other hand, the rendering process also produces poultry grease, which although useful as a by-product, is generally darker and lower in grade then fat recovered from beef or pork rendering (Ockerman and Hansen, 2000).

Feathers are rendered separately from other offal due to their complex protein keratin that must be broken down by hydrolysis to make the protein digestible. The digestibility of feather meal is directly affected by the amount of cooking pressure and time. The more intensive the cooking process, the higher the availability of amino acids and higher biological value (Ockerman and Hansen, 2000). In addition to rendered meal, feathers are also used for clothing, insulation, bedding, decorations, sporting equipment, and fertilizer (Ockerman and Hansen, 2000; Wessels, 1972). Poultry meal is rendered from raw offal and is usually used as a major ingredient in pet food because of its light color and high palatability. Renderers customize the protein and fat levels of poultry meal to meet customer specifications. Finally, poultry blood is collected during the slaughter process, dried and ground and also used in animal feed formulations (Ockerman and Hansen, 2000).

The Natural Life Cycle of Water Bodies

The natural life cycle of water bodies begins when water plants, usually various species of algae, utilize the sun's energy to produce oxygen while converting smaller inorganic molecules to large organic molecules. Water borne animals then consume the organic molecules and the dissolved oxygen produced by the water plants, to build and provide energy to muscle tissue. Once water borne plants and animals die they are converted back into inorganic molecules in the bottom sediments of water bodies by means of fermentation and anaerobic respiration. New aquatic plants utilize the resulting inorganic molecules to begin the cycle again (Liptak, 2000).

When humans add additional inorganic and organic materials to natural waters, the natural life cycle is altered. One result of these excessive non-natural or anthropogenic generated materials on water bodies is their action as an undesirable fertilizer. As an example, phosphorus can cause algae to over populate, resulting in a subsequent reduction in water transparency and accelerating the water body's natural process of aging called 'eutrophication' (Klapper, 1991). One gram of phosphorus released to a water body has the potential to produce 100 grams of wet weight algae biomass that will require 150 grams of oxygen to decompose (Uhlmann and Klapper, 1985).

Wastewater

Wastewater can be defined as the remaining spent water that has been used by humans in homes, commercial establishments, industries, public institutions, and similar entities for various purposes (Sincero and Sincero, 2003). Wastewater enters the environment through either 'point' or 'non-point' sources. Point sources are finite locations, such as pipes, where wastewater enters water bodies. On the other hand, wastewater that comes from diffuse sources such as the runoff from agricultural fields or parking lots are defined as non-point (Welch and Lindell, 1992). Wastewater collected in municipal sewer systems is comprised of domestic or 'sanitary' wastewater, industrial wastewater, infiltration and inflow into sewer lines, and stormwater runoff (Canter and Harfouche, 2000).

Clean Water Act - NPDES

The passage of the Rivers and Harbors Act of 1899 is considered the first law aimed directly at controlling water pollution in the U.S. (Sincero and Sincero, 2003). To control, regulate, and with goals to eventually eliminate pollutants entering U.S. waters, the federal government has instituted a series of environmental regulations commonly referred to as the Clean Water Act, which has its origins in the late 1940s. The original 1948 statute, called the Water Pollution Control Act, authorized the Surgeon General of the Public Health Service to prepare comprehensive programs for reducing or eliminating the pollution of interstate waters aimed at improving the sanitary conditions of surface and ground waters.

Over the next twenty years, the original statute was extensively amended to authorize additional water quality programs, set new standards to govern allowable discharges, and establish funding for construction and general grant programs (Cheremisinoff, 2002). However, despite these early efforts to control water pollution, by the late 1960s many U.S. rivers were little more then open sewers, massive fish kills were common, and raw sewage washed up daily on lake shores. Then as a defining moment in U.S. environmental history, the Cuyahoga River in Cleveland, Ohio, ignited and burned because of the uncontrolled discharge of petroleum by-products (Sincero and Sincero, 2003). In 1972, in direct response to several major detrimental environmental events, the Federal Water Pollution Control Act Amendments or ‘Clean Water Act’ was passed (U.S. Congress, 1972). This legislation totally revised previous laws and established the basis for the regulations we operate under today (Sincero and Sincero, 2003). The amendments of 1972 also led to the creation of the United States Environmental Protection Agency (USEPA) that was given the responsibility and authority to regulate water quality standards and establish enforcement actions.

Three major amendments were added to the 1972 Clean Water Act in 1987: new water quality standards and planning methods, new discharge permits, and new effluent limitations (Canter and Harfouche, 2000). Since the enactment of the 1987 amendments, new point sources of wastewater discharge must apply for National Pollutant Discharge Elimination System (NPDES) permits. These permits address pertinent effluent limitations for conventional and toxic pollutants, establish monitoring and reporting requirements, and set schedules for compliance (Miller *et al.*, 1991).

Sanitary Versus Industrial Wastewater

Sanitary wastewater is comprised of wastewater from residences and includes spent water from restrooms, bathing, and washing of dishes and cloths. These same activities also result in sanitary wastewater generation at commercial and industrial facilities sources (Metcalf and Eddy, Inc., 1991). Untreated sanitary wastewater is characterized by a grayish-brown color, strong odor and is relatively dilute. The five major constituents of sanitary wastewater that are targeted for removal through treatment are organics (measured by biochemical oxygen demand or BOD), total suspended solids (TSS), nitrogen, phosphorus, and pathogenic bacteria (CSUSb, 1993; Welch and Lindell, 1992). Table 1.3 shows the typical concentration range for the most common constituents measured in raw sanitary wastewater. Sanitary wastewater generation rates per person vary based on the type of housing or commercial facility, but average usage typically ranges from 45 to 95 gallons per person per day (Metcalf and Eddy, Inc., 1991).

Unlike the consistency of common constituents found in sanitary wastewater, spent process wastewaters from commercial and industrial facilities are complex and varied, often containing compounds not found in nature. In 1990, U.S. industries discharged over 285 billion gallons of wastewater each day (Corbitt, 1990). These non-sanitary wastewaters are often highly discolored, turbid, alkaline or acid and unique to the generating industry. Depending on the specific nature of the wastewater generated by an industry, various classes of constituents have to be removed prior to discharge (Eckenfelder, Jr., 2000). Food processing wastewaters, like those found in poultry processing plants are characterized by high BOD and TSS that is often ten times the strength of sanitary wastewater (Welch and Lindell, 1992).

Table 1.3. Typical composition of raw sanitary wastewater.

Parameter	Unit	Weak	Medium	Strong
Biochemical Oxygen Demand (BOD)	mg/L	110	220	400
Chemical Oxygen Demand (COD)	mg/L	250	500	1000
Total Organic Carbon (TOC)	mg/L	80	160	290
Total Suspended Solids (TSS)	mg/L	100	220	350
Nitrogen (total as N)	mg/L	20	40	85
Phosphorus (total as P)	mg/L	4	8	15
Fat, Oil & Grease (FOG)	mg/L	50	100	150
Alkalinity (as $CaCO_3$)	mg/L	50	100	200
Chlorides	mg/L	3	5	10
Total Coliforms	no/100 ml	10^6 - 10^7	10^7 - 10^8	10^7 - 10^9

mg/L = milligrams per liter
no/100 ml = number of colony forming units per 100 milliliters
Source: Metcalf and Eddy, Inc., 1991.

Effluent Discharges

Industries that produce non-sanitary process wastewater have two options for disposal: direct and indirect. Direct dischargers are defined as industries that treat their wastewater on-site and then discharge the treated effluent to either a surface water or land application system. Direct dischargers are required to obtain a NPDES permit from state or federal regulators (CSUS, 1994). NPDES permit limits vary depending on the probable use of the receiving waters. Typical water quality indicators have been established for the designated use categories of contact and non-contact recreational, livestock and wildlife, fish propagation, drinking water supply, and irrigation (CSUS, 1993).

Indirect dischargers send their wastewater to a publicly owned treatment works (POTW), also known as a municipal wastewater treatment plant. Indirect discharges may or may not pretreat their wastewater prior to sewer system discharge. These industries are often issued a pretreatment permit by the local regulatory authority that governs their effluent much like a NPDES permit for direct discharges, but usually with less stringent limitations (CSUS, 1991).

Poultry Processing Wastewater

As is typical of many food processing industries, poultry processing is characterized by relatively high usage of water, most of it for non-consumptive purposes (Kroyer, 1991). Typically, broiler slaughter operations produce 5 to 10 gallons of wastewater per bird processed (CAST, 1995). Using the typical range of wastewater generated per bird and the annual production rate of over 8.7 billion chickens, total wastewater generation in the U.S. by broiler plants is between 43.5 and 87.0 billion gallons annually. The profiling of wastewater effluents from U.S. poultry processing plants dates back to the late 1940s. Porges (1950) reported that the BOD concentration from a broiler processing plant was 1275 mg/L. Teletzke (1961) reported the BOD concentration of broiler processing wastewater to be 664 mg/L. Camp and Willoughby (1968) reported broiler processing wastewater levels at 473 mg/L for BOD, 650 mg/L for TS, and 196 mg/L for TSS. In 1969, Nemerow reported a BOD of 630 mg/L when he averaged the results for the processing and sanitation effluents from a broiler slaughter plant. Glide (1968) reported an effluent BOD level of 660 mg/L for a combined poultry slaughter and cannery operations. In addition, Glide noted that the slaughter operation was responsible for 80 percent of the organic load. Carawan *et al.* (1974) reported on a North Carolina broiler processing plant discharging effluent with a BOD of 506 mg/L, TS of 697 mg/L, and a TSS level of 375 mg/L.

In 1973, Singh *et al.* noted the wide fluctuation in BOD concentrations during monthly testing completed at four broiler processing plants. The average BOD concentration at the Virginia plants was 746 mg/L with a coefficient of variation of 0.41. The USEPA (1975) also revealed a wide fluctuation in the concentration of conventional pollutants. The review reported a BOD range of 500 to 1300 mg/L, a TS range of 600 to 700 mg/L, and a TSS range of 200 to 1000 mg/L. A similar fluctuation in BOD concentrations was reported by a research team led by Chen in 1976 following the sampling of nineteen Mississippi broiler processing plants. Whitehead (1976) reported a final broiler processing plant effluent BOD of 1116 mg/L, with a corresponding COD reading of 1691 mg/L.

With the steady increase in poultry processing rates, there has been a corresponding increase in wastewater pollutant concentrations. In 1989, Merka completed a comprehensive study of wastewater pollutant concentrations and loadings in a broiler slaughter plant. The final plant effluent had an average BOD of 2178 mg/L, 3772 mg/L COD, 1,446 mg/L TSS, 1745 mg/L total volatile solids (TVS), 776 mg/L FOG, 129 mg/L TKN, and 13.0 mg/L Ammonia. A team led by Rusten in 1998 tested wastewater that had passed through a 250 micron rotary screen and a grease trap. BOD levels ranged from 660 to 6400 mg/L (1940 mg/L average), TSS readings from 40 to 3700 mg/L (1360 mg/L average), FOG ranging from 55 to 3570 mg/L (970 mg/L average), and total phosphorus (P) from 14.1 to 18.5 mg/L (16.1 mg/L average). Eremektar *et al.* (1999) reported BOD concentrations ranging from 1000 to 2100 mg/L, COD levels of 1500 to 3500 mg/L, total nitrogen results from 150 to 400 mg/L, and P from 16 to 50 mg/l.

Wastewater from Isolated Poultry Processing Areas

Porges and Struzeski (1962) reported that uncollected blood had a BOD of 92,000 mg/L, and contributed 40 percent of a broiler slaughter plant's final effluent organic load. In 1972, Hamm sampled wastewater from seven discrete processing functions at ten plants and found that the scalder produced wastewater with the highest average COD (2268 mg/L), and TVS (1180 mg/L). Woodward *et al.* (1972) reported that 26 percent of a processing plant's BOD load is attributed to the flume transportation of viscera. Approximately seven percent of the BOD load was attributed to the scalder and an additional seven percent to the chiller overflow. Carawan *et al.* (1974) also measured the organic contaminate concentration from seven process functions and found the highest contaminations in the giblet chiller (3958 mg/L COD). Whitehead (1976) reported that supernatant from an offal trailer had the highest BOD (7050 mg/L), while chiller overflow has the least (830 mg/L BOD). Lilliard reported in a 1978 study that the highest organic load was produced by a neck chiller (1723 mg/L BOD) and a gizzard splitter (1484 mg/L BOD). Wang and Gardner (1979) reported that wastewater from the feather picking operation contained the highest concentration of bacteria.

Poultry Processing Wastewater Treatment

In most cases, regardless of a direct or indirect discharge, the majority of the soluble and particulate organic material in poultry processing wastewater must be removed prior to discharge from the plant in order to achieve compliance with established environmental regulations. Depending on the degree of treatment required poultry processors have the option of utilizing physical, chemical and biological treatment systems. Each system type possesses unique treatment advantages and operational difficulties.

Physical Treatment

Physical treatment, in the form of screens, can be defined as the placement of a perforated surface in a wastewater stream designed to retain particulate matter greater in size than the surface gap openings. The second common form of physical treatment are filters. Filters work similar to screens, but instead of a perforated surface, a media such as sand or synthetic fibers retains the particulate matter (AWWA, 1977). Screens are the most popular form of primary physical treatment used in poultry processing wastewater treatment. Screens serve a dual purpose. First, screens recover offal that is a valuable commodity for the poultry rendering industry. Second, screens prepare wastewater for further treatment by removing the larger solid particles from the waste stream that might otherwise impede the operation and maintenance of downstream equipment and treatment processes (Pankantz, 1995). Screening is often the first, simplest and most inexpensive form of treatment.

On the other hand, filters are more commonly used as a final wastewater treatment step to polish effluent for discharge. In 1993, Walsh reported on the use of tertiary filters at a North Carolina turkey plant that helped eliminate chronic BOD and TSS violations. Finer or ‘microscreens’ can also be used as a final polishing treatment step. In 1976, McGrail reported on the use of microscreens and sand filters to treat lagoon effluent from a Maryland poultry plant processing 6000 birds per hour. Orth (1977) reported on the successful use of hydrophilic and hydrophobic fiber filters to remove particulate matter and oil from poultry processing and further processing plants. In 1980, Newswanger and Zuern reported the use of microscreens in a Pennsylvania poultry processing plant as a polishing treatment step following an activated sludge treatment system and secondary clarification. Primary treatment screens used for poultry processing wastewater treatment come in various forms (bar, shaker, rotary), and are classified as:

- Coarse - gaps greater than 6.0 mm (>0.25 in.),
- Fine - gaps 1.5 mm to 6.0 mm (0.059 in.to 0.25 in.),
- Very fine - gaps 0.2 mm – 1.5 mm (0.008 in. – 0.059 in.)
- Microscreens - gaps 1.0 μm – 0.3 mm (3.9×10^{-8} in. – 1.2×10^{-2} in.) (WEF, 1998).

Screens can be utilized as stand alone units or in series, which allows coarser screens to remove larger particles before further screening by finer mesh units (Laughlin and Roming, 1993). Screens must be sized properly to handle both the hydraulic flow and particle size of the waste stream to prevent 'blinding', which is defined as the overload of a screen that results in the coating over of the gaps preventing the passage of water (AWWA, 1977).

The most common form of screens utilized by the poultry processing industry are rotary types. Rotary or drum screens come in two basic forms: internally-fed and externally-fed. In internally-fed rotary screens, wastewater and associated solids are fed inside the drum. Water drains outside the drum while the solids are retained inside and conveyed to handling equipment. On externally-fed units, wastewater and solids flow over the outside of the drum. The water portion of the stream passes through the drum, while the solids rotate on the outside of the drum and are scraped off on the opposite side of the entry point. Common problems associated with screening include mechanical failures and blinding due either to the overloading of the screen or to under sizing of screen gaps (Pankrantz, 1995). Another type of less commonly used screens are shakers. Shaker screens utilize a flat perforated platform that is vibrated at a high rate, allowing solids to be retained on the platform while water flows by gravity through the perforated plate (Walsh, 1993).

The placement of screens is also important to their overall effectiveness. In 1976, Mellor and Gardner reported that a Texas broiler slaughter plant reduced BOD from 880 to 680 mg/L and TSS from 1050 to 270 mg/L when they relocated their primary feather and viscera rotary screens from a post-transfer pump position to a pre-pump position at the headworks of the treatment system.

Physical/Chemical Treatment

Although there are a variety of chemical wastewater treatment processes available for use in the poultry processing industry, by far the most popular form utilized is dissolved air flotation (DAF) (Harper *et al.*, 1988). Best described as a physical/chemical treatment, DAF refers to the process of water-solid separation by the introduction of fine gas (usually air) bubbles to the wastewater stream. The efficiency of the system is enhanced by the addition of chemicals to adjust pH and improve the flocculation of particulate matter. These microbubbles attach to the solid particles in wastewater causing a solid-gas matrix. The resulting increased buoyancy of the matrix causes it to rise to the surface of the water where it can be collected and removed by mechanical skimming. The use of DAF technology has seen widespread application since the mid-1960s (WEF, 1998). 'Air-assisted' DAF units are operated solely as a physical treatment system with no chemical addition (WEF, 1998). In 1996, Smith reported on the successful upgrade of a Georgia poultry processing plant using DAF technology. DAF units operating without chemical addition were able to reduce BOD, TSS, and FOG by 35 percent, 48 percent, and 42 percent, respectively.

The most important aspect of an effectively operating DAF unit is bubble size (Cassell *et al.*, 1975). DAF units produce bubbles that are microscopic in size. Typical DAF bubble size distribution is in the range of 10 to 100 μm (micron). DAF bubbles give wastewater a milky white appearance (WEF, 1998). In addition to the introduction of air, and to increase removal efficiencies, most DAF systems also utilize a variety of flocculent chemicals that aid in the coagulation of the solid materials in the waste stream.

In 1976, Reed and Woodard reported on the critical relationship between pH and aluminum sulfate chemical dosage in DAF units treating poultry processing wastewater. Woodard *et al.* (1977) installed and tested a DAF system in a Maine poultry processing plant and determined the optimum dosages of aluminum sulfate, soda ash, and cationic polyelectrolyte for the treatment system. In 1982, Tookos used pilot plant scale units to show that DAF technology was superior to sedimentation in the treatment of poultry processing wastewater, especially in larger plants. Hopkins (1988) documented that effluent from DAF units treating high strength poultry processing wastewater achieved BOD and TSS levels below 250 mg/L and FOG results less then 100 mg/L. Harper *et al.* (1988) highlighted the importance of frequent jar tests for better pH control, which is critical to optimizing solids removal. The skimmed material from DAF units is considered a viable by-product and is utilized by the poultry rendering industry (Ockerman and Hansen, 2000). The most common problems associated with operating DAF units are mechanical failures and poor solids separation (WEF, 1998).

Biological Treatment

Biological treatment or 'biotreatment' is defined as the treatment of wastewater by microorganisms in a controlled environment. The microorganisms convert biodegradable, organic particles and some inorganic materials in wastewater into a more stable cellular mass and other by-products that are later removed from the remaining water fraction by physical means, such as settling in clarifiers. Biotreatment methods represent a potentially cost effective approach, requiring little or no chemical inputs, and greater then 90 percent removal efficiencies of pollutants in poultry processing wastewaters are readily attainable (CSUS, 1992).

Typical biotreatment systems include activated sludge systems, lagoons, trickling filters, and septic tanks (Nemerov and Dasgupta, 1991). However, based on information provided by poultry industry experts, biotreatment systems consisting of an anaerobic lagoon followed by an activated sludge system are used by an estimated 25 percent of U.S. poultry processing plants, and are probably the most common wastewater biotreatment process configuration in the industry

(Starkey, 2000). Consequently, the focus of discussion is principally on anaerobic digestion and activated sludge treatment. Anaerobic digestion results in the conversion of organic matter into methane and carbon dioxide via a series of interrelated microbial metabolisms under 'septic' (no free oxygen present) conditions. Given the complex interactions between the various microorganism populations, a number of factors can upset the anaerobic digestion process. Despite potential process instabilities arising from competing biochemical activities, anaerobic digestion has an important advantage over aerobic processes in that power requirements are comparatively minimal since aeration is not necessary for treatment to proceed (Nguyen and Shieh, 2000). However, the low pollutant levels required for the final effluent are typically not achievable anaerobically, hence further treatment under aerobic conditions is usually necessary.

Activated sludge, including its many variations, is the most widely used aerobic wastewater treatment process within the poultry processing industry (Starkey, 2000). An activated sludge system consists of two main process units: the aeration basin and the clarifier. The aeration basin provides an environment for the breakdown of soluble and particulate pollutants by microorganisms known collectively as 'activated sludge'. The clarifier provides a quiescent environment that allows the activated sludge solids to separate by flocculation and gravity sedimentation from the treated wastewater (CSUS, 1992).

Solids separation problems in activated sludge systems result in the loss of microbial biomass from the treatment process and eventually lead to process failure. Microbial solids not separated in the clarifier become particulate organic matter carried in the effluent, possibly resulting in non-compliance with treatment objectives for TSS and BOD. Activated sludge system operation, therefore, requires the maintenance of a flocculent, well-settling sludge (Jenkins, 1992; Nguyen and Shieh, 2000). Solid separation problems in activated sludge systems are rather common and can be difficult to control (Jenkins *et al.,* 1993). The Council for Agricultural Science and Technology (CAST, 1995) specifically lists filamentous bulking as a problem in activated sludge treatment of poultry processing wastewaters that must be resolved.

Although traditional activated sludge systems continue to see wide application in treating poultry processing wastewater, innovative technology continues to be tested for improved removal efficiencies. In 1990, Liao and Lo performed laboratory bench scale experiments on poultry processing wastewater using sequencing batch reactors (SBRs), a technology that has seen increased use in municipal and industrial wastewaters, but limited use in food processing applications prior to 1990. A research team led by Rusten (1998) designed a biological treatment plant for poultry processing wastewater using an aerated equalization tank followed by two high-rate moving bed biofilm reactors (MBBRs) in series. The COD removal efficiency of the two MBBRs was found to be 80 to 95 percent. In 2000, Pierson and Pavlostathis evaluated the efficiency of SBRs for the pretreatment of poultry processing wastewater. They found that state-of-the-art instrumentation for real time pH, oxidation-reduction potential (ORP), and dissolved oxygen (DO) were keys to proper system operation and removal efficiencies.

CHAPTER 2

MAIL SURVEY OF U.S. POULTRY PROCESSING WASTEWATER TREATMENT PRACTICES[1]

[1]Kiepper, B., A.E. Reynolds, W. Merka, J. Sellers, and J. Starkey. To be submitted to the *Journal of the American Water Resources Association (JAWRA)*

Literature Review

Surveys

A survey can be defined as the structured or systematic collection of information about the same variables or characteristics from two or more cases that result in the forming of a data matrix. Survey developers seek to obtain an attribute for each variable that results in a structured or 'rectangular' set of data. Regardless of the survey method used, the goal remains to obtain an accurate description for each defined variable in the survey (de Vaus, 1986). Mistakenly, surveys have become synonymous with questionnaires, but other techniques such as structured and in-depth interviews, observations, and content analysis also fit the survey definition (Marsh, 1982). Because questionnaires have proven to be the easiest method to ensure a complete data matrix, they are the most common method used in survey research (de Vaus, 1986).

No one knows at what point humans decided on the need to enumerate themselves and their possessions, and to document the process. However, the use of surveys as a method of data collection can be traced back thousands of years. Most of the earliest documented surveys were in the form of census. Surveys of people and goods are recorded in the Bible and in ancient Babylonian archives. The Roman Empire established an office of 'censores' in 443 B.C., and survey results can be found in the 1086 Domesday Book and in the Napoleon's surveys of 1806 (Erdos, 1970).

Today there are four major types of surveys, based on the data collection method used: personal interview, telephone, mail and computer electronic. The four survey types can be classified into two distinct groups based on the type of interaction that takes place between the surveyor and respondent. During personal interview and telephone surveys the surveyor has the ability to verbally ask questions and guide the respondent through the survey. Mail and computer electronic surveys lack personal contact. The distinction between the two groups gives rise to important differences in survey design, questionnaire construction, respondent motivation, and the advantages and disadvantages of each survey type (Erdos, 1970).

Mail Surveys

Despite the fact that organized postal systems are a relatively modern institution, mail surveys are by no means a recent development. In 1577, King Philip II of Spain used official couriers to conduct a census of his 'New World' possessions. The written memorandum contained 38 questions, included detailed completion instructions for overseas governors (Erdos, 1970). In the United States, mail surveys became popular for marketing research and public opinion polls beginning in the late 1800s, although little or no thought was given to sampling theory or to the percentage of response (Coolsen, 1947; Lockley, 1950). The extensive use of scientific and statistical methods in the development and results analysis of professional mail surveys began in the late 1930s (Brown, 1937; Erdos, 1970). The U.S. government used mail surveys extensively for the first time during the 1960 Census. The government's major goal was to produce better quality data than that obtained under the previous personal interview method, while keeping costs at a reasonable level (Erdos, 1970).

Advantages and Disadvantages of Mail Surveys

Today, mail surveys are considered an essential tool by researchers to obtain information from time constrained industrial personnel. Due to the many advantages of the mail survey, it has become a popular research method in both the commercial and academic sectors. Advantages of mail surveys include a relative low cost, wide distribution capability with geographic flexibility, ample time for respondents to answer questions fully and with care, anonymity of respondents, centralized control, and reduced interviewer bias (Greer *et al.*, 2000). However, mail surveys also have disadvantages that include no direct control over response rate or geographic distribution of responses, inability of interviewer to verbally motivate respondent, and the inability of the interviewer to answer or clarify questions respondent has during participation in the survey (Erdos, 1970; Faria and Dickinson, 1996; Kanck and Berenson, 1975; Mangione, 1995). Because of these disadvantages, a number of research studies have been conducted over the past twenty years to document the effect of response inducement factors (Greer *et al.*, 2000).

Response Inducement Factors

Researchers have concluded that the decision by a respondent to cooperate with an interviewer is simply based on an evaluation of the ratio between the perceived rewards and costs of participating in a mail survey. Survey developers must attempt to maximize the respondents perceived rewards while minimizing the costs (Childers and Skinner, 1996; Dillman, 1978).

Rewards can be classified as tangible and intangible. Tangible rewards include monetary and non-monetary incentives, while intangible rewards include stressing the importance of the survey results, emphasizing the respondent benefits, using survey sponsorship as an appeal, giving written personal appreciation, positioning the respondent as an expert, and conducting follow-up contacts. Costs to the respondent include time, energy, and effort required to complete a mail survey (Greer *et al.,* 2000).

Industrial Mail Surveys

Groups that receive mail questionnaires at their place of employment are referred to as ‘industrial populations’ (Pressley and Tullar, 1977). Studies have documented that industrial populations are less likely to respond to mail surveys than consumer populations. Factors contributing to low industrial population response rates include preoccupation with work, confidentiality of information, company rules and policies, and time constraints (Greer *et al.*, 2000). As a result, the last two decades has seen a surge in the number of studies on response inducement factors aimed at industrial respondents.

Researchers have established several industrial respondent inducement factors that have statistically significant impact on mail survey completion rates. Futrell and Hise measured the significant impact of respondent anonymity in 1982, while Tyagi documented similar results in 1989. In 1990, Clark and Kaminski found a significant difference in response rates when the same mail survey was delivered with a hand written cover letter versus a computer generated form cover letter. Several studies in the 1980s documented the significant positive impact that follow-up contacts in the form of letters, telephone reminders, and letters including another copy of the survey had on survey return rates (Jobber *et al.*, 1985; Jobber and Sanderson, 1983; Swan *et al.*, 1980). Multiple studies in the 1990s revealed that sponsorship by an academic university significantly improved response rates over mail survey with only commercial sponsorship (Faria and Dickinson, 1992, 1996; Greer and Lohtia, 1994). More recently, researchers have attempted to create more holistic hierarchy-of-effects models that seek to combine all the factors of the mail survey response process to improve survey design (Groves and Couper, 1998; Helgeson *et al.*, 2002).

Similar in many ways to mail surveys, computer electronic surveys have seen a dramatic increase in recent use due to the significant expansion of the Internet. Recent studies comparing mail and computer electronic surveys have shown that mail surveys yield a significantly higher response rate and a lower rate of undeliverable or uncompleted surveys. Conversely, the studies also document the beneficial aspects of computer electronic surveys over mail surveys in the areas of associated costs and response times (Bachmann *et al.*, 1996, 2000; Boyer *et al.*, 2002; Cobanoglu *et al.*, 2001; Kiesler and Sproull, 1986; Klassen and Jacobs, 2001; Mavis and Brocato, 1998; Mehta and Sivada, 1995; Schaeffer and Dillman, 1998; Shannon and Bradshaw, 2002; Sheehan and Hoy, 1999; Truell and Bartlett, 2002;).

Industrial Wastewater Surveys

Wastewater characterization mail surveys, also referred to as industrial waste surveys, can be used to establish hydraulic flows, environmental quality parameters, and pollutant loadings at individual industrial facilities. The results of the survey can be used to determine the treatment level required to meet effluent discharge standards, select wastewater treatment processes, assist in discharge permit application preparation, establish pretreatment requirements for the facility prior to discharge to a municipal sewer system, and develop wastewater flow and loading minimization programs (Corbitt, 1990; Canter and Harfouche, 2000). Wastewater characterization studies can also be used to develop industrial user fee structures and surcharges (WPCF, 1977).

Abstract

Traditionally, poultry processing operations have been large users of potable water, and consequently, large generators of wastewater. A broiler slaughter facility will generate 5 to 10 gallons of wastewater per bird processed. Broiler plants processing 150,000 to 200,000 birds per day generate 1.0 to 2.0 million gallons of high strength wastewater. The U.S. Poultry & Egg Association (USPOULTRY) sponsored an independent University of Georgia mail survey aimed at identifying the current practices and experiences of the industry in the area of wastewater treatment. The survey was distributed nationwide to environmental contacts at 241 poultry processing facilities. Fifty-eight (58) poultry processing facilities, located in 16 states, returned completed surveys for a response rate of 24 percent. Survey results for chicken slaughter plants reveal mean values for plant processing rates of 205,587 birds per day (BPD), plant staffing at 982 employees, chicken live weight of 5.8 pounds, potable water use at 1.46 million gallons per day (MGD), and water cost of $1.64 per 1000 gallons. Wastewater treatment survey results are summarized for permitted parameters, non-permitted process control measurements, treatment system configuration, and treatment upsets with operational solutions. Twenty-six (45 percent) of the facilities reported 42 wastewater treatment system operational problems. Of the operational problems reported, the majority involved the inadequate separation of dissolved air flotation (DAF) skimmings.

Keywords <u>Water/Sewage Treatment</u>, Water Conservation, Poultry Processing, Wastewater Treatment, Dissolved Air Flotation, Mail Survey

Introduction

Poultry processing is characterized by relatively high water usage, most of it for non-consumptive purposes (Kroyer, 1991). Typically, broiler slaughter operations produce 5 to 10 gallons of wastewater per bird processed (CAST, 1995). The U.S. Department of Agriculture reported that over 8.7 billion chickens were slaughtered in 2002 (USDA, 2003). Using the typical range of wastewater generated per bird, total wastewater generation by U.S. chicken slaughter plants is now between 43.5 and 87.0 billion gallons annually, the equivalent of that produced by a city of 1.7 to 3.4 million people (Metcalf and Eddy, Inc., 1991). Poultry processing facilities are required to remove the majority of the soluble and particulate organic material in their wastewater prior to discharge from the plant in order to achieve compliance with local, state and federal environmental regulations. Depending on the degree of treatment required poultry processors have the option of utilizing physical, physical/chemical and biological treatment systems. Each system type possesses unique treatment advantages and operational difficulties.

Survey Rationale

The treatment of poultry processing wastewater must be constantly evaluated to operate most efficiently. The evaluation of current poultry processing wastewater treatment technologies are required to stay abreast of the increasingly restrictive environmental regulations related to wastewater treatment and disposal. This evaluation provides a broad based prospective of the wastewater currently discharged by the industry. Also, starting in 2000 the U.S. Environmental Protection Agency (USEPA) began the task of reviewing and revising the wastewater Effluent Limitation Guidelines (ELGs) for U.S. meat processing industries.

The U.S. Poultry & Egg Association (USPOULTRY) determined that an industry wide database of U.S. poultry processing plant's wastewater treatment practices needed to be established. Facility production information, plant water use, and wastewater treatment problems and solutions would also be gathered and included in the database. The project goals were to provide the poultry processing industry with an accurate picture of current wastewater treatment practices, provide poultry industry advocates with accurate data to effectively debate draft federal regulation for Meat Product Industry ELGs, and assist the industry in determining the future focus of scientific and engineering research related to the treatment of poultry processing wastewater. A team from the University of Georgia (UGA) was selected and funded by USPOULTRY to accomplish the established goals.

Materials and Methods

Survey Development

UGA researchers met with USPOULTRY staff to form a working team to debate and select the method of data collection (Boyer *et al.*, 2002; Dillman, 1978; Greer *et al.*, 2000; Truell and Bartlett, 2002). The team established that the collected data should be solicited from all U.S. poultry processing plants. The solicited data should include extensive information on production, plant water use, and wastewater treatment practices. The information should be collected as concisely as possible. Due to proposed ELG regulation scheduling and USPOULTRY project funding guidelines, the data had to be collected in a finite period and be cost effective.

Based on these established guidelines and reviewed literature, it was determined that a mail survey in the form of a questionnaire would be used as the data collection method (Boyer *et al.*, 2002; Dillman, 1978; Greer *et al.*, 2000; Truell and Bartlett, 2002). To increase the mail survey response rate the team determined that the questionnaire would be co-sponsored by UGA and USPOULTRY (Faria and Dickinson, 1992, 1996; Greer and Lohtia, 1994). USPOULTRY would use their industry contact membership roles to distribute surveys to specific environmental staff members at each facility (Clark and Kaminski, 1990). USPOULTRY would also prepare a cover letter emphasizing the confidentiality of the individual plant data and the importance of the information to the future of the poultry processing industry as a whole (Futrell and Hise, 1982; Tyagi, 1989). Finally, the completed survey would be mailed back to USPOULTRY where they would be forwarded to the UGA team for analysis and database entry (Dillman, 1978; Helgeson *et al.*, 2002; Mehta and Sivadas, 1995).

The UGA team developed a seven-page mail survey for distribution to U.S. poultry processing facilities (Appendix A). The survey was divided into three major sections: general plant and production information, potable water use, and wastewater treatment operations.

General plant information included the type of poultry processing operations conducted at the facility, days and hours of operation, number of employees, and shift types. Production information was based on average daily processing levels and maximum plant design capacity versus actual throughput in each processing area. Survey questions on potable water use included total daily plant consumption, percent use by each work shift, unit water cost and major water consuming processes or pieces of equipment.

Wastewater treatment questions included disposal methods for effluent and associated by-products, unit costs and wastewater operation staffing. The survey asked for other process control measures used by facilities to ensure proper operation. The residuals (DAF skimmings, clarifier sludge) resulting from the treatment processes were identified by source, generation rate and final beneficial reuse method. Plants were asked to categorize and describe any wastewater treatment operational problems their facility has experienced and what steps were taken to remedy the problem.

Treatment of Survey Data

To interpret the variability of each category of survey data, the standard deviation (STD) was first calculated. The STD is commonly used to measure the dispersion of a data set and is defined to be the square root of the variance. It provides a numerical value, in the units of the data set, to the clustering tendency of the data (Blank, 1980; Ott, 1993). Once the STD was calculated, a coefficient of variation (COV) was calculated for each data set. The COV is used to express the STD as a percentage of the mean. COV is a relative measure of variability, in contrast to the STD that is in the same units as the data set (Steeel and Torrie, 1960).

Results

The survey was mailed nationwide to environmental personnel at 241 poultry processing facilities. Fifty-eight (58) poultry processing facilities, located in 16 states, returned completed surveys for a response rate of 24 percent. Figure 2.1 shows the location distribution of plants returning completed surveys by state. Of the surveyed plants, fifty-three (91percent) process chickens or chicken by-products, while five plants (9 percent) process turkeys.

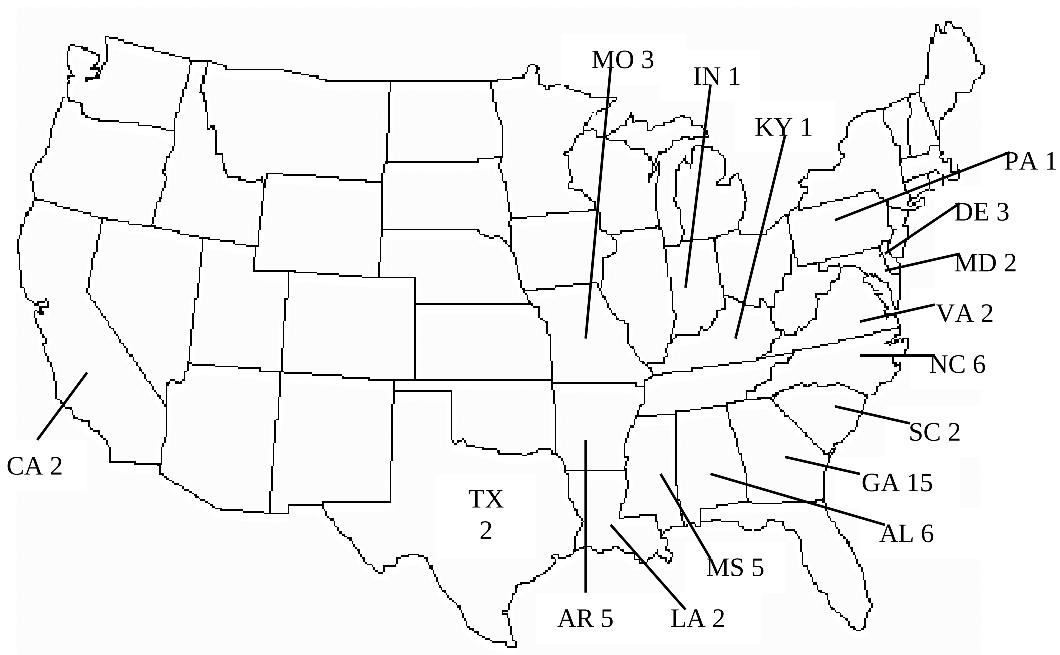


Figure 2.1. Distribution of poultry processing plants returning surveys by state.

Plant Operations

For the purposes of the mail survey, poultry processing operations were divided into four categories. First Processing was defined to include the operations of live bird slaughter, cut-up, and chill pack. Second Processing was inclusive of the operations of deboning, marination, instant quick frozen (IQF), portion control, and mechanically separated chicken/mechanically deboned meat (MSC/MDM).

Unit operations included in Third Processing were par-fry, full-cooked, bar-b-que, breading and breading/cook. Rendering, either on-site at a processing facility or as a stand-alone plant, was designated separately from other unit operations. Table 2.1 shows that the unit operations performed at the surveyed plants, in order of magnitude, were reported as slaughter (88 percent), cut-up and debone (77 percent), marination (44 percent), portion control (37 percent), chill pack (28 percent), MSC/MDM and fully-cooked (18 percent), IQF, breading/cooking and par-fry (14 percent), and breading alone (12 percent). Two plants (four percent) reported bar-b-que as a unit operation. Fifty (88 percent) of the 57 surveyed plants reporting unit operations are slaughtering facilities. This number reflects 45 of the 52 reporting chicken processing plants and all five of the turkey facilities. Table 2.2 reports the number and percentage of plants performing combinations of process operations.

Table 2.1. Unit operations of 57 surveyed poultry processing plants*.

Unit Operation	Number of Plants Performing Unit Operation	Percentage of Plants Performing Unit Operation
First Processing:		
Slaughter	50	88
Cut-up	44	77
Chill pack	16	28
Second Processing:		
Debone	44	77
Marination	25	44
Portion Control	21	37
MSC/MDM	10	18
IQF	8	14
Other	2	4
Third Processing:		
Fully-cooked	10	18
Breading/cook	8	14
Par-fry	8	14
Breading	7	12
Bar-b-que	2	4
Other	3	5
Rendering	11	19

* One of the surveyed plants did not report this information

Table 2.2. Combination of unit operations at 57 reporting poultry processing plants*.

Combinations of Unit Operations	Number of Plants Performing Combination	Percentage of Plants Performing Combination
First and Second	31	54
First, Second, and Third	7	12
First, Second, and Rendering	7	12
First Only	3	5
Third Only	3	5
Rendering Only	2	4
First, Second, Third, and Rendering	2	4
Second Only	1	2
Second and Third	1	2

* One of the surveyed plants did not report this information

First, Second, and Third Processing

The surveyed chicken processing facilities slaughter an average of 205,587 birds per day (BPD) for an average of 1,122,415 total live weight pounds (LWP). Thirty-three plants reported specific live weights per bird with an average of 5.8 pounds. The average output dressed weight was calculated at 837,436 pounds per day, for an average yield of 75 percent. The following assumptions were made in calculating estimated values for unreported data in surveys: average weight of live bird equaled 5.0 pounds, percent yield from live weight slaughter equaled 75 percent (Mead, 1989; Romans *et al.*, 1994; USDA, 2002). The lowest production reported by an individual plant was 55,000 BPD and 275,000 LWP. The highest production reported by a single plant was 600,000 BPD and 3.3 million LWP. Minimum and maximum percent yields for chicken slaughter plants were reported as 61 and 81 percent, respectively. Specific production data survey responses from poultry plants performing second and third processing operations was very limited, and not included in this report.

Renderers

Two completed surveys were received from facilities that only render poultry processing by-products. However, nine other surveyed plants perform rendering onsite at slaughter facilities. Data pertaining to the eleven operations, in tons per day processed, are detailed in Table 2.3.

One of the two reporting stand-alone rendering plants (plant number 10) operates six days a week with 75 production and 138 total employees, and uses an average of 300,000 gallons of water per day. The other stand-alone rendering plant (plant number 11) operates five days a week with 16 production and 20 total employees, and uses an average of 186,000 gallons of water per day.

Table 2.3. Renderer production levels (tons per day).

Plant No.	Offal (In)	Feather (In)	DAF Solids (In)	Blood (In)	Misc. Meat (In)	Oil (Out)	Poultry Meal (Out)	Feather Meal (Out)	Blood Meal (Out)
1	28	11	-	-	87	-	50	-	-
2	30	30	5	-	-	6	15	15	-
3	425	108	23	44	-	75	103	36	6
4	120	75	-	-	-	-	50	25	-
5	95	26	9	12	-	-	-	-	-
6	dnr								
7	200	34	8	-	-	35	30	18	-
8	311	147	40	-	-	59	62	34	-
9	dnr								
10	1125	400	-	-	-	213	297	138	-
11	270	115	-	-	-	-	-	-	-

*dnr – did not report production data

Plant Staffing and Operations

The average number of production employees utilized by all of the surveyed plants is 756, while the average total plant employees were calculated at 841. The lowest number of production and total employees reported was 16 and 20 at a stand-alone rendering plant. The highest employee numbers were listed at 1650 and 1749, respectfully at a chicken slaughter facility. Of the 45 reporting chicken slaughter facilities, 47.5 percent employ more than 1000 people.

Plant Water Use

Potable water use for the chicken slaughter plants was reported by 32 facilities. The mean potable water use per day was 1.46 million gallons per day (MGD). The minimum and maximum reported values were 0.38 and 4.50 MGD, respectively. Forty-five plants reported their percentage of water use by production shift. Table 2.4 summarizes the forty reporting plants that operate three daily shifts (two production, one sanitation), while Table 2.5 shows the remaining five plants operating two daily shifts. Thirty-nine plants reported their cost per 1000 gallons of water ($/Kgal). The mean cost was calculated at 1.64 $/Kgal, while the minimum and maximum values were reported as 0.09 and 6.75 $/Kgal, respectively.

Table 2.4. Percentage of potable water use by production shift – 3 shifts, 40 plants.

	1st Production Shift	2nd Production Shift	Sanitation Shift
Minimum	31	20	8
Maximum	60	46	44
Average	41	39	20

Table 2.5. Percentage of potable water use by production shift – 2 shifts, 5 plants.

	Production Shift	Sanitation Shift
Minimum	65	19
Maximum	81	35
Average	74	26

Wastewater Permitting and Treatment

All of the 58 surveyed poultry processing plants discharge their wastewater effluent under a discharge permit or local sewer ordinance. Table 2.6 summaries the parameters covered by the various discharge permits. Total Suspended Solids (TSS) and pH are required testing at over 90 percent of the surveyed plants.

Table 2.6. Permitted parameters of plants by number and percentage – 58 plants.

Parameter	Number of Plants Permitted	Percentage of Plants Permitted
Total Suspended Solids (TSS)	54	93
pH	53	91
Fat, Oil & Grease (FOG)	47	81
Biochemical Oxygen Demand (BOD)	46	79
Ammonia Nitrogen	35	60
Phosphorus	20	34
Total Kjeldahl Nitrogen (TKN)	19	33
Fecal Coliform	12	21
Nitrate/Nitrite	11	19
Dissolved Oxygen (DO)	11	19
CBOD	9	16
Chemical Oxygen Demand (COD)	7	12
Chloride	6	10
Total Nitrogen	5	9
E. Coli	2	3
Sodium	1	2
Zinc	1	2
Enterococcus	1	2
Organic Nitrogen	1	2
Toxicity	1	2
Temperature	1	2
Total Dissolved Solids	1	2

Wastewater Treatment Processes

Wastewater treatment processes were divided into ‘Physical’ (screening), ‘Physical/Chemical’ (DAF), and ‘Biological’ (anaerobic digestion, activated sludge, aerated and facultative lagoons, pack tower). Other supporting process categories were ‘Finishing’ (clarifier, filtration, polishing ponds, disinfection), and ‘Final Disposal’ (direct discharge: surface water / land application, indirect discharge). All of the surveyed plants use some form of treatment on their wastewater. Table 2.7 shows the number and percentage of plants by wastewater treatment process type utilized.

Table 2.7. Wastewater treatment process categories - 57 plants.

Treatment Process Types	Number of Plants	Percentage of Plants
Physical Only (1)	1	2
Physical/Chemical Only (2)	4	7
Biological Only (3)	1	2
(1) and (2)	17	30
(1) and (3)	13	23
(2) and (3)	2	3
(1), (2) and (3)	19	33

The fifty-six surveyed plants reporting on wastewater treatment staffing employ a total of 120 state certified wastewater treatment personnel, ranging from zero at seven facilities to ten at two facilities. Other personnel numbering 154 are employed to assist certified staff bringing the staffing total at all 56 reporting plants to 274 employees. Ten plants use only certified personnel with no non-certified assistance, while seven plants utilize only non-certified staff.

Wastewater Treatment Methods

Of the fifty-seven surveyed plants reporting data in the wastewater treatment processes category, initial physical treatment in the form of screens are utilized by forty-eight (84 percent). By far the most popular form of screens are rotary types. Of the 48 plants reporting screen use, 42 (88 percent) use internally-fed rotary screens. Other types of screens utilized by the surveyed plants include externally-fed rotary, shaker and bar.

Physical/chemical treatment, in the form of DAF technology, is utilized at 74 percent of the surveyed plants. Plants reported that the solids content of their DAF skimmings range from a low of five percent for materials recovered directly from DAF units, to 47 percent for skimmings further treated with dewatering technology such as filter belt presses and driers. Volumes of skimmings produced per day were reported either as pounds or gallons. Daily pounds produced range from 5,600 to 600,000 with an average of 80,523. Plants reporting gallons of DAF skimmings collected ranged from 2,500 to 25,000 with an average output of 9,098.

Biological treatment was divided into anaerobic digestion, activated sludge, aerated lagoon, facultative (non-aerated) lagoon, and packed tower. Thirty-four plants reported the use of biological treatment. The most popular form of biological treatment is activated sludge with 21 facilities (62 percent) reporting its use. Aerated lagoons and anaerobic digestion were the second most popular types of biotreatment with 17 plants (50 percent) reporting the use of each type. Eleven plants (32 percent) report the use of facultative lagoons, while two plants (6 percent) use packed towers.

Finishing treatment of wastewater was divided into final clarifiers, filtration, polishing ponds and disinfection. Twenty-one plants (62 percent) use final clarifiers ranging in capacity from 4,500 to 1,700,000 gallons. Two plants utilize filtration, while nine plants (26 percent) have final polishing ponds. Twenty-four plants have disinfection systems associated with their wastewater treatment. For disinfection, 16 plants use chlorine, two use sodium hypochlorite, and six plants use a UV (ultraviolet light) system.

Final disposal of treated wastewater was divided into two basic categories: 'direct discharge' to surface water and/or a land application system, or 'indirect discharge' to municipal sewer system. Fifty-three of the surveyed plants reported final disposal information. Thirty-two of the reporting plants (60 percent) are direct discharges. Twenty-one (40 percent) plants use effluent land application systems, nine (17 percent) facilities release effluent to surface water, while two plants (3 percent) use land application and surface water discharge in combination. Twenty-one (40 percent) of the facilities pretreat their waste streams prior to discharge to a municipal sewer system for further treatment.

Process Control Measures

Surveyed plants were asked to list the operating parameters that are regularly monitored and controlled to ensure proper wastewater treatment plant operation. Along with permitted parameters, these tests are used to diagnose operational problems. For each parameter, plants were requested to note sample point and frequency of testing, target testing level, and if monitoring and/or control of parameter is automated. Non-permitted process control tests conducted by reporting plants include Dissolved Oxygen (DO), pH, Sludge Volume Index (SVI), Sludge Density Index (SDI), Mixed Liquor Suspended Solids (MLSS), Chemical Oxygen Demand (COD), BOD, TSS, Ammonia Nitrogen (AN), Nitrate (NO3), Nitrite (NO2), Total Kjeldahl Nitrogen (TKN), Chlorine (CL), and Alkalinity (ALK).

Residuals

Categories of wastewater treatment residuals included offal screenings, DAF skimmings and waste activated sludge. All fifty-eight of the surveyed plants reported some form of wastewater treatment residuals. Of the 43 plants reporting the recovery of screened materials, 41 facilities (95 percent) pass the by-product along to a rendering operation. One plant reported that their screenings are land applied, and one of the rendering plants recycles screenings back into their own rendering process.

The rendering industry also handles the majority of DAF skimmings. Renderers take DAF solids from twenty-seven (64 percent) of forty-two facilities reporting DAF use. Eleven plants utilize land application systems, while four plants report skimmings are contract hauled. Finally, plants utilizing aeration systems were asked about their waste activated sludge. Of the 15 reporting plants, eight use land application, five use anaerobic lagoons, one uses an aerobic lagoon, and one uses a digester.

Wastewater Treatment Operational Problems

Of the 58 plants returning completed surveys, twenty-six (45 percent) reported forty-two wastewater treatment operational problems. A detailed list of the reported problems is summarized in Table 2.8. Ten plants reported the poor separation of DAF skimmings, making it the most frequently reported problem. Eight plants listed poor phosphorus removal as a problem, while five plants listed activated sludge bulking. Four plants reported problems with sour anaerobic digesters.

Table 2.8. Reported wastewater treatment operational problems and solutions.

Problem	Number of Plants	Plant Code	Reported Solutions
Poor DAF Sludge Separation	10	1.05	Check and blow out DAF air nozzles
		1.10	Adjust chemical dosage, skimmer flight speed
		1.12	Experiment with various polymers
		1.13	Install automated controls for pH, chemical addition
		1.14	Added silica gel flocculent
		1.28	Request City maintain potable water pH of 7.2
		1.40	Change chemicals, adjust dosage
		2.3	
		5.1	Reduce aeration, apply coagulant
		5.2	Experiment with new polymers
Poor Phosphorus Removal	8	1.14	Separate collection of high P marinate
		1.18	
		1.20	Change from Alum to liquid Sodium Aluminate
		1.21	
		1.33	Replaced Trisodium Phosphate with Sanova
		1.40	Stopped using Trisodium Phosphate
		1.42	
		5.1	Slow DAF flows and increase coagulant
Activated Sludge Bulking	5	1.19	Increase Return Activated Sludge (RAS), DO
		1.26	Increase DO, chlorinate Aeration basin
		1.27	Increase Waste Activated Sludge (WAS), DO
		1.31	Chlorinate RAS, slow flow
		5.4	Bioaugmentation of aeration tank with microbes
Sour Anaerobic Digester	4	1.10	Change frequency of aeration and WAS
		1.26	Add to aeration cycle
		1.40	Recirculation of effluent back into influent
		5.4	Adding biological catalyst to headworks
High Effluent Nitrate Levels	3	1.33	Addition of carbon source to anaerobic influent
		1.45	Discontinue DAF operation, increase organics
		2.5	
Denitrification In Clarifier	3	1.23	Decrease aeration cycle, add polymers
		1.26	Decrease blower run time
		1.27	Decrease aeration run time
High BOD Effluent Levels	3	1.40	
		2.2	Increase chemical dosage and retention time
		5.4	Add biological microorganisms
Other Problems:	6		
Fluctuating TKN		1.17	Evaluating alternative treatment options
Hydraulic Overload		1.23	Water conservation program
FOG Loading		1.27	Increase aeration, bioaugmentation
Cloudy Effluent		1.32	Decrease Magnesium Hydroxide feed
Solids Runoff		1.37	
High Ammonia		5.1	Increase aeration to bring DO up to 3.0 mg/L

Discussion and Conclusions

Survey Response Rate

Studies have shown that industrial populations are less likely to respond to mail surveys than consumer populations (Greer *et al.,* 2000; Pressley and Tullar, 1977). Researchers of the survey method report that survey developers must attempt to maximize respondents perceived rewards, either tangible or intangible, while minimizing the costs of time and effort (Childers and Skinner, 1996; Dillman, 1978). The UGA/USPOULTRY team focused on employing the response inducement factors of industry and academia co-sponsorship (Faria and Dickinson, 1992, 1996; Greer and Lohtia, 1994), respondent anonymity (Futrell and Hise, 1982; Tyagi, 1989), and telephone reminders (Jobber *et al.,* 1985; Jobber and Sanderson, 1983; Swan *et al.*, 1980) to increase the survey response rate.

Of the 241 mail surveys that were distributed, 58 were returned. This represents a 24 percent response rate, which was less then predicted. Follow-up phone conversation with non-responders indicate that time constraints and company policies on confidentiality of information were the leading factors in failure to return completed surveys (Greer *et al.,* 2000). Despite the lower than expected response rate, the survey results significantly correspond to established and emerging poultry processing industry trends.

Chicken slaughter plants represented 46 (79 percent) of the 58 completed surveys. Five (9 percent) surveys each were received from further processors and turkey slaughter plants, and two (3 percent) stand-alone renderers submitted surveys. It was determined that the number of chicken slaughter plants surveys provided the only statistically significant data (Erdos, 1970; Dillman; 1978; Groves and Couper, 1998).

Survey Response by U.S. State

Ollinger *et al.,* (2002) reported that in 1992, 65.4 percent of broiler slaughter was completed in the Southeast (SE) region (AL, AR, GA, FL, LA, MS, NC, SC, TN), the Central Atlantic (CA) region accounted for 15.1 percent (DE, MD, VA, WV), Southwestern (SW) states made up 10.8 percent (TX, OK, AZ, NM, CA), while the remainder of the country accounted for 8.7 percent. Poultry processing plants in 16 U.S. states returned completed surveys. Georgia had the greatest number of plants responding with 15 completed surveys (26 percent of total received). Figure 2.2 shows the similarity of percentage of U.S. poultry processing to the percentage of received surveys by U.S. region.

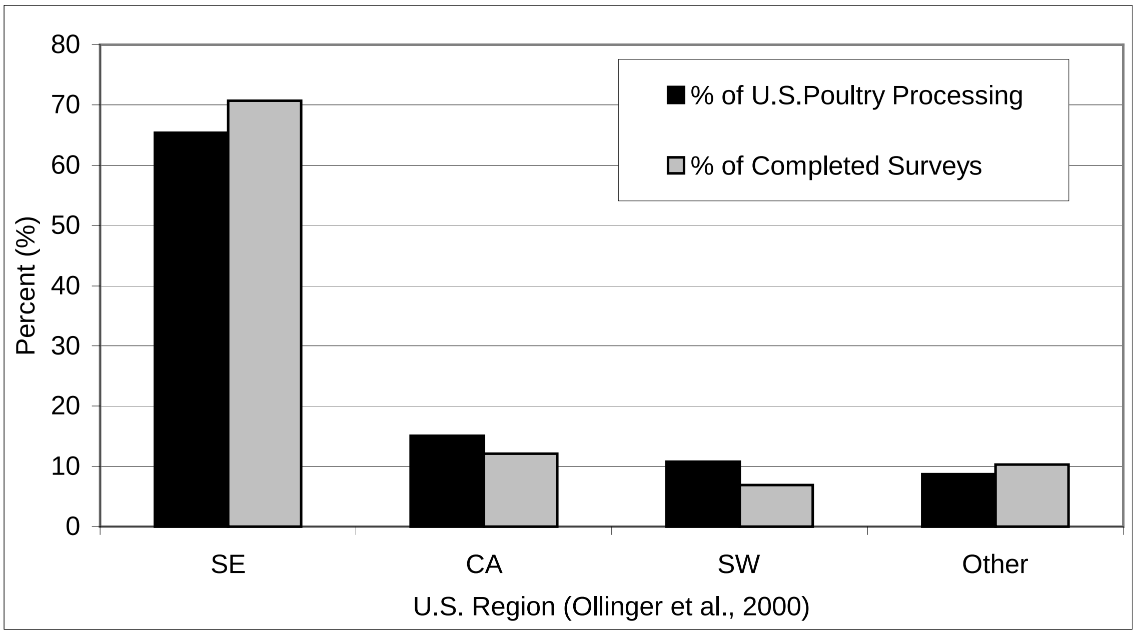


Figure 2.2. Comparison of U.S. poultry processing to completed surveys by U.S. region.

Plant Operations

Ollinger *et al.*, (2002) reported that in contrast to U.S. poultry processing plants in the past, which produced mostly whole carcass birds, modern plants generate a product mix of cut-up parts, deboned meat, and other further processed convenience products. Survey results support this statement. Of the 45 chicken slaughter plants reporting process operations, just one facility reported producing whole carcass birds exclusively. This one facility also was the smallest reporting broiler slaughter plant with a capacity of 55,000 BPD. Whole carcass cut-up (41 plants, 91 percent) and deboning (40 plants, 89 percent) were the additional operations most often performed in the chicken slaughter plants. Similarly, when all 57 of the surveyed plants were compared for combination of unit operations (First, Second, Third, and Rendering), it was found that only nine facilities (16 percent) perform a single operation. The remaining 48 plants (84 percent) perform two or more processing operations.

Plant Size

During the past 30 years, the average slaughter plant has increased in capacity from approximately 60,000 to 200,000 birds per day. In 1972 approximately 25 percent of poultry slaughter plants employed over 400 employees. By 1992, plants employing over 400 people accounted for over 80 percent of poultry slaughter facilities (Ollinger *et al.*, 2000). Survey results show that U.S. chicken slaughter plants continue to increase in size. Figure 2.3 illustrates the normal distribution of the reporting chicken slaughter plants based on the number of birds processed per day. The data set representing 45 plants had mean of 205,587 BPD, a median of 197,400 BPD, a STD of 89,738, and a COV of 0.44.

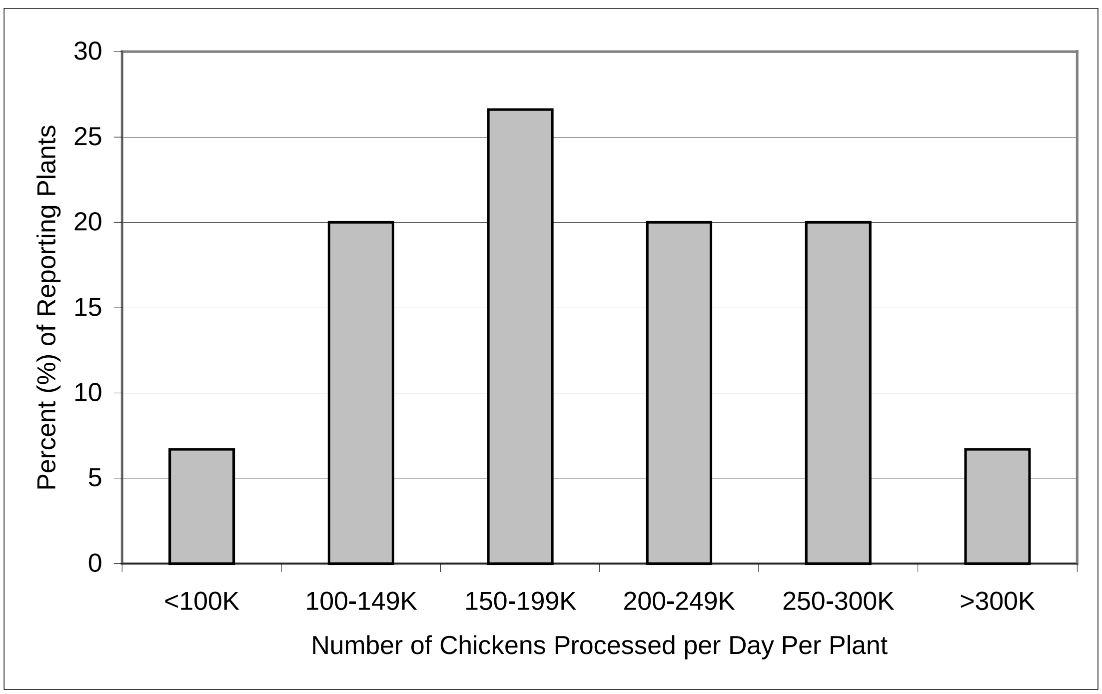


Figure 2.3. Chicken slaughter plants sizes based on number of birds processed per day.

Figure 2.4 shows the distribution of the reporting chicken slaughter plants based on total number of facility employees. The data set representing 40 plants had mean of 982 employees, a median of 933 employees, a standard deviation of 413, and a coefficient of variation of 0.42.

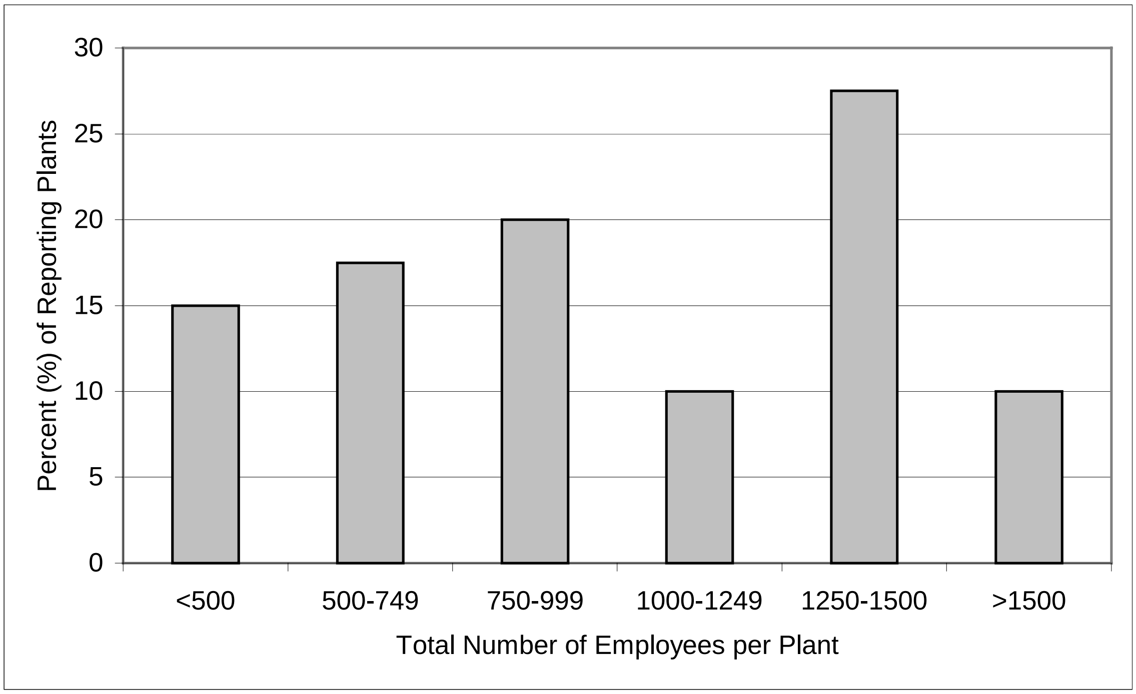


Figure 2.4. Chicken slaughter plants sizes based on total number of employees.

Chicken Size

One of the most significant recent trends in chicken processing has been the consumer demand for increased cut-up piece sizes and larger whole muscle deboned portions (Ollinger *et al.*, 2000; Rankin, 2000). Chicken processing plants have responded to this marketplace demand by slaughtering heavier birds. Combs (1961) reported that in 1934 a market ready chicken weighed 3.5 pounds, and that by the 1960s the mean live weight of slaughtered chickens was between 3.5 and 4.0 pounds. Mountney and Parkhurst (1995) reported that the live mean weight had increased to 4.0 to 4.5 pounds. The USDA (2003) calculated that the mean live weight of chickens slaughtered in the U.S. during 2002 was 5.12 pounds.

Thirty-three chicken slaughter plants reported on the mean live weight of incoming birds. Figure 2.5 illustrates the distribution of the chicken live weight means reported by the plants. The data set had a mean of 5.8 pounds, a median of 5.7 pounds, a STD of 1.0, and a COV of 0.17.

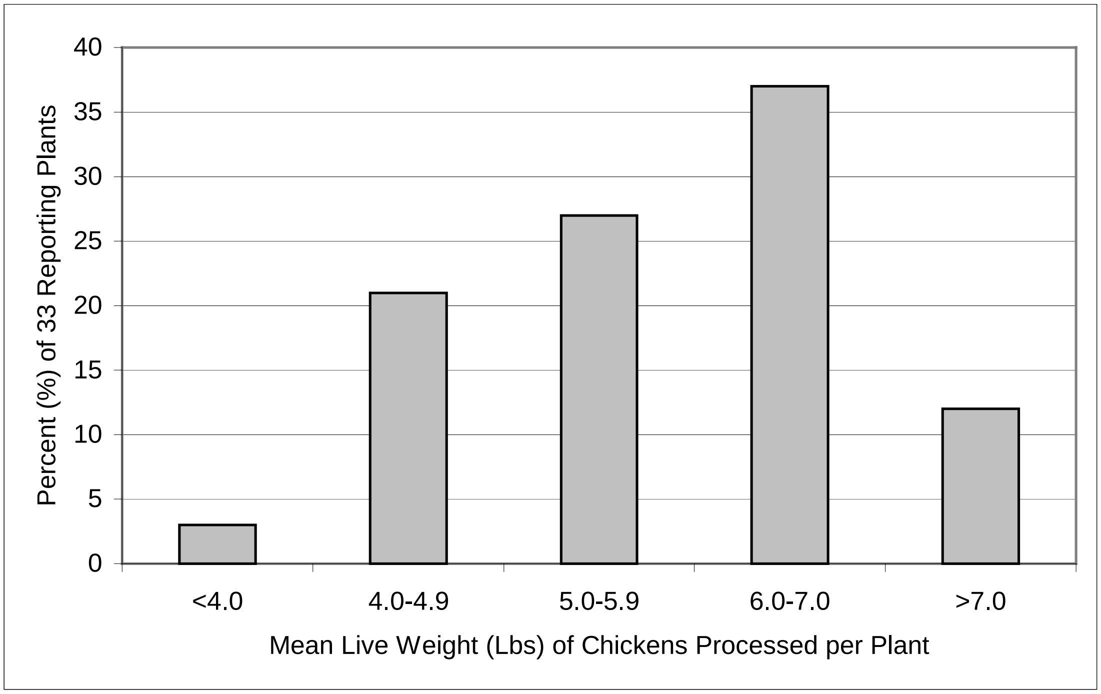


Figure 2.5. Distribution of pre-slaughter chicken live weights in pounds.

Potable Water Use and Costs

Figure 2.6 shows the distribution of the reporting chicken slaughter plants based on daily potable water use. The data set representing 45 plants had mean of 1.46 MGD, a median of 1.40 MGD, a standard deviation of 0.73, and a coefficient of variation of 0.50. The majority of the surveyed chicken slaughter plants (69 percent) consume over 1.0 MGD.

Thirty-nine plants reported data on their potable water cost per 1000 gallons ($/Kgal). Figure 2.7 illustrates the distribution of the reported costs. The data representing 39 plants had mean of 1.64 $/Kgal, a median of 1.44 $/Kgal, a STD of 1.28, and a COV of 0.78. Nearly half (49 percent) of the plants pay 1.00 to 2.00 $/Kgal.

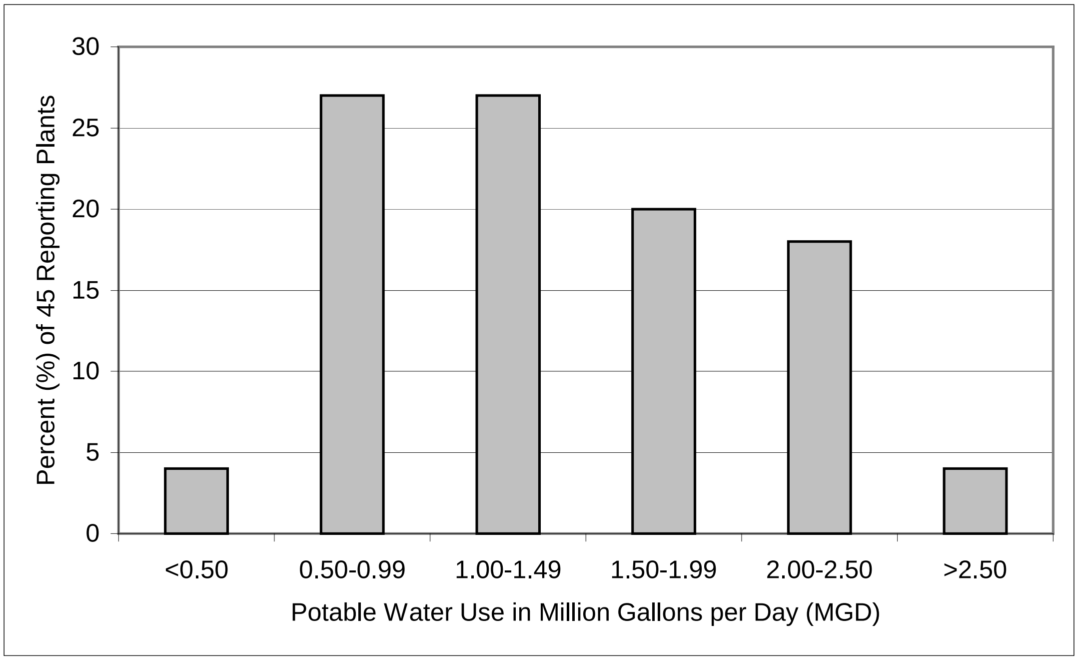


Figure 2.6. Distribution of potable water use in MGD - chicken slaughter plants.

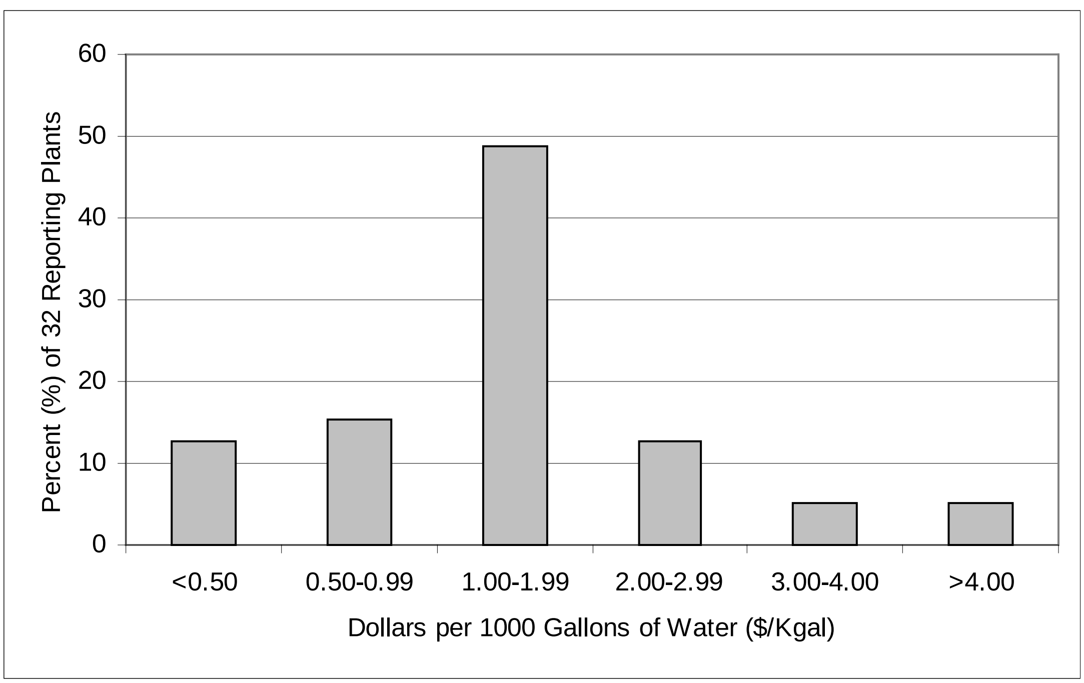


Figure 2.7. Distribution of potable water costs in $/Kgal – 39 reporting plants.

Wastewater

All of the 58 surveyed plants discharge their wastewater effluent under some form of environmental regulation, either through a permit or sewer use ordinance. Five wastewater monitoring parameters (TSS, pH, FOG, BOD, Ammonia Nitrogen) are required testing for over 50 percent of the reporting plants, but 17 other parameters are required testing for a least one plant. Given the wastewater treatment options of physical, physical/chemical, and biological processes, the majority (51 plants, 89 percent) of surveyed plants utilize a combination of more than one process. The most popular combination (19 plants, 33 percent) of processes is to use systems within all three categories. The most popular form of wastewater treatment utilized by the surveyed plants (48 facilities, 84 percent) are physical screens, with internally fed rotary screens being the most common type. Follow-up phone calls to plants not reporting the use of physical screens revealed that some plants consider primary screens as a production process operation, not a wastewater treatment function. Thus, these plants did not list their screens in the survey responses under wastewater treatment.

The most popular wastewater treatment configuration employed by the surveyed plants starts with physical treatment using screens (84 percent), followed by a physical/chemical DAF system (74 percent) in which the residual skimmings are transported to a renderer. Next, 62 percent of the reporting plants then utilize activated sludge systems, while 50 percent use aerated lagoons and anaerobic digestion within the biological treatment category. Finally, 41 percent of reporting plants disinfect their effluent prior to discharge.

Non-permitted analytical testing conducted at various locations throughout wastewater treatment systems and used for process control is an essential activity at all of the surveyed plants. Figure 2.8 illustrates the most popular non-permitted process control tests run on a periodic basis at the reporting plants. Cumulative data shows that pH testing is most commonly used to monitor wastewater treatment operations and prompt system adjustments.

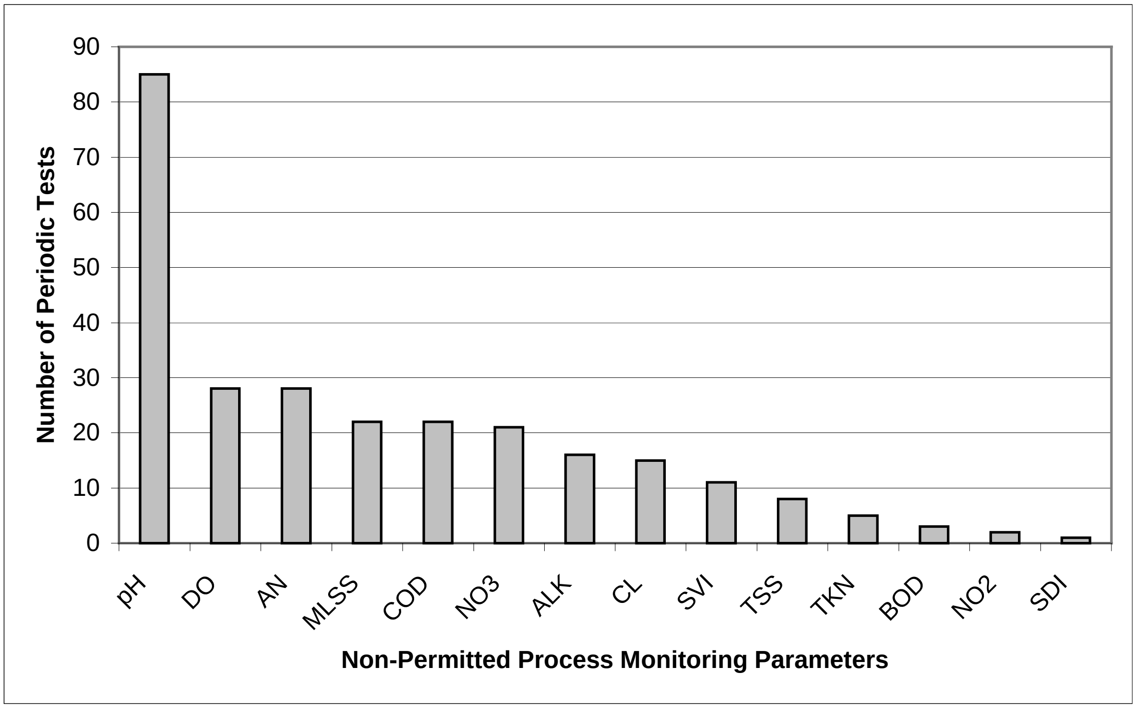


Figure 2.8. Number of non-permitted process control periodic tests conducted.

The remedies reported by the plants to deal with wastewater treatment problems were divided into seven categorizes:

- CHEM – solutions involving chemical use,
- MECH – mechanical repairs or adjustments,
- DO – adjustments in aeration/dissolved oxygen levels in treatment systems,
- P2 – use of pollution prevention techniques,
- Bioaug – bioaugmentation, addition of microbes to enhance biological activity,
- Biomass – adjustments made to level of activated sludge biomass, and
- Other – remedies not fitting previous categorizes

Figure 2.9 shows the relative dominance of each solution category, and reveals that remedies involving chemicals are the most commonly employed method to deal with wastewater treatment system upsets.

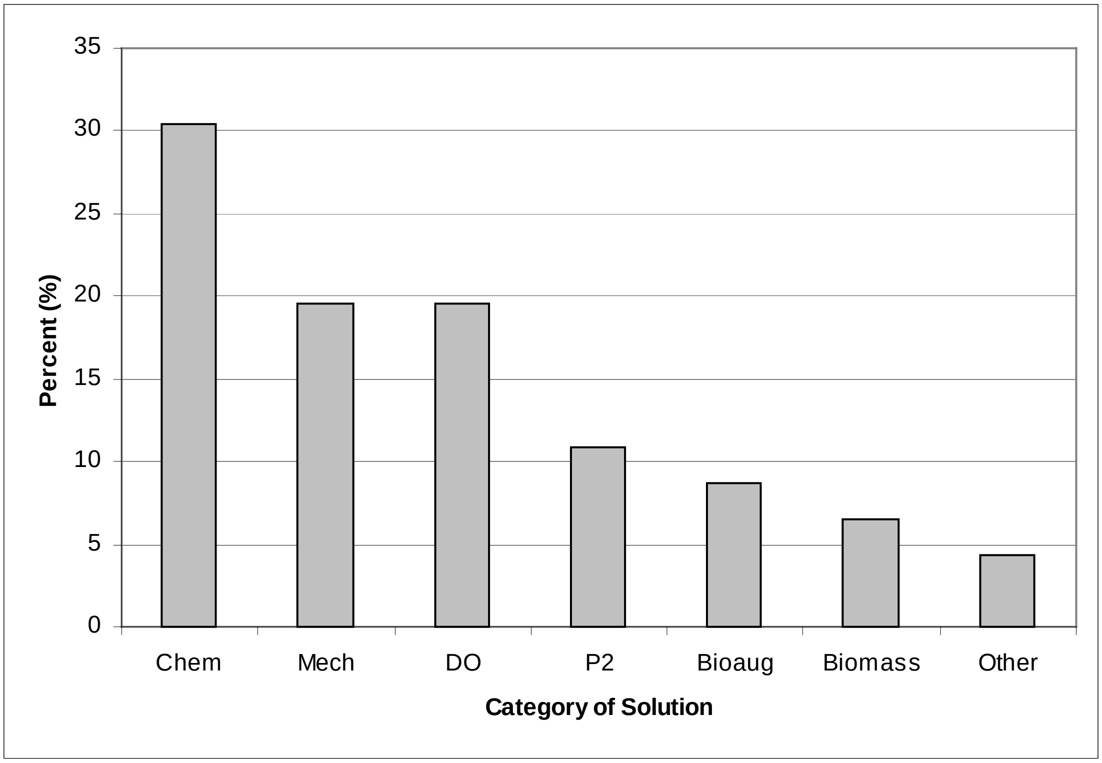


Figure 2.9. Solutions to wastewater treatment plant operational problems by category.

Complete survey results in original database form are available through USPOULTRY Final Report: Project No. 562 (Kiepper and Sellers, 2002).

Acknowledgements

Support for this research was provided by the United States Poultry & Egg Association (USPOULTRY), Tucker, Georgia.

References

Blank, L., 1980. Statistical Procedures for Engineering, Management, and Science. McGraw-Hill, New York, New York.

Boyer, K. K., J. R. Olson, R. J. Calantone, and E. C. Jackson, 2002. Print Versus Electronic Surveys: a Comparison of Two Data Collection Methodologies. Journal of Operations Management 20:357-373.

CAST, 1995. Waste Management and Utilization in Food Production and Processing. Task Force Report No. 124. Council for Agricultural Science and Technology, Ames, Iowa.

Childers, T. L. and S. J. Skinner, 1996. Toward a Conceptualization of Mail Survey Response Behavior. Psychology & Marketing 13:185-209.

Clark, G. L. and P. F. Kaminski, 1990. How to Get More for Your Money in Mail Surveys. Journal of Services Marketing 4:44-47.

Combs, G. F., 1961. Quality and Quantity of Final Product - Poultry. Federation of American Societies of Experimental Biology 20:306-312.

Dillman, D. A., 1978. Mail and Telephone Surveys: The Total Design Method. John Wiley & Sons, New York, New Tork.

Faria, A. J. and J. R. Dickinson, 1992. Mail Survey Response, Speed, and Cost. Industrial Marketing Management 21:51-60.

Faria, A. J. and J. R. Dickinson, 1996. The Effect of Reassured Anonymity and Sponsor on Mail Survey Response Rate and Speed with a Business Population. Journal of Business and Industrial Marketing 11:66-76.

Futrell, C. and R. T. Hise, 1982. The Effect of Anonymity and Same Day Deadline on the Response Rate to Mail Surveys. European Research 10(10):171-175.

Greer, T. V., N. Chuchinprakarn, and S. Seshadri, 2000. Likelihood of Participating in Mail Survey Research: Business Respondent' Perspectives. Industrial Marketing Management 29:97-109.

Greer, T. V. and R. Lohtia, 1994. Effects of Source and Paper Color on Response Rates in Mail Surveys. Industrial Marketing Management 23:47-54.

Helgeson, J. G., K. E. Voss, and W. D. Terpening, 2002. Determinants of Mail-Survey Response: Survey Design Factors and Respondent Factors. Psychology & Marketing 19(3):303-328.

Jobber, D., N. Allen, and J. Oakland, 1985. The Impact of Telephone Notification Strategies on Response to an Industrial Mail Survey. International Journal of Research in Marketing 2:291-306.

Jobber, D. and S. Sanderson, 1983. The Effects of a Prior Letter and Coloured Questionnaires on Mail Survey Response Rates. Journal of the Market Research Society 25:339-349.

Kiepper, B. H. and J. Sellers, 2002. Survey Database of Wastewater Treatment Practices and Experiences in the Poultry Processing Industry. USPOULTY Final Report: Project No. 562. U.S. Poultry and Egg Association, Tucker, Georgia.

Kroyer G. T., 1991. Food Processing Wastes. *In:* Bioconversion of Waste Materials to Industrial Products. A. M. Martin (Editor). Elsevier Applied Science, New York, New York. pp. 293-311.

Mead, G. C., 1989. Processing of Poultry. Elsevier Applied Science, London, England.

Mehta, R. and E. Sivadas, 1995. Comparing Response Rates and Response Content in Mail Versus Electronic Mail Surveys. Journal of the Market Research Society 37(4):429-439.

Metcalf and Eddy, Inc., 1991. Wastewater Engineering. Third Edition. McGraw-Hill, New York, New York.

Mountney, G. J. and C. R. Parkhurst. 1995. Poultry Products Technology. Third Edition. Food Products Press, New York, New York.

Ollinger, M., J. MacDonald, and M. Madison, 2000. Structural Change in U.S. Chicken and Turkey Slaughter. Agricultural Economic Report No. 787. Economic Research Service. U.S. Department of Agriculture, Washington, D.C.

Ott, R. L., 1993. An Introduction to Statistical Methods and Data Analysis. Duxbury Press, Belmont, California.

Pressley, M. M. and W. Tullar, 1977. A Factor Interactive Investigation of mail Survey Response Rates from a Commercial Population. Journal of Marketing Research 41:108-112.

Romans, J. R., W. J. Costello, C. W. Carlson, M. L. Greaser, and K. W. Jones, 1994. The Meat We Eat. Thirteenth Edition. Interstate Publishers, Danville, Illinois.

Rankin, M. D., 2000. Handbook of Meat Product Technology, Blackwell Science, London, England.

Steel, G. D. and J. H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, New York.

Swan, J. E., D. E. Epley, and W. L. Burns, 1980. Can Follow-up Response Rates to a Mail Survey Be Increased By Including Another Copy of the Questionnaire? Psychological Reports 47:103-106.

Truell, A. D. and J. E. Bartlett, 2002. Response Rate, Speed, and Completeness: A Comparison of Internet-Based and Mail Surveys. Behavior Research Methods Instruments & Computers 34(1):46-49.

Tyagi, P. K., 1989. The Effects of Appeals, Anonymity and Feedback on Mail Survey Response Patterns from Salespeople. Journal of the Academy of Marketing Science 17:234-241.

USDA, 2002. Poultry Slaughter – 2001 Annual Summary. Pou 2-1(02). National Agricultural Statistics Service. U.S. Department of Agriculture, Washington, D.C.

CHAPTER 3

CHARACTERIZATION OF PHOSPHORUS AND NITROGEN DISCHARGES IN POULTRY PROCESSING PLANTS WASTEWATER EFFLUENT[1]

[1]Kiepper, B., A. E. Reynolds, W. Merka, and J. Sellers. To be submitted to *Journal of the American Water Resources Association (JAWRA)*

Literature Review

Food processing industries discharge large volumes of wastewater characterized by high organic loads, large amounts of total suspended solids (TSS), and various inorganic constituents including phosphorus (P) and nitrogen (N) (Contreras *et al.*, 2000). Substances released into water bodies do not have to be toxic themselves to result in the death of a species, destruction of an ecosystem, or general degradation of water quality. In some cases their presence is sufficient to set into play a chain of events that can have the same detrimental effect as direct toxicants. Sometimes a substance in limited quantities is important, necessary, and a natural part of the evolution of a given ecosystem. However, these same substances will receive the label of 'pollutant' when the effect they cause is undesirable (Schmitz, 1996).

The addition of nutrients to an aquatic ecosystem is an example of something that is good in the right amounts, but detrimental when present in excess. The addition of nutrients results in the enrichment of a water body that leads to a series of slow processes, collectively referred to as the 'natural aging process' of water bodies. This enrichment process is generally an irreversible one that all water bodies experience and is known as eutrophication.

Eutrophication

Eutrophication can be defined as the naturally occurring biological process of the enrichment of water with nutrients (Welch and Lindell, 1992). Historically, the term eutrophication was first applied to lakes by the German limnologist Thienemann (Rast and Thornton, 1998). Over time, the process of eutrophication has become more broadly defined as high aquatic biological activity resulting from the increased input of either nutrients or organic matter (Berner and Berner, 1996). Strictly speaking, eutrophication is not pollution until man accelerates the process. The appropriate terminology of this accelerated process is 'cultural eutrophication'. With cultural eutrophication, man adds a host of substances that include the limiting elements of phosphorus (P) and nitrogen (N).

Pollution results when the natural check-and-balances of aquatic ecosystems are upset through anthropogenic (manmade) influences (Schmitz, 1996). The cultural eutrophication of major U.S. water bodies has had a dramatic impact on the development of U.S. environmental regulations. In fact, the accelerated eutrophication of the Chesapeake Bay and the clogging of the Potomac River by blue-green algae are considered two of the major reasons for the passage of the Federal Water Pollution Control Act Amendments (The Clean Water Act) of 1972 (Sincero and Sincero, 2003). Eutrophication has been identified as the main problem in surface waters having impaired water quality (USEPA, 1996). Since lakes are the most confined of water bodies, they are the most vulnerable to cultural eutrophication. However, there is a growing concern about the susceptibility of slow flowing rivers, estuaries, and semi-enclosed coastal seas (Tusseau-Vuillemin, 2001). Eutrophication restricts water use due to the increased growth of undesirable algae and aquatic weeds, and subsequent oxygen shortages (Sharpley, 2000).

One positive aspect found during the research of accelerated eutrophication is that the process is usually reversible, provided that the concentrations of input nutrients are decreased. However, while nutrient concentrations may decrease rapidly in response to input source reductions (Bossard and Gachter, 1997), chlorophyll concentrations, as well as upper tropic levels may take more time to restore to normal levels (Vincon-Leite *et al*., 1999). Curative solutions for culturally eutrophicated water bodies include seasonal oxygenation of deep water layers and sediments, harvesting of macrophytes, chemical precipitation of phosphates, flushing of nutrients with dilute waters, and dredging of nutrient-rich sediments (Huser and Welch, 2000).

Phosphorus and nitrogen are often considered as the most important plant nutrients, with one or the other being the limiting factor, most usually phosphorus. Unfortunately, researchers have found that man can supply significant excess sources of P, particularly from wastewater treatment plant effluent and more specifically from detergents. In the U.S. it is estimated that 75 percent of the phosphorus and 80 percent of the nitrogen added to natural waters is from anthropogenic sources (Schmitz, 1996).

Phosphorus

A review of the essential plant nutrients that can negatively impact natural waters should begin with understanding phosphorus, because it is the limiting nutrient in most fresh water ecosystems. The productivity of natural waters is controlled more often by the availability of P than any other nutrient or environmental factor (Welch, 1992). Phosphorus is too active as a nonmetal to be found free in nature. Phosphorus occurs in natural waters and in wastewater almost solely as phosphates. In natural waters, phosphates can be present in the water column, in suspended particles and sediments, and in the bodies of aquatic organisms (APHA, 1992). Phosphates are divided into three major classifications: orthophosphates, condensed phosphates, and organically-bound phosphates.

The orthophosphates of concern in wastewater are sodium phosphate (Na_3PO_4), sodium hydrogen phosphate (Na_2HPO_4), sodium dihydrogen phosphate (NaH_2PO_4), and ammonium hydrogen phosphate [$(NH_4)_2HPO_4$]. All of these orthophosphates can result in algae blooms when released in excess to natural waters (Strikland, 1998). When phosphoric acid is heated, it decomposes and loses water by condensation, thus forming ‘condensed phosphates’. Since the condensed phosphates have more then one phosphate group in the formed molecules, they are also called ‘polyphosphates’. Condensed phosphates undergo hydrolysis in aqueous solutions and transform into orthophosphates. Thus, their control in wastewater effluents is also important. When microorganisms attack organic compounds containing phosphorus they also undergo hydrolysis into the orthophosphate forms (Baker *et al.*, 1998).

<u>*Sources of Phosphorus*</u>

Phosphorus reaches rivers, lakes, and oceans through the natural sources of atmospheric deposition, chemical weathering of rocks, terrestrial runoff of soils, and through anthropogenic point sources (Tusseau-Vuillemin, 2001). The ratio between the natural and anthropogenic sources of P in a given water body is dependent on many land use factors, however the ratio has been studied and calculated for many water bodies. Esser and Kohlmaier (1991) estimated that all of the detergent P (2.2 x 10^{12}g P/year), 5 to 10 percent of fertilizers (1.5 x 10^{12}g P/year), and a substantial amount of P from human waste (about 2 grams of P per person per day) reach water bodies. Over the past decade wastewater treatment plants have seen a greater than expected reduction in phosphorus discharges due to more restrictive discharge permit limits and from the 1990 U.S. phosphorus detergent ban (CBP, 1995; Sharpley, 2000).

Wastewater Treatment for Phosphorus Removal

Either chemical or biological processes usually accomplish phosphorus removal in wastewater treatment operations. Chemical phosphorus removal involves its interaction with calcium, iron, or aluminum for direct precipitation of a metallic phosphate in the case of inorganic substances in wastewater (Sincero and Sincero, 2003). For organic substances in wastewater a simultaneous precipitation formed by the addition of coagulating chemicals at the end of the aeration step in the activated sludge process can be achieved for phosphorus removal (Eckenfelder, 2000).

Biological phosphorus removal is accomplished by bacteria and is removed from wastewater with the excess wasted sludge. The basic principle of the process involves the exposure of bacteria alternatively to anaerobic and aerobic conditions. Certain bacteria, most notably *Acinetobacter*, possess the ability to absorb low molecular weight organics under anaerobic conditions. The energy to accomplish this absorption is made available by the release of phosphorus bound as polyphosphates in the protoplasm of the bacteria. Under subsequent exposure to aerobic conditions, the organic matter is oxidized and the energy is made available for growth and for the reaccumulation of phosphates into polyphosphates in the bacteria. The resulting net effect is a buildup of phosphorus in the bacteria (Eckenfelder, 2000). These bacteria have a competitive edge over other bacteria, since they can hoard the readily available organic matter for their own consumption. Under proper conditions, these bacteria can flourish and dominate the wastewater microbial population, resulting in increased phosphorus content in the waste sludge (Marais *et al*., 1983).

Nitrogen

Nitrogen (N), in its many forms, is the second limiting nutrient of great interest in wastewater treatment and subsequent aquatic ecosystems (Welch, 1992). Because of the many forms N can take, it plays an important role in several environmental pollution problems. Since organisms perform most of the conversions of N from one form to another, it is referred to as a 'biochemical cycle'. In fact, it is the most complex of the biochemical cycles. Nitrogen has a high number of oxidation states from +5 to –3, and thus can exist in a number of different forms (Schmitz, 1996). The forms of N range from nitrates (+5) and nitrites (+3) to ammonia, amino acids, and proteins, which all have an oxidation state of –3.

Ammonia (NH_3), as well as ammonium ions (NH_4), exists as by-products of biological activity, specifically resulting from the degradation of plant and animal proteins and amino acids. It is usually in excess and must be eliminated. In mammals it occurs as uric acid, $C_5H_4N_4O_3$, in urine. The liquid waste of aquatic animals is urea, NH_2CONH_2 (Schmitz, 1996).

In the laboratory, organic nitrogen and ammonia can be determined together in a test called total Kjeldahl nitrogen (TKN). Typical organic nitrogen concentrations in raw sewage are approximately 20.0 mg/L (APHA, 1992). Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate generally occurs in trace quantities in surface waters, but may obtain high levels in groundwater. Excessive nitrates in drinking water supplies can lead to an illness in infants known as methemoglobionemia. To prevent the disease, a nitrate limit of 10.0 mg/L has been imposed for drinking water.

Sources of Nitrogen

Anthropogenic activities generate the majority of the excess nitrogen released to aquatic ecosystems. Wastewater treatment plant effluents are a major source of nitrogen into natural water bodies. In raw wastewater, approximately 60 percent of the nitrogen is in the form of ammonia, about 40 percent is in the organic form, and less than one percent exists as nitrites and nitrates. Once processed in traditional secondary treatment systems, almost all of the nitrogen in wastewater has been converted to nitrates and nitrites, with a typical discharge of 15.0 to 50.0 mg/L (Schmitz, 1996). Four forms of N hold the greatest interest in wastewater, listed in order of decreasing oxidation state: nitrate (NO^-_3), nitrite (NO^-_2), ammonia (NH^+_4), and organic nitrogen (NH_3). Organic nitrogen is defined as organically bound nitrogen in the trinegative oxidation state, and thus does not include all organic nitrogen compounds.

Wastewater Treatment for Nitrogen Removal

Many wastewater treatment systems are designed to attain a high degree of nitrogen removal. The degree of nitrogen removal required is usually dictated by the maximum allowable limit of ammonia nitrogen and nitrite/nitrate discharged within the plant's final effluent (CSUS, 1993a). For nitrogen to be removed from wastewater, processes known as nitrification and denitrification must be completed. During nitrification, ammonia is converted to nitrite and then nitrate under aerobic (free oxygen) conditions. Nitrification is a biological process accomplished primarily by two types of bacteria: *Nitrosomonas* and *Nitrobacter*. Unlike most of the common organisms found in wastewater treatment systems, these specialized microorganisms derive energy from inorganic compounds such as ammonia. The first step in the process is the conversion of ammonium to nitrite by *Nitrosomonas* bacteria. The second step is the conversion of nitrite to nitrate by *Nitrobacter* bacteria (CSUS, 1993a).

During denitrification, nitrates are converted by heterotrophic bacteria to gaseous nitrogen forms of nitrous oxide (N_2O) and nitrogen gas (N_2) under anaerobic (no free oxygen) conditions. These heterotrophic bacteria are unique in that they have the ability to use the oxygen bound in nitrate during a process called bacterial dissimilation. The key to successful bacterial dissimilation hinges on an anaerobic environment that has no free oxygen, but contains a defined carbon food source. Without these two elements, denitrification will not occur (CSUS, 1993a).

Abstract

The discharge of excessive phosphorus and nitrogen from industrial sources into U.S. waters is a major environmental concern. Organic wastewater streams, such as those produced by poultry processors, often contain high levels of nutrients that must be removed from wastewater prior to discharge. In order to meet established environmental regulations, the U.S. poultry industry has been thorough in tracking nutrient discharges in final wastewater effluents from processing plants. However, little scientific research has been conducted to identify which specific poultry processing steps contribute the highest percentage of nutrient loading to wastewater streams. With this knowledge poultry processors can identify production operations to target for reducing nutrient discharges as effluent environmental limits become more strict. Three chicken slaughter plants and three further processing facilities were identified for sampling. Three discrete sampling points with independent sections of the total wastewater stream were sampled in each plant, along with post-screened wastewater for a minimum of three 24-hour periods. Each workday was divided into six, four-hour periods. Each sample was analyzed for total phosphorus (P) and total Kjeldahl nitrogen (TKN). Standard deviation (STD) and coefficient of variation (COV) are calculated for each data set to compare similarities between plants with common operations. The slaughter plants showed the least variation in the mean percentage of nutrient loading. The COV values for P and TKN were 0.25 and 0.20, respectively. In contrast, the mean COV values for the further processing plants reveal their greater variance, as the P and TKN mean COV values were calculated as 0.65 and 0.50, respectively.

Keywords Water/Sewage Treatment, Environmental Engineering, Poultry Processing, Wastewater Treatment, Phosphorus, Nitrogen

Introduction

The discharge of excessive phosphorus and nitrogen from agricultural and industrial sources into U.S. waters is a major environmental concern (Gaskin and Harris, 1999; Sharpley, 2000; Tusseau-Vuillemin, 2001). Organic wastewater streams, such as those produced by poultry processors, often contain high levels of phosphorus and nitrogen that must be broken down and removed from wastewater prior to discharge. Kroyer (1995) reported that food processing wastewater in general contains large amounts of organic materials, high biochemical (BOD) and chemical (COD) oxygen demands, and often high nutrient concentrations. In order to meet established environmental regulations, the poultry industry has documented the discharge of nitrogen (N) and phosphorus (P) discharges in final wastewater effluents from processing plants (Carawan, 1989; Westerman *et. al*., 1989).

Nitrogen concentrations in raw municipal wastewaters generally range from 15.0 to 50.0 mg/L. Of that amount, approximately 60 percent is in the form of ammonia nitrogen, 40 percent is organic nitrogen, and a negligible amount (usually less than one percent) is in the form of nitrites or nitrates (Canter and Harfouche, 2000). However, nitrogen concentrations in poultry processing wastewater are often double or triple the amount found in raw domestic wastewater.

In 1975, the U.S. Environmental Protection Agency (USEPA) reported poultry processing plant average values for TKN at 90.0 mg/L, ammonia nitrogen at 11.0 mg/L, nitrites at 0.3 mg/L and nitrates at 0.4 mg/L. In contrast, at about the same time, Metcalf and Eddy (1972) reported domestic sanitary sewage average values for the same parameters as 40.0 mg/L, 25.0 mg/L, 0.0 mg/L and 0.0 mg/L, respectively.

Merka (1989) measured the wastewater stream characteristics at a broiler slaughter plant and reported final effluent mean values of 140.0 mg/ L (573.0 lbs/day) for TKN and 15.7 mg/L (64.1 lbs/day) for ammonia nitrogen during day shift operations. The average values during the evening production shift decreased to 118.0 mg/L (441.2 lbs/day) for TKN and 10.2 mg/L (39.7 lbs/day) for ammonia nitrogen. Eremektar *et al.* (1999) ran a series of four sets of conventional wastewater parameter tests on poultry processing wastewater that showed high nitrogen values. TKN values averaged 342.5 mg/L, ammonia nitrogen averaged 104.0 mg/L, while nitrites and nitrates averaged 0.06 and 0.005 mg/L, respectively. In 2000 during a study of the use of sequential batch reactors (SBRs) in treating poultry processing wastewater, Pierson and Pavlostathis reported influent ammonia nitrogen ranged from 11.0 to 23.2 mg/L (16.5 mg/L mean) and nitrate ranged from 0.7 to 13.5 mg/L (4.7 mg/L mean) during the two daily production shifts. When the wastewater generated during the nightly sanitation shift was composited with the production shifts, the range of values changed to 1.7 to 16.0 mg/L (8.7 mg/L mean) and 2.9 to 13.5 mg/L (6.2 mg/L mean), respectively.

The discharge of phosphorus from poultry processing plants has also been observed and reported by researchers. In 1998, a Norwegian research team led by Rusten reported on effluent from a poultry processing plant that was pretreated using a 250 μm (micron) rotating drum screen followed by a grease trap. Total phosphorus levels ranged from 14.1 to 18.5 mg/L, with an average value of 16.1 mg/L. The research team led by Eremektar in 1999 reported high P levels in untreated poultry processing wastewater. During four separate sampling events, the team reported P values of 48.0, 16.0, 18.0, and 40.0 mg/L. Pierson and Pavlostathis (2000) reported that the BOD:N:P ratio of raw poultry plant effluent was consistently greater than 100:5:1. The post-DAF wastewater profiled during the project typically contained BOD concentrations ranging from 200.0 to 400.0 mg/L (approximately 40 to 60 percent of the total COD), 80.0 to 90.0 mg/L total nitrogen, and 5.0 to 20.0 mg/L total phosphorus.

Extensive work conducted in France during the late 1990s revealed that food processing industries contributed 53 percent of the phosphorus entering municipal wastewater treatment facilities. The main sources of the phosphorus discharges were from meat processing, dairy industries, and vegetable processing. The majority of the tested industries produced wastewater effluent containing 90.0 to 500.0 kg P/day. The greatest contributing factor to the P load in food processing plants was determined to be the chemical cleaning products (phosphoric acid) used for surfaces and equipment rather than resulting from the processing of raw food materials themselves (Tusseau-Vuillemin, 2001). In the U.S., phosphates are widely used in meat processing industries to improve product binding, water holding capacity, yield, and to retard spoilage caused by oxidation (Lin and Lin, 2002). Trisodium phosphate (TSP) has seen wide use in U.S. poultry processing plants. Bender and Brostsky (1991) reported that TSP reduces microbial contamination on carcass surfaces. The USDA has approved TSP to be utilized in poultry processing to reduce possible contamination of *salmonella* (Giese, 1992, 1993) and *Escherichia coli* O157:H7 (Kim and Slavik, 1994).

To increase the poultry processing industry's ability to control nutrient discharges under increasing restrictive limits, research is needed to identify the work shifts and processing steps that contribute the highest percentage of nutrient loading to wastewater streams. The major objective of this research project was to establish the specific times and processing operations that contribute the highest loading of nitrogen and phosphorus to wastewater streams, thus identifying target areas for reducing future nutrient discharges. In addition, the project had the objective of identifying similar trends of nutrient discharges for facilities with analogous operations.

To accomplish these objectives the research team collected 24-hour representative samples of process wastewater from three segregated processing locations and from the effluent of wastewater treatment screens at six poultry processing facilities. Sampling was conducted for a minimum period of three consecutive days at each plant. Three slaughter plants and three further processing plants were selected for the project.

Each plant had four specific sampling sites where 24 hourly discrete samples were collected daily and then composited based on individual plant production and sanitation shift schedules. Each representative sample was then analyzed for total Kjeldahl nitrogen (TKN) and total phosphorus (P). By combining the resulting concentration data with observed, recorded and estimate wastewater flows, a pounds of nutrient loading value for each sample was calculated and graphed based on work shifts.

Materials and Methods

Poultry Processing Plant Selection and Descriptions

Six poultry processing plants were selected for sampling, all operating under Standard Industrial Code (SIC) 2015 – Poultry Slaughter and Processing. The plants include three facilities that slaughter chickens and three plants that further process whole chicken carcasses or parts of birds. The selected slaughter plants (coded A, B, C) were similar in their process operations and wastewater treatment systems. All three plants followed the slaughtering of chickens with two additional processes to the whole carcass birds (cut-up, debone, or marination). Differences between the slaughter plants included the number of birds processed per day and the pounds of dressed poultry undergoing additional processes. Table 3.1 summarizes the slaughter plants processes and wastewater operations.

Waste generation in the slaughter plants is very similar. Solid organic waste and wastewater are generated in three major areas of the plant. The first is the kill/defeathering operation that results in feathers and some blood (most blood is captured for rendering) that combine in a water flume to flow to the on-site wastewater treatment system. The second area captures solids and wash water used in the evisceration process along with any further process operation areas. These sources combine into a single ‘viscera’ flume. The third area captures the runoff and clean-up water from the live haul area where birds are removed from trailers and loaded into the facility. The wastewater from the live haul area is characterized by low flow, but high concentration of contamination due to dirt, fecal material and other debris.

In addition to waste generation, each of the slaughter plants’ wastewater treatment systems are also similar. The feather and viscera flumes flow into two parallel primary internally fed rotary screens, while the wastewater flow from the live haul area flows into the treatment plant separately and may or may not receive primary screening. The effluent from the feather and viscera primary screens along with the wastewater from the live haul area combine into a single stream that flows to a secondary, internally fed rotary screen.

The combined wastewater from two of the three plants is treated in dissolved air flotation (DAF) units prior to discharge to a publicly owned treatment works (POTW). The third plant follows DAF treatment with an additional biological treatment system in the form of lagoons.

Table 3.1. Summary of process and wastewater operations – slaughter plants.

	Plant A	Plant B	Plant C
Birds Slaughtered per Day	245,000	170,000	140,000
Other Processing Operations:			
- Cut-Up	X	X	X
- Marination	X		
- Deboning		X	X
Wastewater Treatment			
- Physical Systems			
Screen Types*	IR	IR	IR
No. of Screens	3	3	3
Feather Screen Gap Size#	3175	1588	1500
Viscera Screen Gap Size#	4763	3175	1500
Secondary Screen Gap Size#	508	508	800
- Physical/Chemical Systems	DAF	DAF	DAF
- Biological Systems	-	-	Lagoons
- Effluent Disposal	POTW	POTW	Land Application

* IR – Internally Fed Rotary, # microns (μm)

Unlike the slaughter plants, the three further processing plants (coded D, E, F) were each unique in the process operations and wastewater treatment systems (see Table 3.2). Plant D is designated as a ‘cook plant’, which is defined as the cooking and deboning of spent foul into meat, fat and broth for inclusion in convenience food products. The majority of solid organic waste generated in Plant D is from the deboning operation, which is transported by hand to offal trucks destined for a rendering facility. Plant E receives raw deboned meat from primary processing plants and then portion controls the raw product using various techniques, including water knifes. The portioned controlled raw product is then sent to a number of different processing operations. The final products are then instant quick frozen (IQF) prior to packaging.

The majority of solid organic waste generated in Plant E is from breading operations. This material (dry breading and wet batters) is collected in large bins by hand and retained for animal feed manufacturers. Other minor solid organic waste is created in the portion control phase of the operation and is transported to inedible containers and retained for rendering off-site. Wastewater generation occurs mainly from cleanup, sanitation, and runoff from the water knifes and other portion control operations.

Table 3.2. Summary of process and wastewater operations – further processing plants.

	Plant D	Plant E	Plant F
Pounds Processed per Day	275,000	320,000	200,000
Processing Operations:			
- Product Forming	X		X
- Fully Cooked	X		X
- Breading/Batter		X	X
- Parfry		X	
- Marination		X	X
- BBQ		X	
- IQF	X	X	X
Wastewater Treatment			
- Physical Systems			
Screen Types*	Static / IR	IR / ER	IR
No. of Screens	2	2	1
Primary Screen Gap Size#	12700	1588	400
Secondary Screen Gap Size#	508	508	-
- Physical/Chemical Systems	DAF	DAF	DAF
- Biological Systems	Aerobic Tank	-	Lagoons
- Effluent Disposal	POTW	POTW	POTW

* IR – Internally Fed Rotary, ER – Externally Fed Rotary, # microns (μm)

Plant F operates two main processing lines, although each line produces several different products. The first line involves the marination and grinding of chicken into a meat matrix. The meat matrix is then extruded into various forms, left plain or battered and breaded, and steam cooked. The resulting products are instant quick frozen for packaging. The second processing line involves the marination of whole muscle meat. The meat is then pressed, cooked and sliced for packaging. Solid organic waste generated in the plant is mainly in the form of raw or cooked product making contact with the floor. The material is collected in inedible containers and transferred to offal trucks destined for a rendering facility. Wastewater is generated from cleanup and sanitation of all plant areas, steam condensation and runoff in cooking areas.

Sampling Site Selection

The goal of sampling site selection was to isolate areas of each plant where nitrogen and phosphorus output could be effectively measured to determine at which times and in which areas the release the nutrients to the wastewater stream was highest. The four sites selected for sampling within the three slaughter plants were comparable due to the similarity of the wastewater treatment systems. Site 1 in each plant was established on the feather flume after the primary screen. Site 2 captured the wastewater effluent from the primary screen on the viscera flume. Site 3 isolated and captured unscreened runoff from the plants' live haul area. Finally, site 4 gathered samples from the secondary screen that combined flows of the other three sites.

Due to the uniqueness of each further processing plant, the sampling sites were also unique. In plant D, site 1 captured the condensate from the broth evaporation system. Site 2 collected wastewater from the major cooking and deboning areas, as well as site 1 flow. Site 3 received all the flow from the plant, including the raw forming area and sites 1 and 2. Finally, site 4 gathered the effluent from the secondary internally fed fine rotary screen prior to entry into the DAF unit. Site 1 in plant E captured runoff from one of the plant's water knife units. Site 2 collected wastewater from the remaining raw portion control area, as well as the water knife. Site 3 received flow from the par-fry cook room, and sites 1 and 2. Finally, site 4 was the effluent from the secondary externally fed fine rotary screen prior to entry into the DAF unit. Plant F's site 1 captured wastewater from the plant's major raw meat tumbler (marination) area. Site 2 collected wastewater from the raw extrusion area, while site 3 received flow from the steam cooking area. Finally, site 4 gathered the effluent from the internally fed fine rotary screen prior to entry into the equalization pit.

Sample Collection & Preparation

All composite wastewater samples at each of the six plants were collected using ISCO 3700 Standard Portable Samplers (ISCO, Inc., Lincoln, Nebraska). The samplers were configured to collect 24 discrete hourly aliquots over a minimum of three consecutive days at each facility. Due to the lack of primary flow measuring devices at the individual sampling locations, samplers were programmed to collect time-paced composite samples. Observed, documented, and estimated flow measurements taken from various sources in each plant were used to calculate and pour up actual shift composite samples manually after each sample cycle was completed. The portable samplers were configured to hold twenty-four, 1000 mL plastic bottles. A varied length vinyl 3/8-inch suction line with strainer attached was used to collect wastewater at each site. The units were programmed in a time-paced multiplexed (samples per bottle) mode, which collected a 150 ml sample every 10 minutes. Six samples were collected each hour and composited into a corresponding sample bottle.

Each sampler was set-up at a designated location and time, bottom units were filled with ice and sample collection occurred over a 24-hour period. After 24 hours, the sample unit bottom was removed and replaced with new clean bottles, fresh ice, and the unit reset. This cycle continued at each plant for a minimum of three consecutive days. Due to occasional unit malfunction, some sample sites were sampled over four consecutive days to obtain required data. The recovered bottom of each unit was then transported to an on-site trailer where samples bottles were composited based on available flow data and processing shift information. Composited samples were placed in one liter glass jars, sealed, marked and place in iced coolers for transportation to the University of Georgia for laboratory analysis.

Laboratory Analytics

Total Phosphorus (P): Method 4500-P B.5. Persulfate Digestion Method followed by colormetric analysis (Standard Methods, 18^{th} Edition, pp. 4-112) was utilized to measure P (APHA, 1992).

Total Kjeldahl Nitrogen (TKN): TKN was used to measure the combination of organic plus ammonia nitrogen forms of protein-based material in the various waste streams. Method 4500-N_{org} B. Macro-Kjeldahl Method (Standards Methods, 18^{th} Edition, pp. 4-95) was utilized to measure TKN (APHA, 1992).

Wastewater Generation Rates

Various techniques were utilized at each processing plant to obtain the most accurate wastewater flow data for use in the nutrient loading calculations. First, the total wastewater flow per day for each plant was obtained from the actual permit required flow meters and data recorders on each of the plants' effluent discharges and is considered accurate. Second, wastewater generation use per production and sanitation shift at plants A, B, D, and E were also taken directly from flow data recorders on effluent flow meters and are considered accurate. Production and sanitation shift wastewater generation at plants C and F had to be estimated based on project team observations and interviews with plant staff due to the lack of continuous flow rate information, and thus was calculated using a percentage estimate.

Slaughter Plants: Due to recycling in each of the three slaughter plants' wastewater treatment systems, the project team was unable to accurately measure flows from the isolated streams of the feather flume, viscera flume and live haul areas. Based on project team observations and interviews with plant personnel, an estimated flow percentage for all three areas were developed and used to calculate nutrient loadings. The estimates were established at 25 percent for the feather flume flow (due mainly to recycling of flume water), 70 percent for the viscera flume, and five percent for the live haul area. Total daily wastewater generation and flows from isolated production areas in the slaughter plants are summarized in Table 3.3.

Further Processors: Multiple techniques were utilized to determine wastewater generation rates within the isolated production areas of the three further processing plants. In plant D, accurate flow rates from the evaporator condensation area were measured using the stopwatch-and-bucket method, while times of discharge were taken from operator notes. Wastewater generation flows from sites 2 and 3 were estimated based on project team observations and interviews with plant personnel. In plant E, accurate flow rates from the water knife were measured using the stopwatch-and-bucket method, while times of discharge were taken from line supervisor records. Wastewater generation flows from sites 2 and 3 were estimated based on project team observations and interviews with plant personnel. In plant F, all three in-plant location wastewater generation rates were estimated based on project team observations and interviews with plant personnel. Based on the actual wastewater generation values measured and estimated flow rates, total daily wastewater generation and flows from the isolated production areas in the further processing plants are summarized in Table 3.4.

Table 3.3. Slaughter plant wastewater generation by area (MGD*).

	Plant A			Plant B			Plant C		
Day>	1	2	3	1	2	3	1	2	3
TF*	1.517	1.464	1.626	2.033	1.954	2.002	0.718	0.697	0.935
FF*	0.379	0.366	0.407	0.508	0.488	0.501	0.179	0.174	0.234
VF*	1.062	1.025	1.138	1.423	1.368	1.401	0.503	0.488	0.655
LH*	0.076	0.073	0.081	0.102	0.098	0.100	0.036	0.035	0.046

*MGD – million gallons per day, TF – Total Flow (100%) , FF – Feather Flume (25%), VF – Viscera Flume (70%), LH – Live Haul Area (5%)

Table 3.4. Further processing plant wastewater generation by area (MGD*).

	Plant D			Plant E			Plant F		
Day>	1	2	3	1	2	3	1	2	3
TF*	0.262	0.236	0.233	0.120	0.145	0.133	0.122	0.120	0.116
1*	0.013	0.012	0.012	0.004	0.004	0.004	0.003	0.003	0.003
2*	0.183	0.165	0.163	0.084	0.102	0.093	0.016	0.015	0.014
3*	0.065	0.059	0.058	0.032	0.039	0.036	0.042	0.042	0.041

*MGD – million gallons per day, TF – Total Flow, 1 – Site 1, 2 – Site 2, 3 – Site 3

Loading Calculation

Once wastewater flow measurements were developed and laboratory concentration values compiled, loading of TKN and P from the various plant areas, based on work shifts, were calculated using the following pounds loading equation:

Flow (MGD) x Concentration (mg/L) x 8.34 = Pounds per Day (Lbs/d)

Treatment of Data

Screened Wastewater: The 24 hourly samples collected after wastewater treatment screening in each of the six plants were manually composited into six final samples of based on plant work shifts after each sampling sequence. The six work shift categories, each one representing approximately four hours, were designated as:

- P1.1 – 1st Production Shift / 1st Half of Shift
- P1.2 – 1st Production Shift / 2nd Half of Shift
- P2.1 – 2nd Production Shift / 1st Half of Shift
- P2.2 – 2nd Production Shift / 2nd Half of Shift
- S1 – Sanitation Shift /1st Half
- S2 – Sanitation Shift / 2nd Half

Laboratory concentration data, reported in mg/L, was complied using one replication of each test performed on each of the six samples. This was accomplished by drawing two independent samples from each sample bottle and testing separately. The resulting values were then averaged to determine a mean concentration value for each shift category each day. This procedure was repeated for three consecutive days. The resulting three daily values for each shift category were then averaged to determine a mean concentration value per shift category per plant tested. These mean concentration values were then inserted into the pounds loading equation, along with the associated total flow volume for that day, and a loading value was calculated per shift category. Finally, a percentage value for loading by each shift category was calculated.

Isolated Processing Areas: The 24 hourly samples collected at each of the isolated processing areas in each plant were manually composited into three final samples based on plant work shifts. The three shift categories, each one representing approximately eight hours, were designated as:

- P1 – 1st Production Shift
- P2 – 2nd Production Shift
- S – Sanitation Shift.

Exceptions to this protocol included the compositing of a single live haul sample each day at the slaughter plants due to the limited amount of time runoff was collected during cleaning each day (2 to 4 hours). Also, further processing plant sampling times and composites were compressed at the Plant D's evaporator system and Plant E's water knife. The laboratory concentration data was complied using the same procedure as the screened wastewater.

To interpret the variability of each data set within each category, elements of the Central Limit Theorem (CLT) were utilized. Most statistical inference and estimation techniques are based on the normal distribution. However, many data sets have a distribution far from normal. The CLT allows the assumption of a normal distribution of sample means when samples are drawn at random from a non-normal distribution. To accomplish this, inferences are made with the mean values of the sample data, not the individual sample values. Using this theory, the standard deviation of the mean (STDM) was first calculated for each work shift category for each plant. The STDM provides a numerical value, in the units of the data set, to the clustering tendency of the data means (Blank, 1980; Ott, 1993). Once the STDM was calculated, a coefficient of variation (COV) was calculated for each data set. The COV is used to express the STDM as a percentage of the mean and was used to evaluate the similarity in variation and centered tendency between plants utilizing similar process operations. COV is a relative measure of variability, in contrast to the STDM (Steel and Torrie, 1960).

Results

Slaughter Plants

Screened Wastewater: Figures 3.1 and 3.2 show the concentration values for both TKN and P in each of the slaughter plants. Mean TKN concentration values ranged from a low of 25.0 mg/L during the S2 shift in Plant B to a high of 195.0 mg/L during the P2.2 shift in Plant C. Mean P concentration values ranged from a low of 5.20 mg/L during the S2 shift in Plant A to a high of 38.02 mg/L during the P2.2 shift again in Plant A. Figures 3.3 and 3.4 illustrate the wastewater loading values for TKN and P. Mean TKN loading values ranged from a high of 434.0 Lbs/day during the P2.2 shift in Plant A to a low of 14 Lbs/d during the S2 shift again in Plant A. Mean P loading values ranged from a high of 108.13 Lbs/d during the P2.2 shift in Plant A to a low of 1.87 Lbs/d during the S2 shift again in Plant A.

The loadings of nutrients to the waste streams at each slaughter plant were also calculated on a percentage basis and are shown in figures 3.5 and 3.6. The maximum percentage output of TKN and P, 24.8 and 25.36 percent respectively, occurred during the second half of the second production shift. Percentage outputs during the other production shift categories ranged from between 20.29 and 21.6 percent for both nutrients. First half sanitation loading percentages for TKN and P were 9.9 and 11.67 percent respectively, while the second half of sanitation accounted for only 1.5 percent of TKN loading and 1.72 percent of P loading.

Isolated Production Areas: Figures 3.7 and 3.8 show the concentration values for TKN and P in the screened feather and viscera flumes, as well as the live haul area samples. In the case of TKN, the viscera flume mean concentration values were the lowest, ranging in value from 46 to 145 mg/L. The range of mean concentration values seen in the feather flumes increased from 69 to 327 mg/L. The highest TKN mean concentrations were seen in the unscreened live haul area waste stream that ranged from 267 mg/L (Plant A) to 451 mg/L (Plant C). Similarly, P mean concentrations in the slaughter plant viscera flumes were the lowest, ranging in value from 15.10 to 32.07 mg/l. The range of P mean concentration values seen in the feather flumes increased to

13.73 to 42.54 mg/L. Like TKN, the highest P mean concentrations were seen in the unscreened live haul area waste stream that ranged in value from 66.10 mg/L (Plant B) to 178.87 mg/L (Plant A). In contrast, figures 3.9 and 3.10 illustrate the TKN and phosphorus loading (Lbs/d) values in each isolated area. Live haul area loadings for TKN and phosphorus, 73.0 and 10.45 Lbs/d respectively, were the lowest amounts seen in the slaughter plant isolated areas.

Further Processing Plants

Screened Wastewater: Figures 3.11 and 3.12 show the concentration values for both TKN and P for each of the further processing plants. Mean TKN concentration values ranged from a low of 28.0 mg/L during the S2 shift in Plant E to a high of 292.0 mg/L during the P2.2 shift in Plant F. Mean P concentration values ranged from a low of 7.67 mg/L during the S2 shift in Plant E to a high of 130.0 mg/L during the P2.2 shift again in Plant F. Figures 3.13 and 3.14 illustrate the wastewater loading values for TKN and P. Mean TKN loading values ranged from a high of 78.0 Lbs/day during the P2.1 shift in Plant D to a low of 2.0 Lbs/d during the S2 shift again in Plant E. Mean P loading values ranged from a high of 26.90 Lbs/d during the P2.2 shift in Plant F to a low of 0.55 Lbs/d during the S2 shift in Plant E.

The loadings of nutrients to the waste streams at each further processing plant were also calculated on a percentage basis and are shown in figures 3.15 and 3.16. The maximum percentage output of TKN was 29 percent and occurred the second half of the second production shift in Plant E. The lowest percentage output of TKN (1.0 percent) occurred during the second half of the sanitation shift in Plant F. The highest percentage output of P was 28.92 percent and occurred the second half of the second production shift in Plant D. The lowest percentage output of P (1.91 percent) occurred during the second half of the sanitation shift in Plant E.

Isolated Production Areas: Figures 3.17 through 3.28 show the concentration and loading levels of TKN and P in the isolated production areas of the three further processing plants.

Discussion and Conclusions

Slaughter Plants

Screened Wastewater: The results of nutrient concentration in the screened wastewater of all three slaughter plants show consistent trends when plotted graphically. There is a small to moderate increase of nutrient concentrations over the two production shifts that reachs a maximum concentration towards the end of the second production shift. Then a moderate to rapid decrease in concentration is seen over the course of the sanitation shift. These trends indicate that TKN and P concentrations remain relatively stable during the production shifts, with a slight increase over time due to the increase of organic material that builds up on processing equipment and floors over the processing day.

Conventional thought is that the highest nutrient concentrations discharges occur during the transition between the second production shift and the start up of sanitation when the majority of the heaviest cleaning of equipment and floors occurs, and results in the largest release of organic material to the waste stream (Merka, 1982, 1990). The concentration results support this hypothesis. The moderate to rapid decline in TKN and P concentration during the sanitation shift supports the conventional thought that the wastewater stream becomes less contaminated as nutrient rich residuals are removed from the plant by the sanitation process.

This similarity in trends over the production day and support of conventional thought continues when nutrient loading is analyzed (Merka and Whittle, 1996). The impact and importance of the pounds equation is highlighted when analyzing the slaughter plant nutrient loading data for TKN. Although Plant C consistently had the highest concentration of TKN in its screened wastewater, the TKN loading graph (figure 3.3) shows that Plant C has the lowest actual output of TKN due to reduced wastewater flows. The range of loading values is even more pronounced in P discharge (figure 3.4). The closest association between the three slaughter plants is seen in the percentage comparison of nutrient loading by work shift as shown in figures 3.5 and 3.6. The similarity is also shown using COV values for the six work shift categories. If the six work shift COV values are averaged for TKN the result is a mean COV of 0.20. Likewise, the mean COV value for P in the screened wastewater was 0.25. In contrast, the mean COV values for the further processing plants reveal their dissimilarity, as the TKN and P mean COV values were calculated as 0.50 and 0.65, respectively.

Isolated Production Areas: The nutrient concentration trends from the isolated production areas were similar to those seen in the slaughter plants' screened wastewater. All three plants follow the same trend of a slow to moderate increase of nutrient concentrations over the two production shifts, followed by a moderate to rapid decrease in concentrations during the sanitation shift (figures 3.7 and 3.8). In both the feather and viscera flumes the second production shift had the highest nutrient concentration, followed by the first production shift. The sanitation shift had the lowest TKN and P concentrations in all three plants. The unscreened live haul area wastewater had the highest nutrient concentration values.

Figure 3.9 shows that the mean loading rates of TKN from both the feather and viscera flumes are similar. Figure 3.10 reveals that P loading from the viscera flume is consistently over twice that of the feather flume in all three slaughter plants. The lowest nutrient loading rates for TKN and P occur during the sanitation shift. In slaughter plants, the start of the sanitation shift is characterized by high flows and nutrient concentrations, while the end of the shift produces low concentrations and flow volumes.

Further Processing Plants

Screened Wastewater: Unlike the slaughter plants, which are similar in their production processes and wastewater treatment systems, each of the three further processing plants are unique. It was not expected that their results or nutrient discharge trends would be comparable. While concentrations values for TKN in plants E and F were similar to those seen in the slaughter plants, Plant D had a steady decline in concentration values during the processing day until a sudden increase is seen during the second half of the sanitation shift. However, increased TKN concentrations in Plant D corresponds to the P1.1 concentrations indicating an overlap between the end of the sanitation shift and the beginning of processing operations each day. Many of the nutrient concentration values seen in the further processing plants were higher than those found in the slaughter plants and are attributed to the increase in level of raw meat processing. As an example, the concentration values for TKN in Plant F were greater than those of any of the slaughter plants, while the concentrations of P in Plants F and D were also substantially higher than any concentrations of P in the slaughter plants. Conversely, due to reduced wastewater flows, the further processing plants had lower nutrient loading rates then the slaughter plants.

Isolated Production Areas: The variation in impact of various pieces of processing equipment is highlighted in the results from the further processing plants' isolated production areas. In the case of Plant D, the evaporation system produced both low concentration and minimal loading to the waste stream. On the other hand, the water knife in Plant E produced the highest nutrient concentrations, but minimal loading impact due to low hydraulic flows. Again in Plant F, the tumbler area produced some of the highest concentration values, but loading was kept to a minimum by low hydraulic flow. Also, by comparing nutrient concentration and loading data with specific processing operations during the day, the isolated impact of such procedures as dumping of brine solutions, slug releases of cleaning and sanitation chemicals, and major equipment wash down could be pinpointed on nutrient discharge graphs.

Complete laboratory analysis results and individual nutrient discharge graphs for each plant in original database form are available through USPOULTRY Final Report: Project No. 558 (Kiepper *et al.*, 2001).

Acknowledgements

Support for this research was provided by the United States Poultry & Egg Association (USPOULTRY), Tucker, Georgia.

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	122	123	145	140	84	39
Plant B	72	76	84	92	75	25
Plant C	145	167	169	195	159	85
Mean	113	122	133	142	106	50
STDM	37	46	44	52	46	31
COV	0.33	0.37	0.33	0.36	0.44	0.63

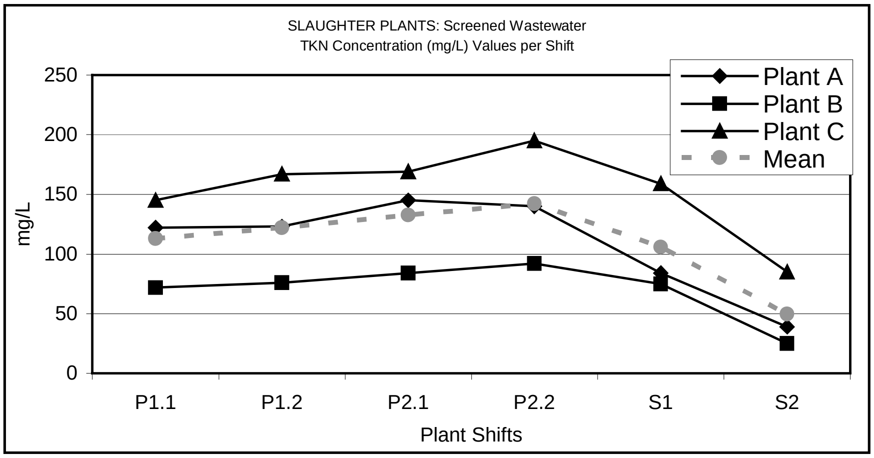


Figure 3.1. Slaughter plants: screened wastewater - TKN concentrations per shift (mg/L).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	27.89	28.59	36.00	38.02	26.94	5.20
Plant B	20.00	21.75	23.90	26.47	27.15	8.05
Plant C	16.78	19.85	19.66	23.56	20.62	15.35
Mean	21.56	23.40	26.52	29.35	24.90	9.53
STDM	5.72	4.60	8.48	7.65	3.71	5.24
COV	0.27	0.20	0.32	0.26	0.15	0.55

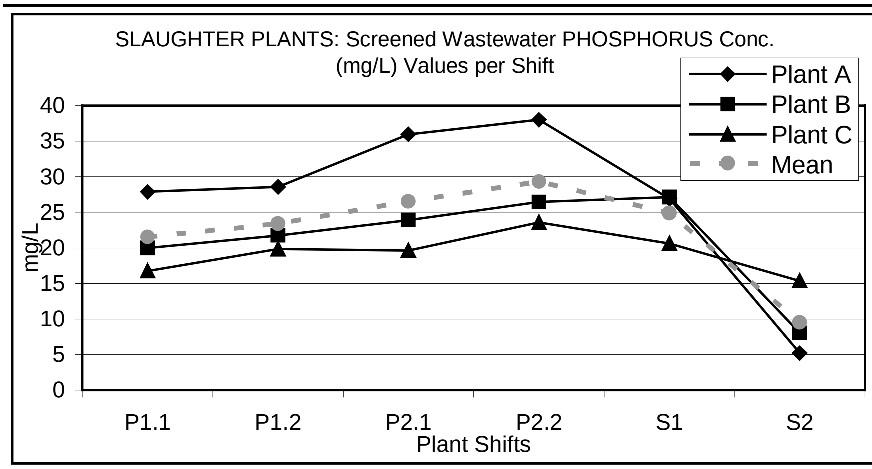


Figure 3.2. Slaughter plants: screened wastewater- P concentrations per shift (mg/L).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	434	351	311	398	89	14
Plant B	248	261	289	317	156	17
Plant C	179	205	208	240	118	21
Mean	287	272	269	318	121	17
STDM	132	74	54	79	34	4
COV	0.46	0.27	0.20	0.25	0.28	0.20

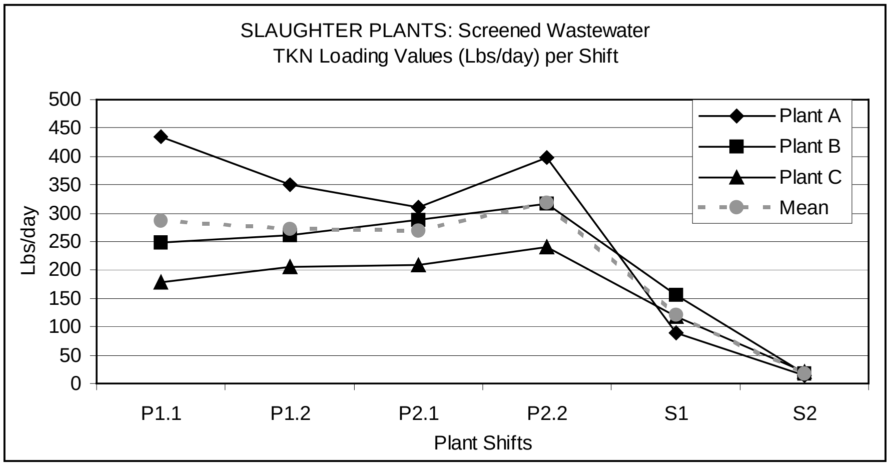


Figure 3.3. Slaughter plants: screened wastewater - TKN loading per shift (Lbs/d).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	99.31	81.31	76.86	108.13	28.68	1.87
Plant B	69.12	75.16	82.59	91.49	56.30	5.56
Plant C	20.68	24.47	24.23	29.04	15.24	3.78
Mean	63.04	60.31	61.23	76.22	33.41	3.74
STDM	39.67	31.19	32.17	41.70	20.93	1.85
COV	0.63	0.52	0.53	0.55	0.63	0.49

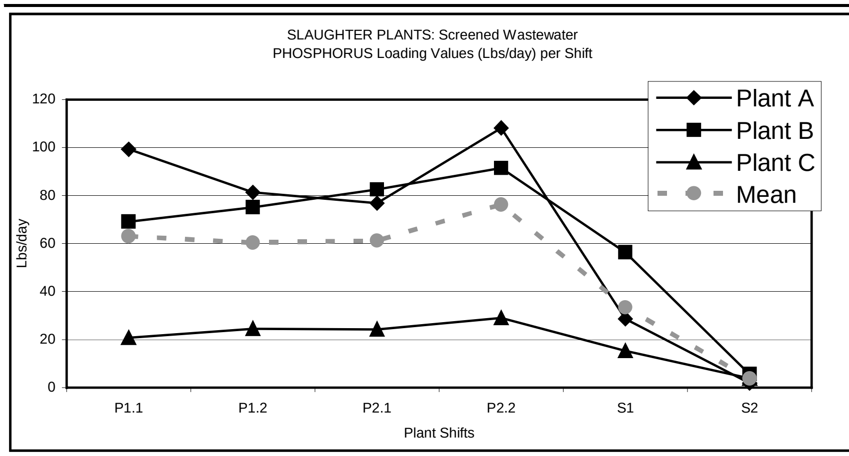


Figure 3.4. Slaughter plants: screened wastewater – P loading per shift (Lbs/d).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	27.2	22.0	19.5	24.9	5.6	0.9
Plant B	19.3	20.3	22.4	24.6	12.1	1.3
Plant C	18.4	21.1	21.4	24.7	12.2	2.2
Mean	21.6	21.1	21.1	24.8	9.9	1.5
STDM	4.8	0.9	1.5	0.2	3.8	0.7
COV	0.22	0.04	0.07	0.01	0.38	0.47

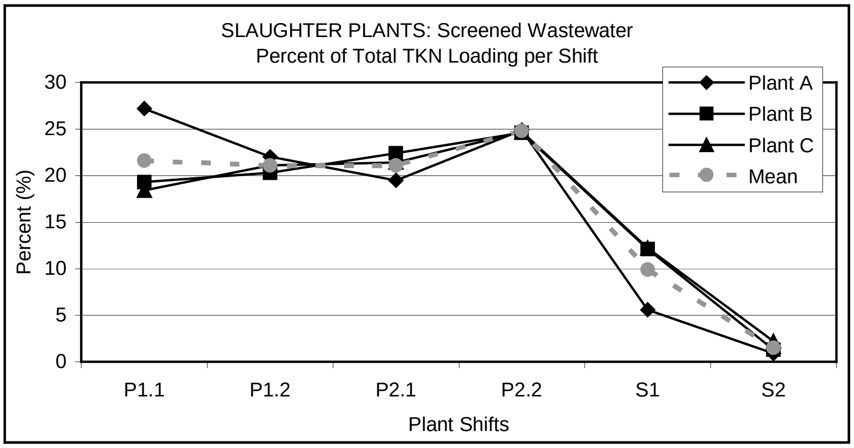


Figure 3.5. Slaughter plants: screened wastewater – percent (%) of TKN loading per shift.

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant A	25.07	20.52	19.40	27.29	7.24	0.47
Plant B	18.18	19.77	21.72	24.06	14.81	1.46
Plant C	17.61	20.84	20.63	24.73	12.98	3.22
Mean	20.29	20.38	20.58	25.36	11.67	1.72
STDM	4.15	0.55	1.16	1.71	3.95	1.39
COV	0.20	0.03	0.06	0.07	0.34	0.81

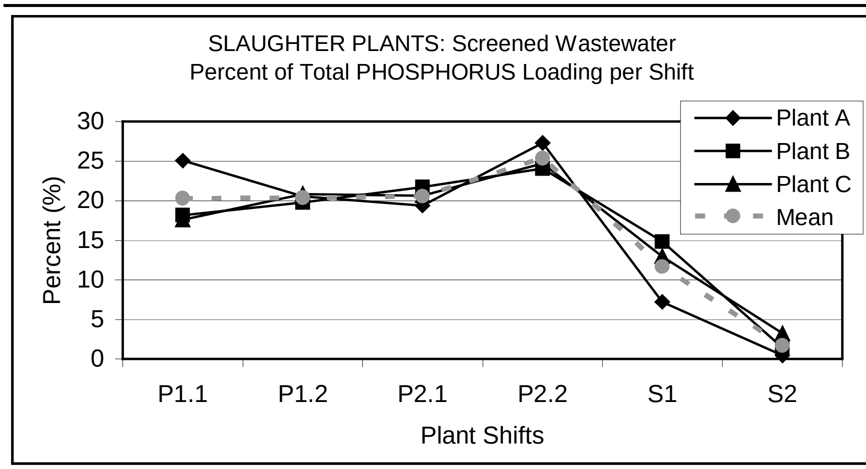


Figure 3.6. Slaughter plants: screened wastewater – percent (%) of P loading per shift.

	Feather Flume			Viscera Flume			Live Haul
	P1	P2	S	P1	P2	S	*
Plant A	248	327	106	77	84	43	267
Plant B	130	162	69	46	52	46	358
Plant C	198	232	92	134	145	87	451
Mean	192	240	89	86	94	59	359
STDM	59	83	19	45	47	25	92
COV	0.31	0.34	0.21	0.52	0.50	0.42	0.26

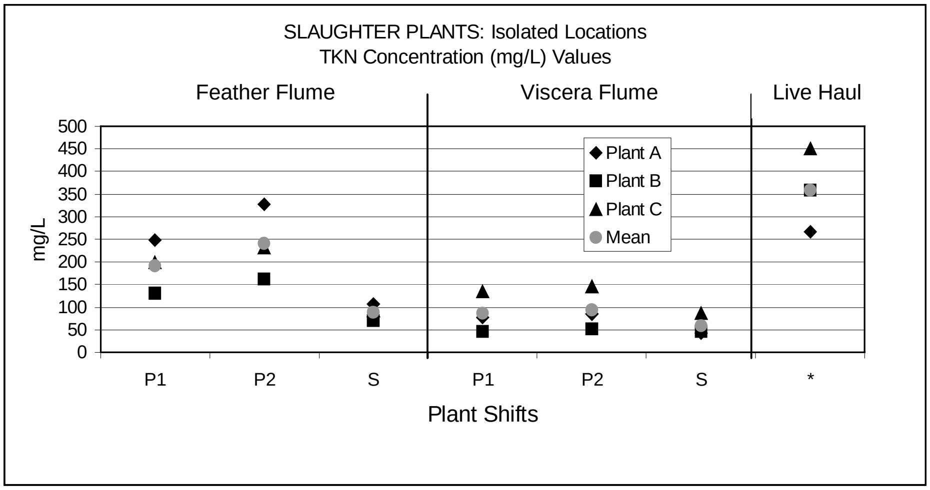


Figure 3.7. Slaughter plants: isolated area wastewater - TKN concentrations (mg/L).

	Feather Flume			Viscera Flume			Live Haul
	P1	P2	S	P1	P2	S	*
Plant A	31.04	42.54	13.73	27.75	32.07	18.67	178.87
Plant B	21.62	29.50	15.63	19.10	23.69	19.72	66.10
Plant C	23.30	27.41	14.12	15.10	17.19	15.58	66.24
Mean	25.32	33.15	14.49	20.65	24.32	17.99	103.74
STDM	5.02	8.20	1.00	6.47	7.46	2.15	65.07
COV	0.20	0.25	0.07	0.31	0.31	0.12	0.63

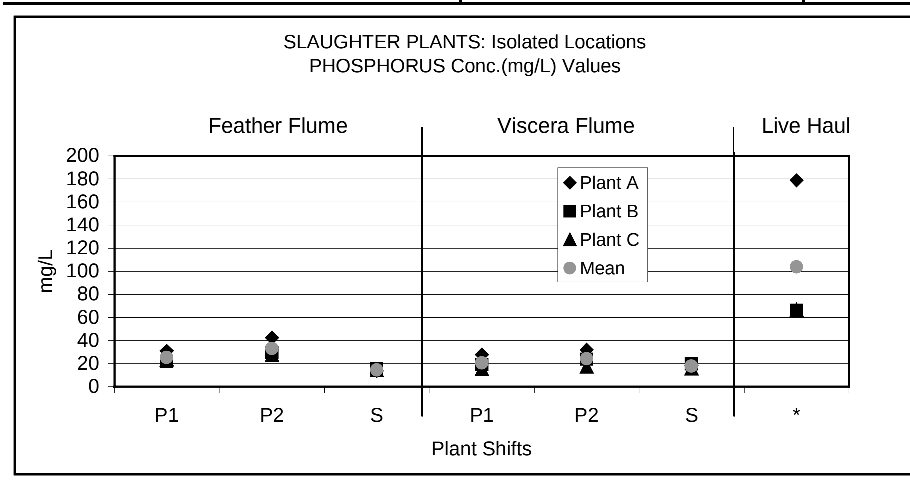


Figure 3.8. Slaughter plants: isolated area wastewater - P concentrations (mg/L).

	Feather Flume			Viscera Flume			Live Haul
	P1	P2	S	P1	P2	S	*
Plant A	396	406	38	348	292	43	99
Plant B	226	281	48	223	255	90	72
Plant C	135	159	25	231	250	61	49
Mean	252	282	37	267	266	65	73
STDM	132	124	12	70	23	24	25
COV	0.53	0.44	0.31	0.26	0.09	0.37	0.34

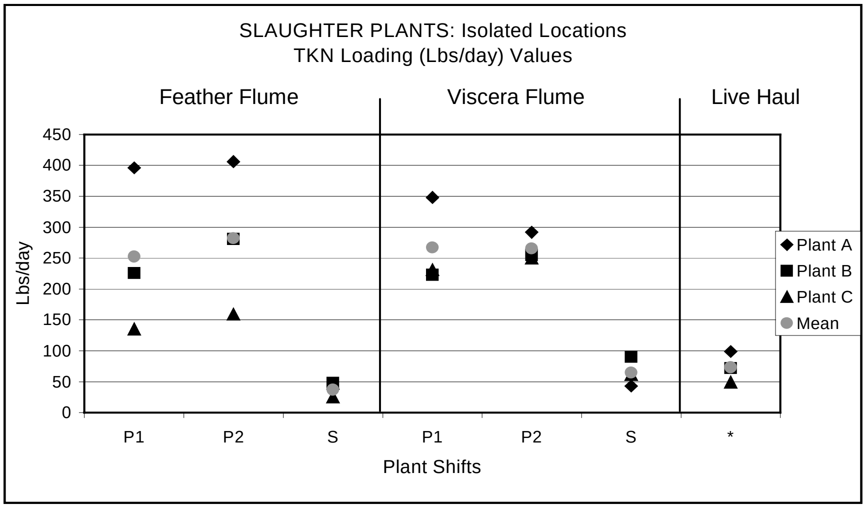


Figure 3.9. Slaughter plants: isolated area wastewater - TKN loading (Lbs/day).

	Feather Flume			Viscera Flume			Live Haul
	P1	P2	S	P1	P2	S	*
Plant A	49.70	52.86	4.89	125.09	111.72	18.69	12.78
Plant B	37.49	51.16	10.84	92.40	115.27	38.38	11.27
Plant C	15.86	18.65	3.85	25.97	29.65	10.92	7.29
Mean	34.35	40.89	6.53	81.15	85.55	22.66	10.45
STDM	17.14	19.28	3.77	50.51	48.44	14.15	2.84
COV	0.50	0.47	0.58	0.62	0.57	0.62	0.27

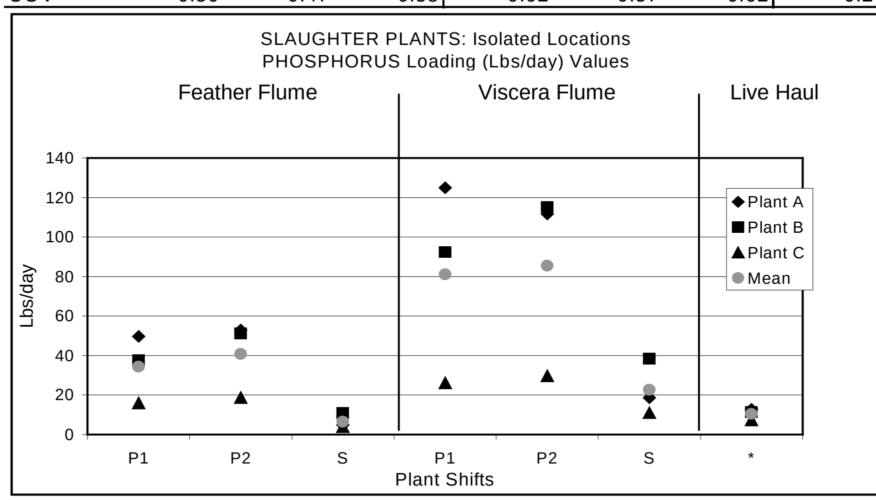


Figure 3.10. Slaughter plants: isolated area wastewater - P loading (Lbs/day)

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	184	144	144	115	62	168
Plant E	115	111	106	168	97	28
Plant F	175	292	264	260	128	42
Mean	158	182	171	181	96	79
STDM	38	96	82	73	33	77
COV	0.24	0.53	0.48	0.41	0.35	0.97

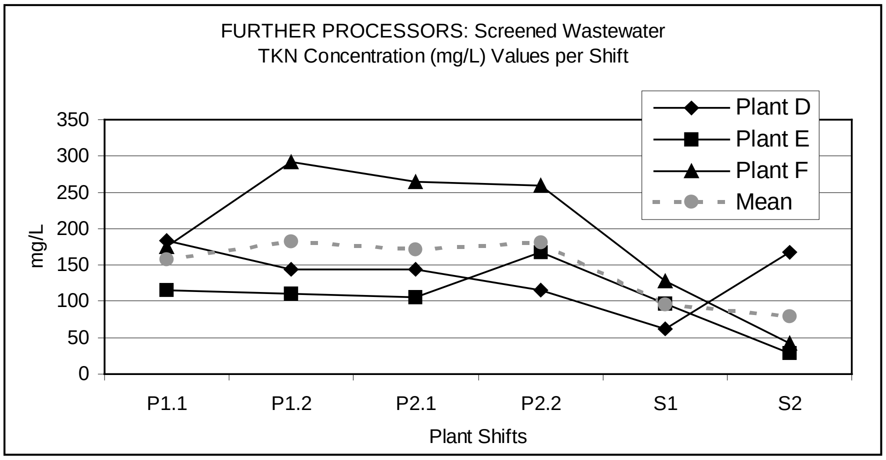


Figure 3.11. Further processing plants: screened wastewater - TKN Conc. per shift (mg/L).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	42.03	36.16	35.88	94.22	75.13	50.04
Plant E	20.74	23.04	35.93	31.30	26.59	7.67
Plant F	84.74	96.98	93.83	130.00	87.76	26.34
Mean	49.17	52.06	55.21	85.17	63.16	28.02
STDM	32.59	39.45	33.44	49.97	32.29	21.23
COV	0.66	0.76	0.61	0.59	0.51	0.76

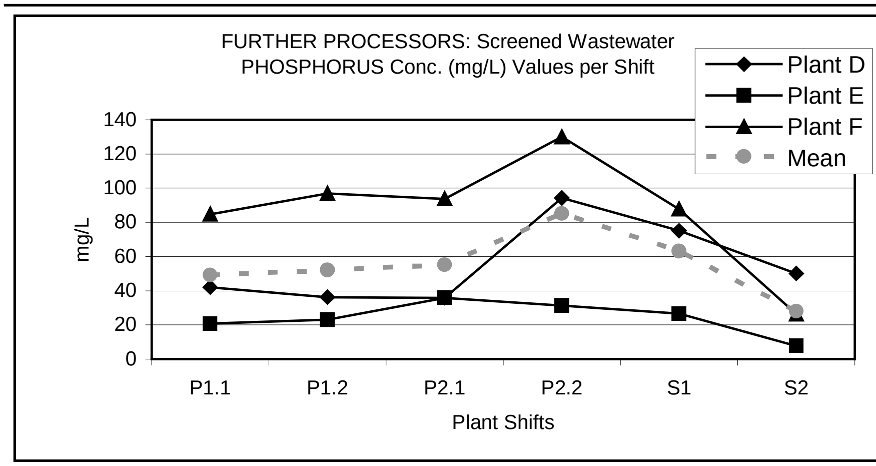


Figure 3.12. Further processing plants: screened wastewater - P conc. per shift (mg/L).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	78	49	61	39	21	28
Plant E	30	29	23	37	7	2
Plant F	36	60	54	53	11	3
Mean	48	46	46	43	13	11
STDM	26	16	20	9	7	15
COV	0.54	0.34	0.44	0.20	0.55	1.34

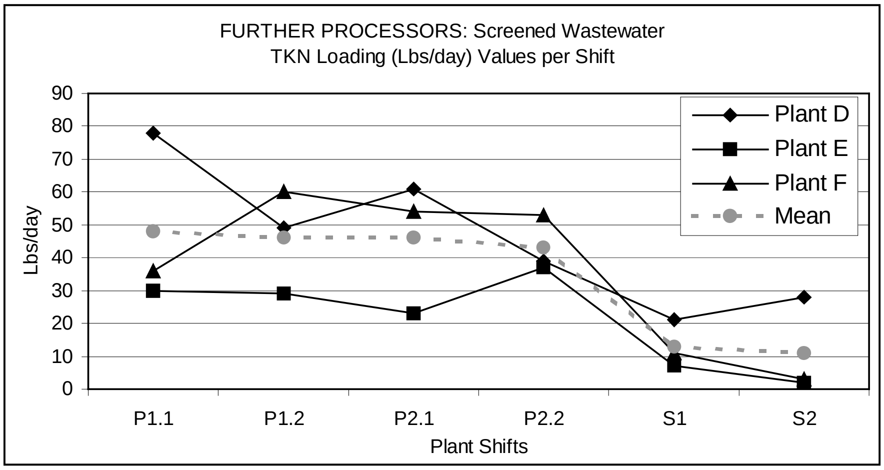


Figure 3.13. Further processing plants: screened wastewater - TKN loading per shift (Lbs/day).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	17.08	12.26	15.21	31.94	25.47	8.48
Plant E	5.39	5.99	7.96	6.94	1.91	0.55
Plant F	17.53	20.06	19.41	26.90	7.26	2.18
Mean	13.33	12.77	14.19	21.93	11.55	3.74
STDM	6.88	7.05	5.79	13.22	12.35	4.19
COV	0.52	0.55	0.41	0.60	1.07	1.12

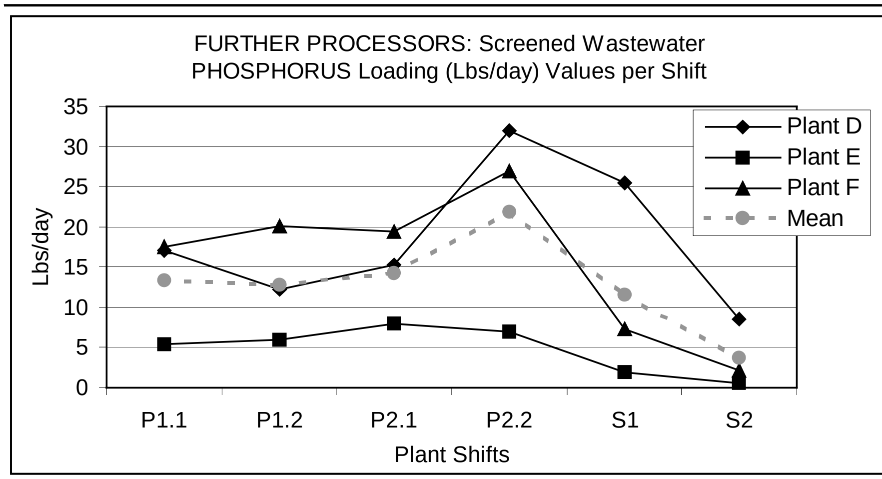


Figure 3.14. Further processing plants: screened wastewater - P loading/ shift (Lbs/day).

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	28	18	22	14	8	10
Plant E	23	23	18	29	5	2
Plant F	17	28	25	24	5	1
Mean	23	23	22	22	6	4
STDM	6	5	4	8	2	5
COV	0.24	0.22	0.16	0.34	0.29	1.14

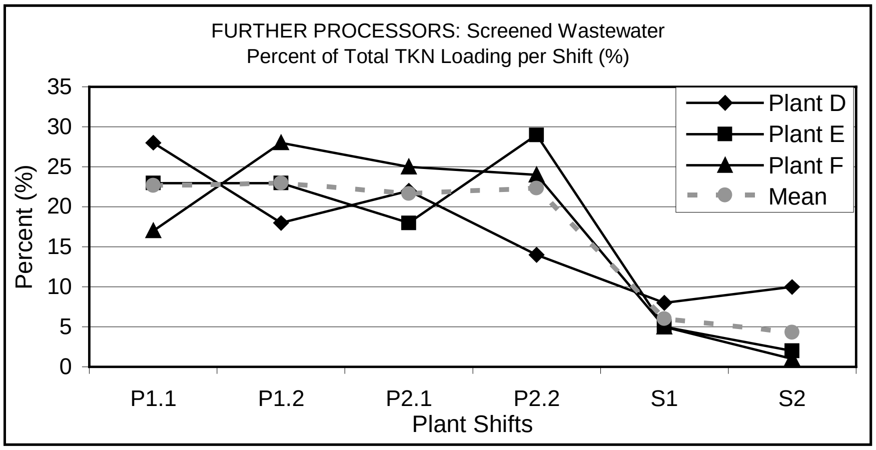


Figure 3.15. Further processing plants: screened wastewater – percent (%) of TKN loading.

	P1.1	P1.2	P2.1	P2.2	S1	S2
Plant D	15.47	11.10	13.77	28.92	23.06	7.28
Plant E	18.75	20.84	27.70	24.15	6.65	1.91
Plant F	18.78	21.49	20.79	28.82	7.78	2.34
Mean	17.67	17.81	20.75	27.30	12.50	3.84
Mean	1.90	5.82	6.97	2.73	9.17	2.98
COV	0.11	0.33	0.34	0.10	0.73	0.78

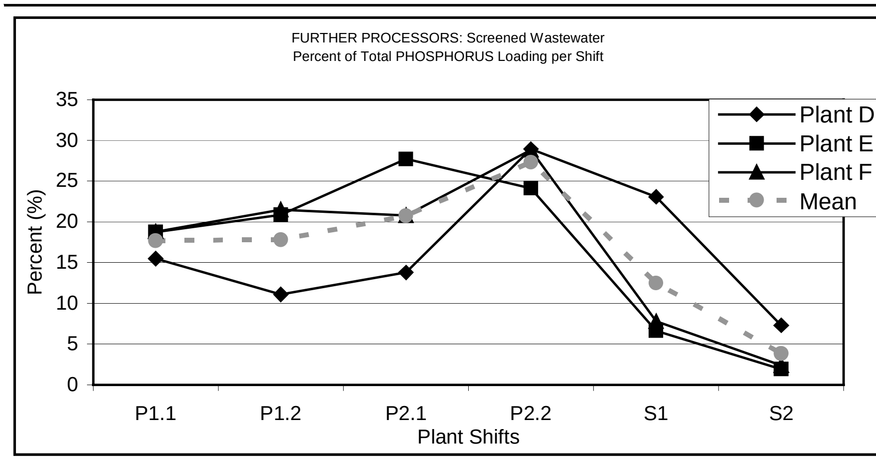


Figure 3.16. Further processing plants: screened wastewater – percent (%) of P loading.

	Evaporator (1)			Debone (2) + (1)			Raw (3) + (1) + (2)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant D	32	17	53	363	576	150	209	112	209

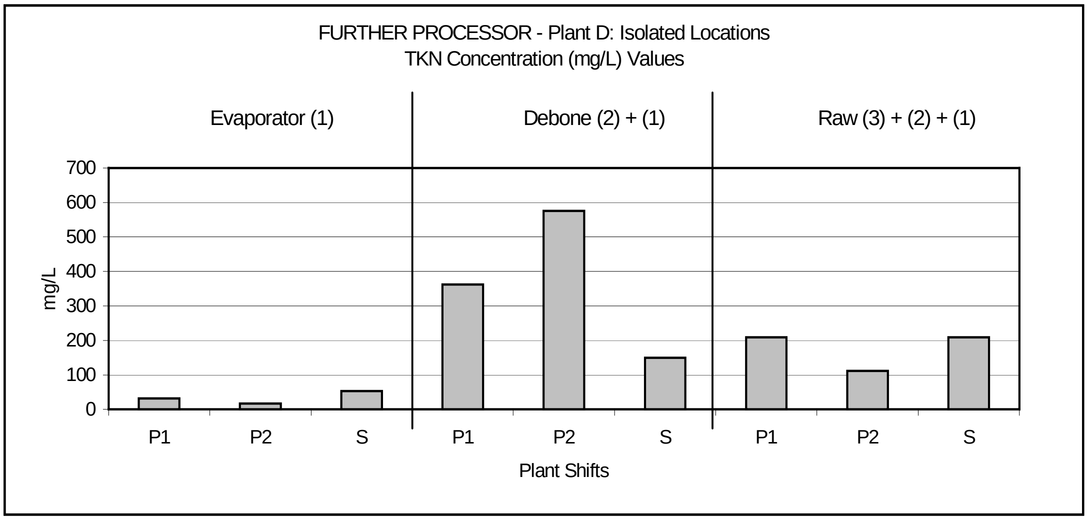


Figure 3.17. Further processing plant D: isolated locations – TKN concentration (mg/L).

	Evaporator (1)			Debone (2) + (1)			Raw (3) + (1) + (2)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant D	1.255	0.940	2.155	79.27	130.6	65.79	45.2	72.8	84.12

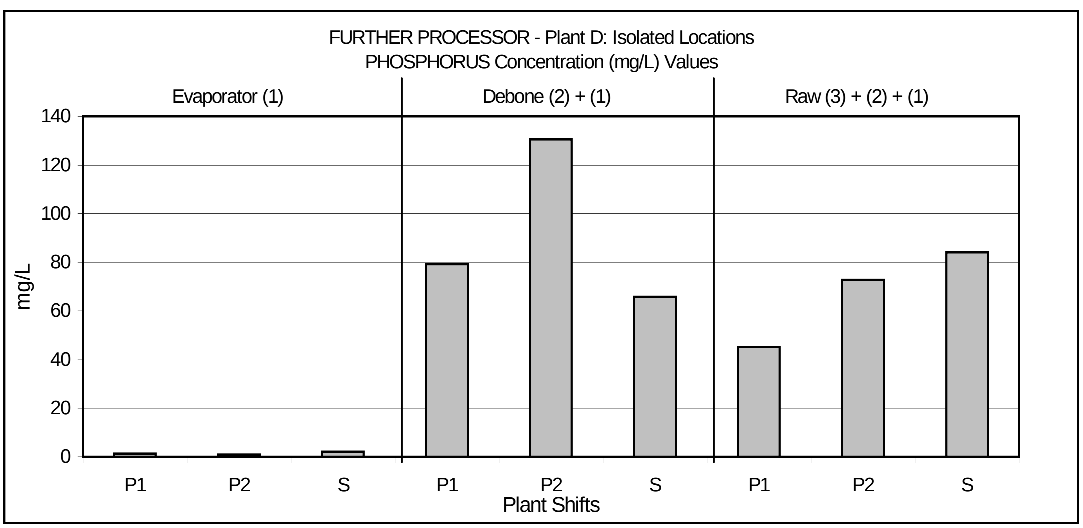


Figure 3.18. Further processing plant D: isolated locations – P concentration (mg/L).

	Evaporator (1)			Debone (2) + (1)			Raw (3) + (1) + (2)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant D	1.09	0.57	1.75	208	329	57	367	415	163

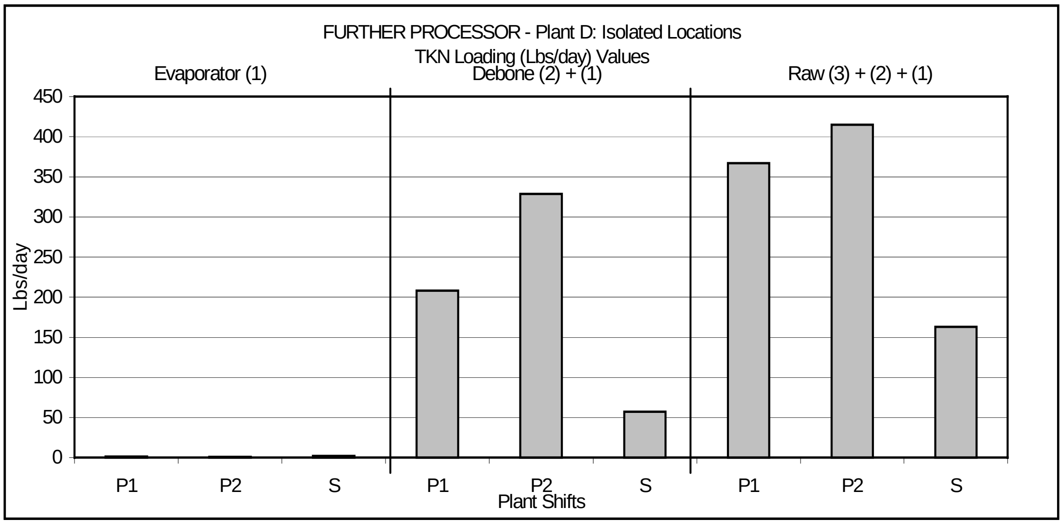


Figure 3.19. Further processing plant D: isolated locations – TKN loading (Lbs/day).

	Evaporator (1)			Debone (2) + (1)			Raw (3) + (1) + (2)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant D	0.0424	0.032	0.0729	45.35	74.69	25.09	79.83	130.22	67.87

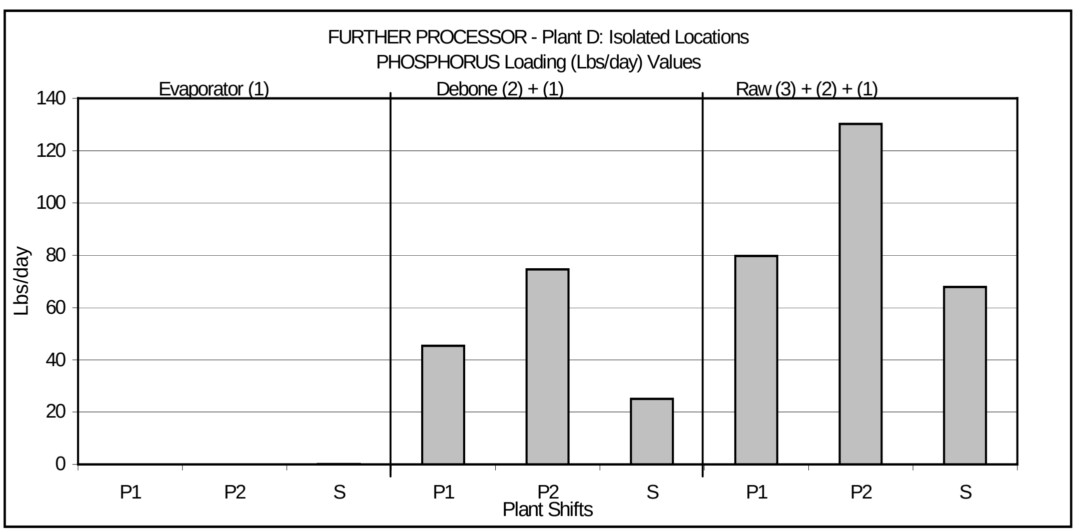


Figure 3.20. Further processing plant D: isolated locations – P loading (Lbs/day).

	Water Knife (1)		Raw Processing (2) + (1)			Cooking (3) + (1) + (2)		
	P1	P2	P1	P2	S	P1	P2	S
Plant E	503	521	128	183	62	331	159	214

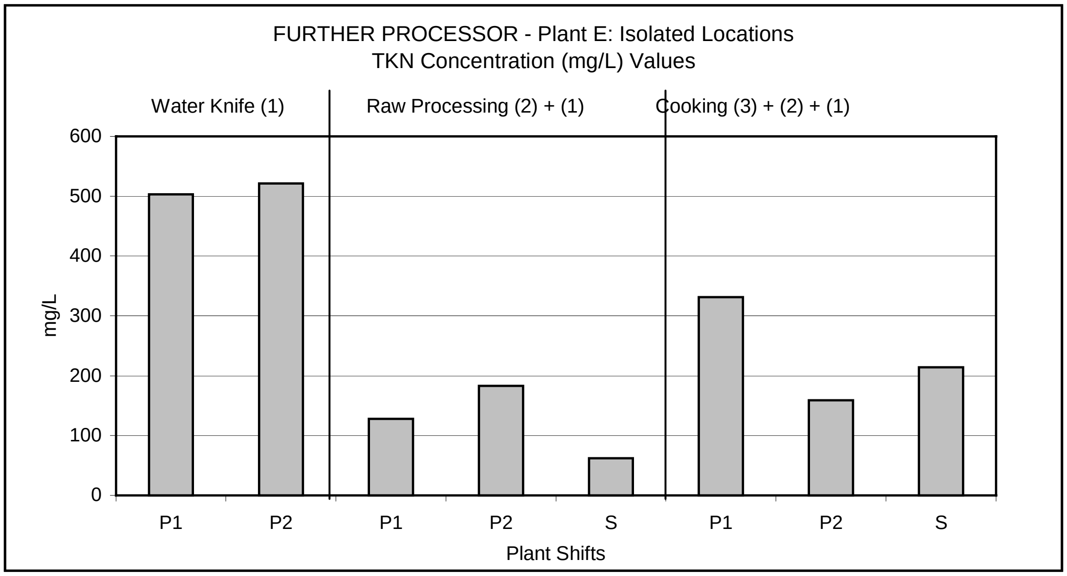


Figure 3.21. Further processing plant E: isolated locations – TKN concentration (mg/L).

	Water Knife (1)		Raw Processing (2) + (1)			Cooking (3) + (1) + (2)		
	P1	P2	P1	P2	S	P1	P2	S
Plant E	46.64	47.26	28.96	43.48	37.2	48.07	28.74	35.11

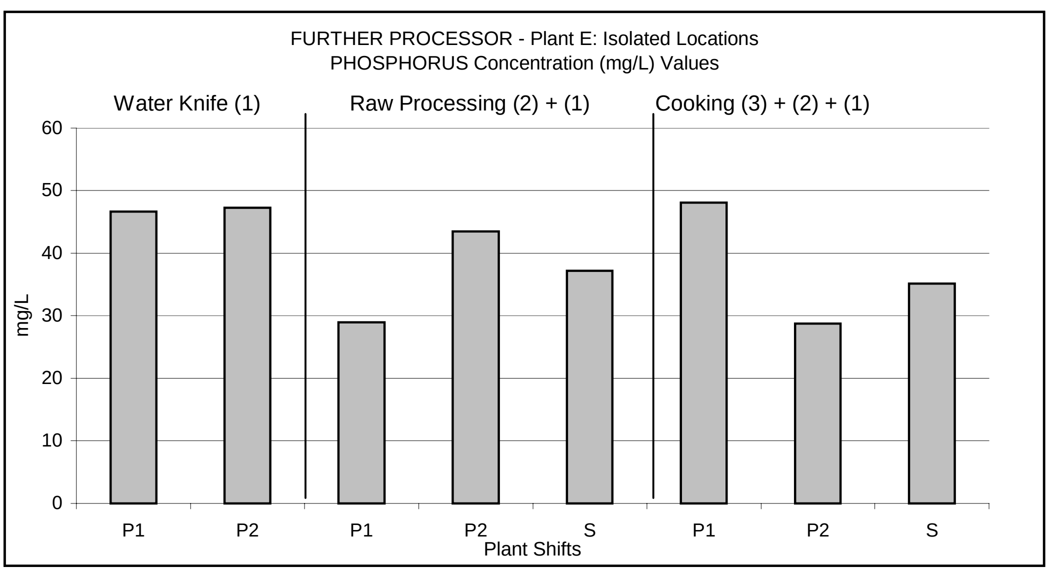


Figure 3.22. Further processing plant E: isolated locations – P concentration (mg/L).

	Water Knife (1)		Raw Processing (2) + (1)			Cooking (3) + (1) + (2)		
	P1	P2	P1	P2	S	P1	P2	S
Plant E	7.92	6.67	49	49	6	132	92	28

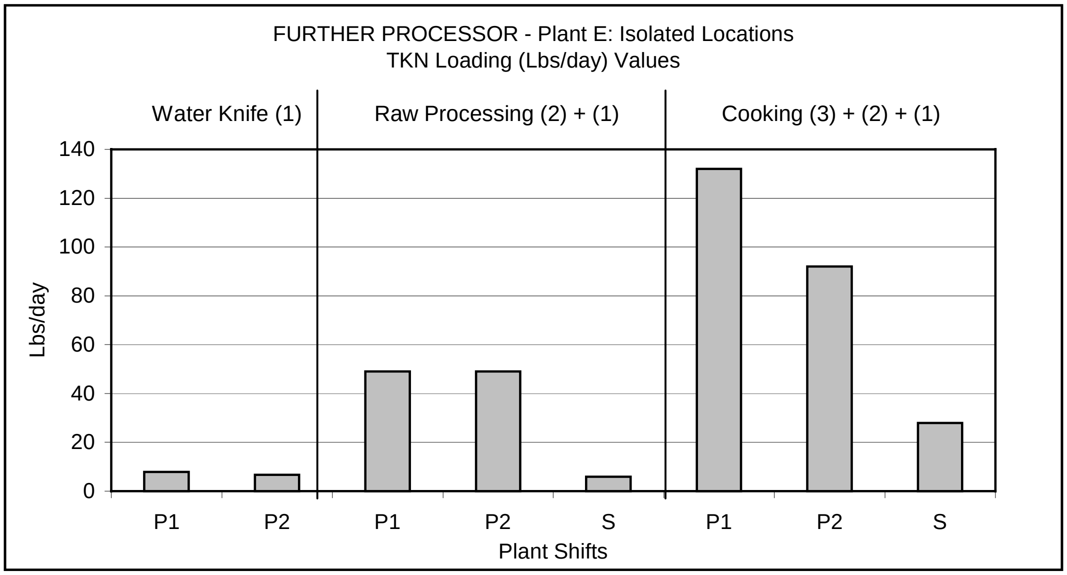


Figure 3.23. Further processing plant E: isolated locations – TKN loading (Lbs/day).

	Water Knife (1)		Raw Processing (2) + (1)			Cooking (3) + (1) + (2)		
	P1	P2	P1	P2	S	P1	P2	S
Plant E	0.7341	0.6054	11.16	11.92	3.91	23.33	16.70	4.60

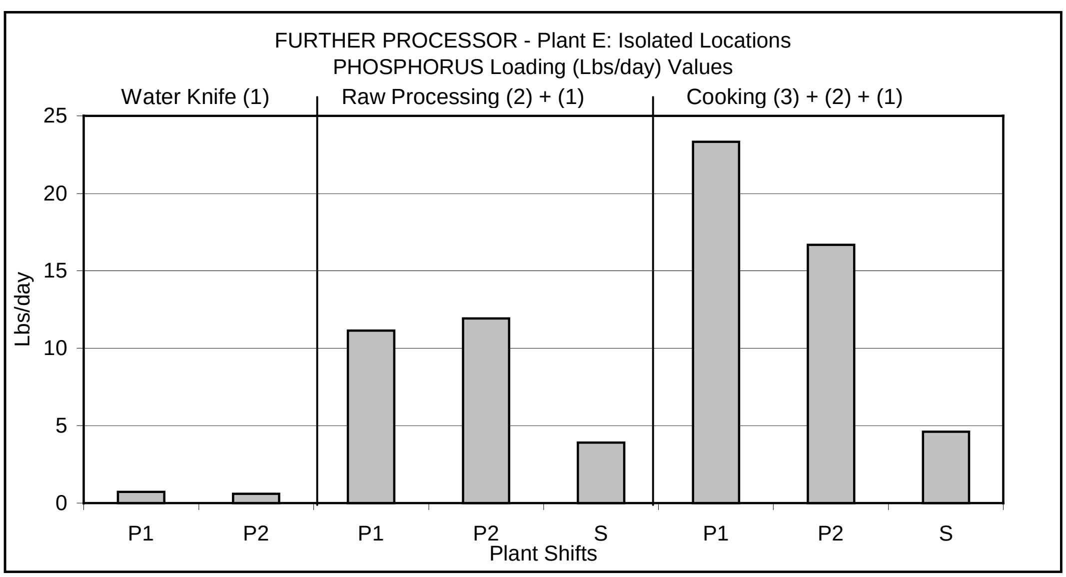


Figure 3.24. Further Processing Plant E: Isolated Locations – PHOSPHORUS Loading (Lbs/day)

	Tumbler Area (1)			Raw Forming Area (2)			Cook Line (3)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant F	522	337	129	699	231	185	492	465	154

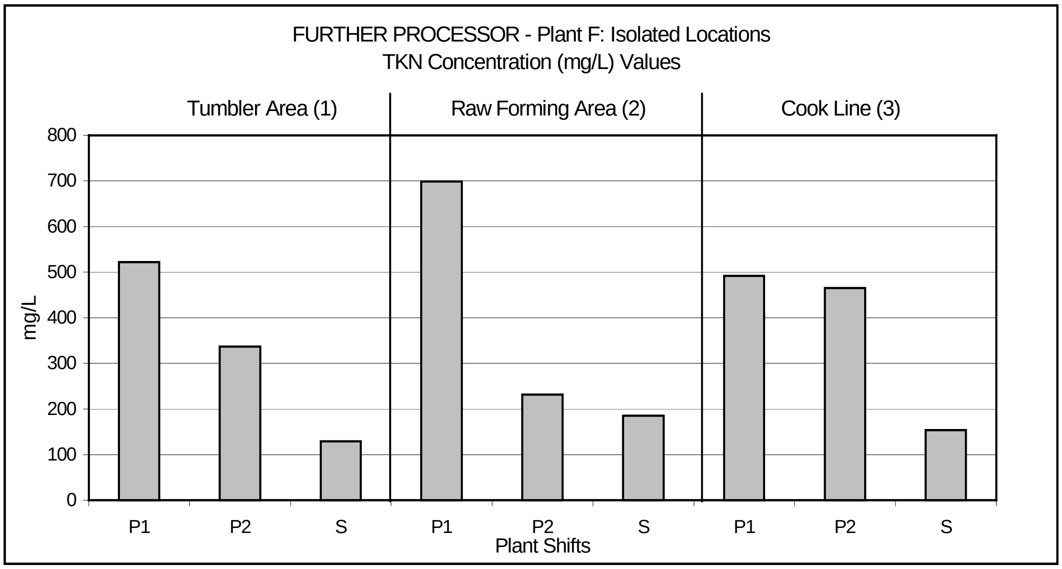


Figure 3.25. Further processing plant F: isolated locations – TKN concentration (mg/L).

	Tumbler Area (1)			Raw Forming Area (2)			Cook Line (3)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant F	181.0	443.4	55.94	177.9	194.4	406.4	313.2	500.4	79.69

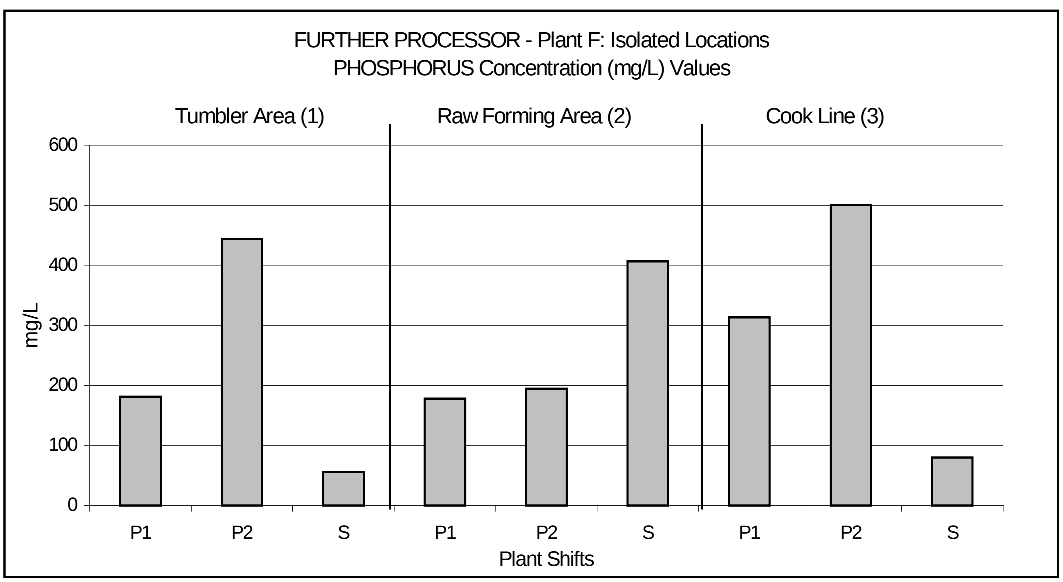


Figure 3.26. Further processing plant F: isolated locations – P concentration (mg/L).

	Tumbler Area (1)			Raw Forming Area (2)			Cook Line (3)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant F	3.90	2.52	1.29	26	9	9	52	49	22

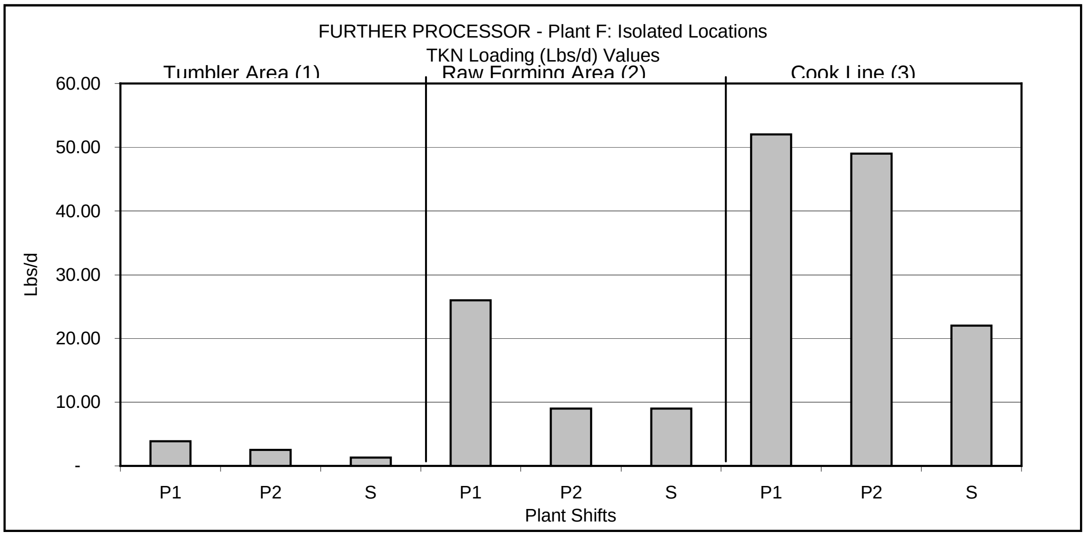


Figure 3.27. Further processing plant F: isolated locations – TKN loading (Lbs/d).

	Tumbler Area (1)			Raw Forming Area (2)			Cook Line (3)		
	P1	P2	S	P1	P2	S	P1	P2	S
Plant F	1.35	3.30	0.56	6.62	7.23	20.17	32.64	51.65	10.97

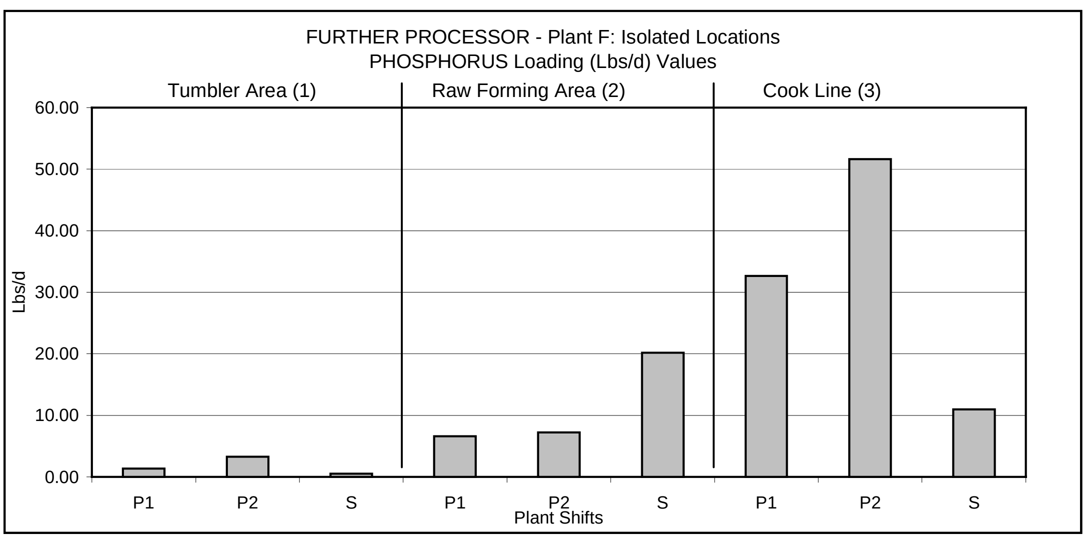


Figure 3.28. Further processing plant F: isolated locations – P loading (mg/L).

References

Bender, F. G. and E. Brotsky, 1991. Process for Treating Poultry Carcasses to Control Salmonella Growth. U.S. Patent 5,069,922. U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C.

Blank, L., 1980. Statistical Procedures for Engineering, Management, and Science. McGraw-Hill, New York, New York.

Carawan, R. E, 1989. Environmental Issues Facing Food Processors in the 1990's. *In:* 1989 Food Industry Environmental Conference Proceedings. Georgia Institute of Technology, Atlanta, Georgia. pp. 217-237.

Canter, L. W. and N. Harfouche, 2000. Sources and Characteristics. *In:* Wastewater Treatment. D. H. F. Liu and and B. G. Liptak (Editors). Lewis Publishers, New York, New York. pp. 114-142.

Eremektar, G., E. Ubay Cokgor, S. Ovez, F. Germirli Babuna, and D. Orhon, 1999. Biological Treatability of Poultry Processing Plant Effluent – a Case Study. Water Science and Technology 40(1):323-329.

Gaskin, J. and G. Harris, 1999. Nutrient Management – Farm Assessment System: Georgia Farm*A*Syst. Cooperative Extension Service Bulletin No. 1152-16. College of Agricultural and Environmental Sciences. The University of Georgia, Athens, Georgia.

Giese, J., 1992. Press Conference Reports: Experimental Process Reduces *Salmonella* in Poultry. Food Technology 46: 112.

Giese, J., 1993. *Salmonella* Reduction Process Receives Approval. Food Technology 47: 110.

Kiepper, B. H., W. C. Merka, A. E. Reynolds, and J. Sellers, 2001. Profile and Production Process Determination of Phosphorus and Nitrogen Discharges from Poultry Processing Plants. USPOULTRY Final Report: Project No. 558. U.S. Poultry and Egg Association, Tucker, Georgia.

Kim, J. M. and M. F. Slavik, 1994. Trisodium Phosphate (TSP) Treatment of Beef Surfaces to Reduce *Escherichia coli* O157:H7 and *Salmonella typhimurium*. Journal of Food Science 59: 20-22.

Kroyer, G. T., 1995. Impact of Food Processing on the Environment: An Overview. Lebensm-Wiss Technology 28:547-552.

Lin, K. W. and S. N. Lin, 2002. Effects of Sodium Lactate and Trisodium Phosphate on the Physicochemical Properties and Shelf Life of Low-Fat Chinese-Style Sausage. Meat Science 60: 147-154.

Merka, W. C., 1982. A Study of the Waters of Turkey Processing: Utilization Patterns, Chemical and Physical Properties, Wastewater Treatment Efficiency. Doctorate Dissertation. Texas A&M University, College Station, Texas.

Merka, W. C., 1989. Characteristics of wastewater. Broiler Industry 52(11):20-27.

Merka, W. C., 1990. A Characterization of Wastewaters Discharged by a Modern Broiler Processing Plant. Project 335 Final Report. Southeastern Poultry and Egg Association, Tucker, Georgia.

Merka, W. C. and E. Whittle, 1996. Correlation of Wastewater Test Results. *In:* 1996 National Poultry Waste Management Symposium Proceedings. P. H. Patterson and J. P. Blake (Editors). Auburn University Printing Service, Auburn, Alabama. pp. 274-281.

Ott, R. L., 1993. An Introduction to Statistical Methods and Data Analysis. Duxbury Press, Belmont, California.

Pierson, J. A. and S. G. Pavlostathis, 2000. Real-Time Monitoring and Control of Sequencing Batch Reactors for Secondary Treatment of a Poultry Processing Wastewater. Water Environment Research 72(5):585-592.

Rusten, B., J. G. Siljudalen, A. Wien, and D. Eidem, 1998. Biological Pretreatment of Poultry Processing Wastewater. Water Science and Technology 38(4-5):19-28.

Sharpley, A. N., 2000. Agriculture and Phosphorus Management: The Chesapeake Bay. Lewis Publishers, Boca Raton, Florida.

Steel, G. D. and J. H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, New York.

Tusseau-Vuillemin, M. H., 2001. Do Food Processing Industries Contribute to the Eutrophication of Aquatic Systems? Ecotoxicology and Environmental Safety 50:143-152.

USEPA, 1975. Development Document for Proposed Effluent Limitations, Guidelines and New Source Performance Standards for the Poultry Segment of the Meat Product and Rendering Process Point Source Category. EPA 440/1-75-1031b, Group I, Phase II. U.S. Environmental Protection Agency, Washington, D.C.

Westerman, P. W., W. L. Hankins, and L. M. Safley, 1989. Nitrogen Availability from Poultry Processing Plant DAF Sludge. Transactions of the ASAE 32(4):1287-1294.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The periodic and comprehensive characterization of wastewater generated by U.S. poultry processing plants is necessary due to the industry's rapid expansion over the past 60 years. Between 1960 and 1999, annual U.S. per capita consumption of chicken increased from 27.8 to 78.8 pounds (Ollinger *et al.,* 2000). The poultry processing industry has responded to this growing demand with larger plants, faster processing line speeds, and more employees. In 2002, U.S. poultry plants processed over nine billion chickens, turkeys, and ducks with a total live weight of 52.04 billion pounds. In addition to producing whole birds, slaughter plants today generate a product mix of cut-up parts, deboned meat, and other further processed convenience products (Ollinger *et al.,* 2000).

Beginning in 1972, following the approval of the Clean Water Act, poultry meat processors have been required to continually improve the treatment of their wastewater prior to discharge. At the same time, poultry plant water use has risen in response to food safety protocols such as the Hazard Analysis Critical Control Point (HACCP) and Zero Tolerance for fecal material programs (Cates *et al.*, 2001). This increased generation of wastewater and treatment requirements has led to the development and use of larger and more efficient wastewater treatment systems. These advanced treatment systems remove by-products and pollutants that allow for effluent discharge within environmental regulatory limits.

One essential element in the development of a comprehensive wastewater characterization involves the laboratory analysis of organic, chemical, and/or particulate constituents present in the wastewater stream. As important, thorough documentation of process operations and wastewater treatment methods is required to develop a complete picture of the wastewater generated by U.S. poultry processors.

Utilizing the methods of a self-administered mail survey and nutrient discharge monitoring, this study provides a comprehensive depiction of current processing operations, wastewater generation, and wastewater treatment systems within the U.S. poultry processing industry. Each method had advantages and disadvantages in collecting study data.

Mail Survey Method

The mail survey method had many advantages in gathering data associated with U.S. poultry processing:

- Survey development and compilation of data were completed at a relative low cost versus other methods,
- A self-administered paper questionnaire was inexpensively distributed nationwide and directed to specific environmental personnel at each facility,
- Respondents had the flexibility of completing the questionnaire at their own pace and over an extended period of time, which could be difficult if personal interviews were used, and
- Respondents could complete the questionnaire at any location due to its portability, which is an advantage over a computer electronic survey.

The mail survey method however had disadvantages. The interviewer had no direct control over the response rate (Faria and Dickinson, 1996; Mangione, 1995), which was lower (24 percent) than predicted prior to survey distribution. Post-survey phone interviews revealed that time constraints and company policies concerning confidentiality were the leading causes of non-response. Due to the poultry processing industry's trend towards consolidation (Ollinger *et al.*, 2000), firms that operate more than one facility received multiple mail surveys. The majority of U.S. poultry processing firms have dedicated environmental managers that oversee all the environmental issues at all of the firm's facilities, and in many cases completed all the surveys for plants owned by their firm.

The inability of the interviewer to clarify questions the respondents had during participation in the survey was a disadvantage. One example occurred when respondents were asked about their total water use, which included both process (production and sanitation) use and non-process (sanitary) use. The questionnaire did not make a clear distinction between the use of the word ‘sanitation’ versus ‘sanitary’. Consequently, these amounts were often miscalculated or interchanged.

The mail survey developed for this study lacked two elements that became apparent during the data compilation stage. First, a sample questionnaire should be distributed to selected environmental manager for comments and questions concerning clarity and completeness. Second, a predetermined portion of budgeted resources should be allocated to perform an extensive series of follow-up phone interviews to ensure survey accuracy and completeness.

Mail Survey Results

The results of the mail survey provided confirmation of current industry conditions, revealed some unexpected distributions, and in one case identified an emerging market trend. First, results confirmed the industry’s growth towards larger plant sizes. The mean processing rate among the surveyed plants of over 200,000 BPD, and 73.3 percent of the surveyed plants process over 150,000 BPD. Second, larger plant sizes equate to more employees per plant. Results show that 47.5 percent of the reporting chicken kill plants employ more then 1000 workers, and 27.5 percent of facilities employ between 1250 to 1500 people. Third, the mean potable water use was 1.46 MGD, while 69 percent of the plants reporting water use in excess of 1.0 MGD.

Results of potable water costs revealed an unexpected data distribution. Despite the general consensus of rising water costs, 77.0 percent of the facilities report paying less than 2.00 dollars per 1000 gallons. An oversight occurred in the survey development in the water cost area. The questionnaire failed to distinguish possible potable water sources. Although respondents could accurately record their water costs, they were not asked if their water supply was received from a public distribution system or private wells. This is an important distinction since private well water usually has lower associated costs than public supplies.

The results did accurately represent the emerging market trend towards the slaughtering of larger live weight chickens to meet the consumer demand for increased cut-up piece sizes and whole muscle deboned portions (Ollinger *et al.*, 2000; Rankin, 2000). The USDA calculated the mean live weight of chickens slaughtered in the U.S. during 2002 at 5.12 pounds, up over 0.5 pound from the mean range reported by Mountney and Parkhurst in 1995. The survey results reveal the continuation of this trend with a mean live weight of 5.8 pounds. Thirty-seven percent of the facilities reported slaughtering live weight chickens between 6.0 and 7.0 pounds.

One of the objectives of the survey was to document an accurate industry mean for the amount of potable water consumed in processing each chicken, traditionally defined as gallons per bird (GPB). After scrutinizing the survey results, this objective was not completed. Slaughter plants today generate a product mix of whole birds, cut-up parts, deboned meat, and other further processed convenience products. This is in stark contrast to most plants in the past that produced only whole birds (Ollinger *et al.*, 2000). Only one of the 45 surveyed chicken slaughter plants solely produce whole birds. This has caused the traditional GPB calculation, which is simply the number of birds processed per day divided by the total potable water use, to become obsolete. Because the vast majority of whole birds go on to additional process operations, the traditional GPB calculation is not representative of a plant's true water consumption rate. A more accurate calculation would involve first dividing the total pounds of chicken processed per day in each unit operation by 1000. Second, this result is divided into the total potable water consumed per day in gallons. This final result would represent the gallons of water consumed per 1000 pounds of chicken processed, and would provide a more accurate representation of true water consumption.

The results in poultry processing wastewater treatment include the identification of 22 separate permitted parameters that at least one of the surveyed poultry processors must meet to discharge their effluent. The large number of parameters is evidence that environmental regulators produce specialized discharge permits containing a unique combination of testing parameters that best serves to protect and preserve specific receiving waters. This is in contrast to the perceived need to develop nationwide environmental standards to regulate the wastewater effluent discharges of all poultry processing facilities regardless of location (USEPA, 2002).

Study results reveal that the monitoring and control of pH at various points of wastewater treatment systems is the most preferred method of process control. Wastewater plant operators use pH three times more than any other tests to optimize the efficiency of their DAF units and gauge the health of their biological treatment systems. When treatment problems do arise, adjustments and changes to wastewater chemicals are the most often utilized solution. Study results also identify the emergence of bioaugmentation in the management of wastewater treatment problems. Although the use of specialized biological microbes accounted for less than ten percent of the reported remedies, bioaugmentation was used in multiple problem areas including activated sludge bulking, poor anaerobic digestion, and excessive BOD and FOG loadings.

Nutrient Discharge Monitoring Method

Characterizing poultry processing wastewater using nutrient discharge monitoring has multiple advantages. Traditionally, nutrient monitoring in poultry processing facilities has generally focused on wastewater effluents. This method isolates the wastewater generated in specific plant areas. Thus, specific times, process operations, and pieces of equipment that have the greatest nutrient loading impact can be identified. This information can be used to move beyond simple monitoring programs and into the development of pollution prevention activities that can target and reduce specific nutrient discharges.

The nutrient discharge monitoring method used in this study has the flexibility to provide the sampled facility with precise information pertaining to their particular location. Once multiple processing plants conducting similar operations have been profiled, statistically significant trends can be identified and published for use by the industry as a whole.

Nutrient Discharge Monitoring Results

The periodic measurement of nutrient discharges can be a valuable tool in monitoring the effectiveness of waste minimization practices such as the amount of solid waste lost to the floor or in process equipment. The use of 'The Pounds Loading Equation', which combines nutrient concentration data with hydraulic flow, aids in producing an accurate depiction of a plant's true nutrient discharges. The live haul wastewater discharge of the sampled slaughter facilities is a good example of the advantage of the pounds loading equation. In all three slaughter plants the live haul area produced the highest concentrations of TKN and P, with means of 359 and 103.74 mg/L, respectively, versus the other isolated wastewater streams. However, when hydraulic flows were taken into account using the pounds loading equation, the results showed that the live haul area had the lowest impact of TKN and P on the final wastewater effluent at 73 and 10.45 pounds per day, respectively. Due to the similarity in the production processing lines within the three slaughter plants, it was expected that the trends in the discharge of TKN and P would be similar. Despite differences in number of birds processed per day and the amount of dressed poultry undergoing various additional processes, the mean COV for the percentage of TKN and P discharged during each shift was 0.20 and 0.25, respectively.

The wastewater stream generated in a poultry processing plant, viewed through the use of 'The Pounds Loading Equation', provides invaluable insight into how efficiently birds are processed, how effectively water is used, and how well employees carry out the waste minimization practices established by management to improve product yields.

Economic Impact of Wastewater Characterization

The results of the mail survey and nutrient monitoring methods highlight the potential of wastewater characterization studies beyond their traditional application of meeting environmental permit reporting requirements. The wastewater stream generated in a poultry processing plant provides invaluable insight into how efficiently birds are processed, how effectively water is used, and how well employees carry out the waste minimization practices established by management to improve product yields. As an example, work by Merka (1989, 1990) reveals that each pound of TKN identified in a poultry processing wastewater stream represents an equivalent loss of approximately 31 pounds of chicken meat. Using this information and a periodic TKN wastewater discharge monitoring plan, processing plants can accurately place a fiscal value on their loss of product to the waste stream. The three study slaughter plants had a total mean loading of 1,284 pounds of TKN per day. This represents an equivalent loss of 39,804 pounds of chicken meat to the waste stream. By comparing this result to the total pound of meat processed over time, a measurable efficiency value can be documented and monitored.

Future Research

Two areas for future research were identified from the results of this study. First, by widening the database of wastewater characterization studies, accurate models can be developed to predict the discharge of nutrients and other wastewater parameters from poultry processing plants with similar operations. These models then can be used by the poultry industry as a whole to predict the environmental impact of plant expansions, new product lines, and purchasing of new equipment based on a minimum of input data into a simple spreadsheet. One example for poultry slaughter plants would be number of birds processed per day, daily plant water use, and total pounds of product undergoing further processing.

Second, this study reveals the potential for the development of an objective rating system applied to various types of poultry processing equipment based on its probable nutrient discharge impact to the wastewater stream. A rating system can also be established to compare the impact of automated equipment to manual processing operations. This information can assist processing plant managers facing restrictive effluent limits in the decision making process to start new production lines, make plant improvements, or purchase new equipment based on potential nutrient discharge impacts.

REFERENCES

APHA, 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edition. A. E. Greenberg, L. S. Clesceri, and A. D. Eaton (Editors). American Public Health Association, Washington, D.C.

AWWA, 1977. Wastewater Treatment Plant Design: A Manual of Practice. American Water Works Association. Lancaster Press Inc., Lancaster, Pennsylvannia.

Backmann, D. P., J. Elfrink, and G. Vazzana, 1996. Tracking the Progress of E-mail vs. Snail Mail. Marketing Research 8(2):31-35.

Backmann, D. P., J. Elfrink, and G. Vazzana, 2000. E-mail vs. Snail Mail Face Off in Rematch. Marketing Research 11(4):10-15.

Baker, M. J., D. W. Blowes, and C. J. Ptacek, 1998. Laboratory Development of Permeable Reactive Mixtures for the Removal of Phosphorus from Onsite Wastewater Disposal Systems. Environmental Science and Technology 32(15):2308-2316.

Baker, R. C. and C. A. Bruce, 1989. Further Processing of Poultry. In: Processing of Poultry. G.C. Mead (Editor). Elsevier Applied Science, London, England. pp. 90-112.

Bender, F. G. and E. Brotsky, 1991. Process for Treating Poultry Carcasses to Control Salmonella Growth. U.S. Patent 5,069,922. U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C.

Berner, E. K. and R. A. Berner, 1996. Global Environment: Water, Air and Geochemical Cycles. Prentice Hall, New York, New York.

Blank, L., 1980. Statistical Procedures for Engineering, Management, and Science. McGraw-Hill, New York, New York.

Bossard, P. and R. Gachter, 1997. Interdiction des Phosphates: Theses et Antitheses. EAWAG News 42F: 18-20.

Boyer, K. K., J. R. Olson, R. J. Calantone, and E. C. Jackson, 2002. Print Versus Electronic Surveys: a Comparison of Two Data Collection Methodologies. Journal of Operations Management 20:357-373.

Brown, L.O., 1937. Market Research and Analysis. The Ronald Press Company, New York, New York.

Bugos, G. E., 1992. Intellectual Property Protection in the American Chicken-Breeding Industry. Business History Review 66:127-168.

Camp, W. J. and E. Willoughby, 1968. Extended Aeration Purifies Effluent. Food Engineering 40:72-74.

Canter, L. W. and N. Harfouche, 2000. Sources and Characteristics. In: Wastewater Treatment. D. H. F. Liu and and B. G. Liptak (Editors). Lewis Publishers, New York, New York. pp. 114-142.

Carawan, R. E, 1989. Environmental Issues Facing Food Processors in the 1990's. In: 1989 Food Industry Environmental Conference Proceedings. Georgia Institute of Technology, Atlanta, Georgia. pp. 217-237.

Carawan, R. E., W. M. Crosswhite, J. A. Macon, and B. K. Hawkins, 1974. Waste and Waste Management in Poultry Processing. EPA-660/2-74-031. Environmental Protection Technology Service. U.S. Environmental Protection Agency, Washington, D.C.

Cassell, E. A., K. M. Kaufman, and E. Matijevic, 1975. The Effects of Bubble Size on Microflotation. Water Resources 9:1017.

CAST, 1995. Waste Management and Utilization in Food Production and Processing. Task Force Report No. 124. Council for Agricultural Science and Technology, Ames, Iowa.

Cates, S. C., D. W. Anderson, S. A. Karns, and P. A. Brown, 2001. Traditional Versus Hazard Analysis Critical Control Point-Based Inspection: Results from a Poultry Slaughter Project. Journal of Food Protection 64(6):826-832.

CBP, 1995. The State of Chesapeake Bay, 1995. Chesapeake Bay Program. U.S. Government Printing Office, Washington, D.C.

Chen, T. C., J. E. Hioll, and R. L. Hayes, 1976. Quality Characteristics of Raw and Treated Effluents from Mississippi Poultry Processing Plants. Poultry Science 55:2390-2395.

Cheremisinoff, N. P., 2002. Handbook of Water and Wastewater Technologies. Pollution Engineering. Butterworth-Heinemann, Boston, Massachusetts.

Childers, T. L. and S. J. Skinner, 1996. Toward a Conceptualization of Mail Survey Response Behavior. Psychology & Marketing 13:185-209.

Childs, R. E. and R. E. Walters, 1962. Methods and Equipment for Eviscerating Chickens. Marketing Research Report No. 549. U.S. Department of Agriculture, Washington, D.C.

Clark, G. L. and P. F. Kaminski, 1990. How to Get More for Your Money in Mail Surveys. Journal of Services Marketing 4:44-47.

Cobanoglu, C., B. Warde, and P. J. Moreo, 2001. A Comparison of Mail, Fax, and Web-Based Survey Methods. International Journal of Market Research 43(4):441-452.

Combs, G. F., 1961. Quality and Quantity of Final Product - Poultry. Federation of American Societies of Experimental Biology 20:306-312.

Contreras, E. M., L. Giannuzzi, and N. E. Zaritzky, 2000. Growth Kinetics of the Filamentous Microorganism Sphaerotilus Natans in a Model System of a Food Industry Wastewater. Water Resources 34(18):4455-4463.

Coolsen, F. G., 1947. Pioneers in the Development of Advertising. Journal of Marketing 12(1):80-86.

Corbitt, R. A., 1990. Wastewater disposal. In: Standard Handbook of Environmental Engineering. R.A. Corbitt (Editor). McGrew-Hill, New York, New York. pp. 6.1-6.274

CSUS, 1991. Pretreatment Facility Inspection. Second Edition. Office of Water Programs. Department of Civil Engineering. California State University, Sacramento. Hornet Foundation, Inc., Sacramento, California.

CSUS, 1992. Operation of Wastewater Treatment Plants. Volume 1. Fourth Edition. Office of Water Programs. Department of Civil Engineering. California State University, Sacramento. Hornet Foundation, Inc., Sacramento, California.

CSUS, 1993a. Advanced Waste Treatment. Second Edition. Office of Water Programs. Department of Civil Engineering. California State University, Sacramento. Hornet Foundation, Inc., Sacramento, California.

CSUS, 1993b. Operation of Wastewater Treatment Plants. Volume 2. Fourth Edition. Office of Water Programs. Department of Civil Engineering. California State University, Sacramento. Hornet Foundation, Inc., Sacramento, California.

CSUS, 1994. Industrial Waste Treatment. Second Edition. Office of Water Programs. Department of Civil Engineering. California State University, Sacramento. Hornet Foundation, Inc., Sacramento, California.

Davis, L. L. and M. E. Coe, 1954. Bleeding of Chickens During Killing Operations. Poultry Science 33:616-619.

de Vaus, D. A., 1986. Surveys in Social Research. George Allen & Unwin, London, England.

Dillman, D. A., 1978. Mail and Telephone Surveys: The Total Design Method. John Wiley & Sons, New York, New Tork.

Drewniak, E. E., E. R. Baush, and L. L. Davis, 1955. Carbon Dioxide Immobilization of Turkeys Before Slaughter. Circular No. 958. U.S. Department of Agriculture, Washington, D.C.

Eckenfelder, Jr., W. W., 2000. Industrial Water Pollution Control. Third Edition. McGrew-Hill, New York, New York.

Erdos, P. L., 1970. Professional Mail Surveys. McGraw-Hill, New York, New York.

Eremektar, G., E. Ubay Cokgor, S. Ovez, F. Germirli Babuna, and D. Orhon, 1999. Biological Treatability of Poultry Processing Plant Effluent – a Case Study. Water Science and Technology 40(1):323-329.

Esser, G. and G. H. Kohlmaier, 1991. Modeling Terrestrial Sources of Nitrogen, Phosphorus, Sulfur, and Organic Carbon to Rivers. In: Biogeochemistry of Major World Rivers. E. T. Degens, S. Kempe, J. E. Richey (Editors). Wiley, Inc., Chichester, England, pp. 297-322.

Faria, A. J. and J. R. Dickinson, 1992. Mail Survey Response, Speed, and Cost. Industrial Marketing Management 21:51-60.

Faria, A. J. and J. R. Dickinson, 1996. The Effect of Reassured Anonymity and Sponsor on Mail Survey Response Rate and Speed with a Business Population. Journal of Business and Industrial Marketing 11:66-76.

Froning, G. W., 1979. Characteristics of Bone Particles from Various Poultry Meat Products. Poultry Science 58:1001-1003.

Froning, G. W., F. E. Cunningham, and D. R. Suderman, 1979. Characterization of Bone Particles from Cooked and Uncooked Mechanically Deboned Chicken Meat. Poultry Science 58:1058.

Froning, G. W., F. E. Cunningham, D. R. Suderman, and B. M. Sackett, 1981. Characterization of Bone Particles and Measurement of Bone Particle Size from Mechanically Deboned Poultry. Poultry Science 60:1443-1447.

Futrell, C. and R. T. Hise, 1982. The Effect of Anonymity and Same Day Deadline on the Response Rate to Mail Surveys. European Research 10(10):171-175.

Gaskin, J. and G. Harris, 1999. Nutrient Management – Farm Assessment System: Georgia Farm*A*Syst. Cooperative Extension Service Bulletin No. 1152-16. College of Agricultural and Environmental Sciences. The University of Georgia, Athens, Georgia.

Giese, J., 1992. Press Conference Reports: Experimental Process Reduces *Salmonella* in Poultry. Food Technology 46: 112.

Giese, J., 1993. *Salmonella* Reduction Process Receives Approval. Food Technology 47: 110.

Glide, L. C., 1968. Cannery and Poultry Waste Treatment. Water and Sewage Works 15:338-342.

Greer, T. V., N. Chuchinprakarn, and S. Seshadri, 2000. Likelihood of Participating in Mail Survey Research: Business Respondent' Perspectives. Industrial Marketing Management 29:97-109.

Greer, T. V. and R. Lohtia, 1994. Effects of Source and Paper Color on Response Rates in Mail Surveys. Industrial Marketing Management 23:47-54.

Groves, R. M. and M.P. Couper, 1998. Nonresponse in Household Interview Surveys. John Wiley & Sons, New York, New York.

Grummer, R. R., 1992. Inedible Fats and Greases. In: Inedible Meat By-Products. A. E. Pearson and T. R. Dutson (Editors). Elsevier Applied Science, New York, New York. pp. 113-148.

Hamm, D. H., 1972. Characteristics of Effluents in Ten Southeastern Poultry Processing Plants. Poultry Science 51:825-829.

Harp, H. H., and D. F. Durham, 1963. Comparative Costs of Consumers of Convenience Foods and Home-Prepared Foods. Economic Research Service, Marketing Research Report No. 609. U.S. Department of Agriculture, Washington, D.C.

Harper, S. R., G. E. Valentine, and C. C. Ross, 1988. Feasibility of Packed-Bed Anaerobic Treatment of Poultry Processing Wastewater. Proceedings of the 42nd Industrial Waste Conference. Purdue University, West Lafayette, Indiana, May 12-14. Lewis Publishers, Chelsea, Michigan.

Hedrick, H. B., E. D. Aberle, J. C. Forrest, M. D. Judge, and R. A. Merkel, 1994. Principles of Meat Science. Kendall Hunt Publishing Company, Dubuque, Iowa.

Helgeson, J. G., K. E. Voss, and W. D. Terpening, 2002. Determinants of Mail-Survey Response: Survey Design Factors and Respondent Factors. Psychology & Marketing 19(3):303-328.

Hodgson, R.E. 1959. Livestock Production in Transition. In: Food, The Yearbook of Agriculture. U.S. Department of Agriculture, Washington, D.C. pp. 35-49.

Hopkins, K., 1988. Case Histories: Pretreatment of Poultry Processing Wastewater. Proceedings of the 38th Industrial Waste Conference. Purdue University, West Lafayette, Indiana, May 10-12. Butterworth Publishers, Boston, Massachusetts.

Huser, B. and E. B. Welch, 2000. Amount of Phosphorus Inactivated by Alum Treatments in Washington Lakes. Limnology and Oceanography 45:226-230.

Jenkins D., 1992. Towards a Comprehensive Model of Activated Sludge Bulking and Foaming. Water Science and Technology 25(6):215-230.

Jenkins D., M. G. Richard, and G. T. Daigger, 1993. Manual on the Causes and Control of Activated Sludge Bulking and Foaming. CRC Press, Boca Raton, Florida.

Jobber, D., N. Allen, and J. Oakland, 1985. The Impact of Telephone Notification Strategies on Response to an Industrial Mail Survey. International Journal of Research in Marketing 2:291-306.

Jobber, D. and S. Sanderson, 1983. The Effects of a Prior Letter and Coloured Questionnaires on Mail Survey Response Rates. Journal of the Market Research Society 25:339-349.

John, R. E., 1991. Quality-Disease Concerns with Rendered Animal Products. 3-18. Proceedings of the Maryland Nutrition Conference for Feed Manufacturers, College Park, Maryland.

Kanuk, L. and C. Berenson, 1975. Mail Surveys and Response Rates: A Literature Review. Journal of Marketing Research 12:440-453.

Kiepper, B. H., W. C. Merka, A. E. Reynolds, and J. Sellers, 2001. Profile and Production Process Determination of Phosphorus and Nitrogen Discharges from Poultry Processing Plants. USPOULTRY Final Report: Project No. 558. U.S. Poultry and Egg Association, Tucker, Georgia.

Kiepper, B. H. and J. Sellers, 2002. Survey Database of Wastewater Treatment Practices and Experiences in the Poultry Processing Industry. USPOULTY Final Report: Project No. 562. U.S. Poultry and Egg Association, Tucker, Georgia.

Kiesler, S. and L. S. Sproull, 1986. Response Effects in the Electronic Survey. Public Opinion Quarterly 50(3):402-413.

Kim, J. M. and M. F. Slavik, 1994. Trisodium Phosphate (TSP) Treatment of Beef Surfaces to Reduce *Escherichia coli* O157:H7 and *Salmonella typhimurium*. Journal of Food Science 59: 20-22.

Klapper, H. K., 1991. Control of Eutrophication in Inland Waters. Ellis Horwood, New York, New York.

Klassen, R. D. and J. Jacobs, 2001. Experimental Comparison of Web, Electronic and Mail Survey Technologies in Operations Management. Journal of Operations Management 19:713-728.

Klose, A. A., M. F. Pool, D. de Fremery, A. A. Campbell, and H. L. Hanson, 1960. Effect of Laboratory Scale Agitated Chilling of Poultry on Quality. Poultry Science 39:1193-1198.

Kotula, A. W., E. E. Drewnaik, and L. L. Davis. 1961. Experimentation with In-Line Carbon Dioxide Immobilization of Chickens Prior to Slaughter. Poultry Science 40:213-216.

Kotula, A. W. and N. V. Helbacka, 1966. Blood Retained in Chicken Carcasses and Cut-up Parts as Influenced by Slaughter Method. Poultry Science 45:404-410.

Kroyer G., 1991. Food Processing Wastes. In: Bioconversion of Waste Materials to Industrial Products. A. M. Martin (Editor). Elsevier Applied Science, New York, New York. pp. 293-311.

Kroyer, G. T., 1995. Impact of Food Processing on the Environment: An Overview. Lebensm. Wiss. Technology 28:547-552.

Lasley, F. and A. Baker, 1984. From Barnyard Flocks to Big Business. Farmline 5(3):4-6.

Laughlin, J. E. and W. C. Roming, 1993. Design of Rotary Fine Screen Facilities in Wastewater Treatment. Public Works 124(4):47-50.

Liao, P. H. and K. V. Lo, 1990. Treatment of Poultry Processing Wastewater Using Sequencing Batch Reactors. Canadian Agricultural Engineering CAEOAI 32(2):299-302.

Lilliard, H. S., 1978. Improving Quality of Bird Chiller Water for Recycling of Diatomaceous Earth Filtration and Chlorination. Journal of Food Science 43:1528-1531.

Lin, K. W. and S. N. Lin, 2002. Effects of Sodium Lactate and Trisodium Phosphate on the Physicochemical Properties and Shelf Life of Low-Fat Chinese-Style Sausage. Meat Science 60: 147-154.

Liptak, B. G., 2000. Wastewater Treatment. Lewis Publishers, New York, New York.

Lockley, L. C., 1950. Notes on the History of Marketing Research. Journal of Marketing 14(5):733-736.

Mangione, T. W., 1995. Mail Surveys: Improving the Quality. Sage Publications, Thousand Oaks, California.

Marais, G. V. R., R. E. Loewenthal, and I. P. Siebritz, 1983. Observations Supporting Phosphate Removal by Biological Excess Uptake - A Review. Water Science and Technology 15(3):15-41.

Marsh, C., 1982. The Survey Method: The Contribution of Surveys to Sociological Explanation. George Allen & Unwin, London, England.

Mavis, B. E. and J. J. Brocato, 1998. Postal Surveys Versus Electronic Mail Surveys: The Tortoise and the Hare Revisited. Evaluation and the Health Professions 21(3):395-408.

McGrail, D. T., 1976. Poultry Processing Wastewater – Advanced Treatment and Reuse. Technical Report EPA-600/2-76-304. U.S. Environmental Protection Agency, Washington, D.C.

McKee, S., 2001. Chilling of Poultry: Is it in the Air or in the Water? The Food Chain 6: 1-3.

Mead, G. C., 1989. Processing of Poultry. Elsevier Applied Science, London, England.

Mehta, R. and E. Sivadas, 1995. Comparing Response Rates and Response Content in Mail Versus Electronic Mail Surveys. Journal of the Market Research Society 37(4):429-439.

Mellor, P. B., and F. A. Gardner, 1976. Reducing Waste Loads from Poultry Processing Plants. Technical Bulletin, December 10. Texas Agricultural Extension Service, College Station, Texas.

Merka, W. C., 1982. A Study of the Waters of Turkey Processing: Utilization Patterns, Chemical and Physical Properties, Wastewater Treatment Efficiency. Doctorate Dissertation. Texas A&M University, College Station, Texas.

Merka, W. C., 1989. Characteristics of Wastewater. Broiler Industry 52(11):20-27.

Merka, W. C., 1990. A Characterization of Wastewaters Discharged by a Modern Broiler Processing Plant. Project 335 Final Report. Southeastern Poultry and Egg Association, Tucker, Georgia.

Merka, W. C. and E. Whittle, 1996. Correlation of Wastewater Test Results. In: 1996 National Poultry Waste Management Symposium Proceedings. P. H. Patterson and J. P. Blake (Editors). Auburn University Printing Service, Auburn, Alabama. pp. 274-281.

Metcalf and Eddy, Inc., 1991. Wastewater Engineering. Third Edition. McGraw-Hill, New York, New York.

Mickelberry, W. C., D. V. Schwall, and W. J. Stadelman, 1962. The Effect of Ice:Water Coolant Ratios Upon Moisture Absorption and Rate of Chilling of Eviscerated Chicken Carcasses. Poultry Science 41:1550-1553.

Miller, L. A., R. S. Taylor, and L. A. Monk, 1991. NPDES Permit Handbook. Government Institutes, Rockville, Maryland.

Mountney, G. J., 1966. Poultry Products Technology. AVI, Westport, Connecticut.

Mountney, G. J. and C. R. Parkhurst. 1995. Poultry Products Technology. Third Edition. Food Products Press, New York, New York.

Nemerow, N. L., 1969. Baffled Biological Basins for Treating Poultry Plant Wastes. Water Pollution Control Federation Journal 41:1602-1608.

Nemerov N. L. and A. Dasgupta, 1991. Industrial and Hazardous Waste Treatment. Van Nostrand Reinhold, New York, New York.

Newell, G. W. and C. J. Shaffner, 1950a. Blood Volume Determination in Chickens. Poultry Science 29:78-87.

Newell, G. W. and C. J. Shaffner, 1950b. Blood Loss by Chickens During Killing. Poultry Science 29:271-275.

Newswanger, L., and H. E. Zuern, 1980. Effective Wastewater Treatment in Poultry Processing Operations. Industrial Water Engineering 17(5):19-21.

Nguyen, V. T., and W. K. Shieh, 2000. Secondary Treatment. In: Wastewater Treatment. D. H. F. Liu and B. G. Liptak (Editors). Lewis Publishers, New York, New York. pp. 210-232.

Ockerman, H. W. and C. L. Hansen, 2000. Animal By-Product Processing and Utilization. Technomic Publishing Company, Lancaster, Pennsylvania.

Ollinger, M., J. MacDonald, and M. Madison, 2000. Structural Change in U.S. Chicken and Turkey Slaughter. Agricultural Economic Report No. 787. Economic Research Service. U.S. Department of Agriculture, Washington, D.C.

Orth, G. O., Jr., 1977. Filter System and Method of Filtering Animal Processing Wastes. U.S. Patent No. 4-026-792. Official Gazette of the United States Patent Office 958(5):2118.

Ott, R. L., 1993. An Introduction to Statistical Methods and Data Analysis. Duxbury Press, Belmont, California.

Pankratz, T. M., 1995. Screening Equipment Handbook – for Industrial and Municipal Water and Wastewater Treatment. Second Edition. Technomic Publishing Company, Lancaster, Pennsylvania.

Pearson, A. M. and T. R. Dutson, 1995. HACCP in Meat, Poultry and Fish Processing. Advances in Meat Research Series – Volume 10. Chapman & Hall, New York, New York.

Pierson, J. A. and S. G. Pavlostathis, 2000. Real-Time Monitoring and Control of Sequencing Batch Reactors for Secondary Treatment of a Poultry Processing Wastewater. Water Environment Research 72(5):585-592.

Pool, M. F., E. P. Mecchi, H. Lineweaver, and A. A. Klose, 1954. The Effect of Scalding Temperature on the Processing and Initial Appearance of Turkeys. Poultry Science 33:274-279.

Porges, R., 1950. Wastes from Poultry Processing Establishments. Sewage and Industrial Wastes 22:531-535.

Porges, R. and E. J. Struzeski, 1962. Wastes from Poultry Processing Industry. U.S. Department of Health Education and Welfare, Cincinnati, Ohio.

Pressley, M. M. and W. Tullar, 1977. A Factor Interactive Investigation of mail Survey Response Rates from a Commercial Population. Journal of Marketing Research 41:108-112.

Rast, W. and J. Thornton, 1998. Trends in Eutrophication Research and Control. In: Water Quality Trends. N. E. Peters, O. P. Bricker, and M. M. Kennedy (Editors). Wiley Publishing, New York, New York, pp. 171-189.

Reed, S. W. and F. E. Woodard, 1976. Dissolved Air Flotation of Poultry Processing Waste. Journal Water Pollution Control Federation 48(1):107-120.

Romans, J. R., W. J. Costello, C. W. Carlson, M. L. Greaser, and K. W. Jones, 1994. The Meat We Eat. Thirteenth Edition. Interstate Publishers, Danville, Illinois.

Rankin, M. D., 2000. Handbook of Meat Product Technology, Blackwell Science, London, England.

Rusten, B., J. G. Siljudalen, A. Wien, and D. Eidem, 1998. Biological Pretreatment of Poultry Processing Wastewater. Water Science and Technology 38(4-5):19-28.

Schaeffer, D. R. and D. A. Dillman, 1998. Development of Standard E-mail Methodology: Results on an Experiment. Public Opinion Quarterly 62(3):378-397.

Schmitz, R. J., 1996. Introduction to Water Pollution Biology. Gulf Publishing Company, Houston, Texas.

Shannon, D. M. and C. C. Bradshaw, 2002. A Comparison of Response Rate, Response Time, and Costs of Mail and Electronic Surveys. The Journal of Experimental Education 70(2):179-192.

Sharpley, A. N., 2000. Agriculture and Phosphorus Management: The Chesapeake Bay. Lewis Publishers, Boca Raton, Florida.

Sheehan, K. B. and M. G. Hoy, 1999. Using E-mail to Survey Internet Users in the United States: Methodology and Assessment. Journal of Computer-Mediated Communication 4(3). Available at http://www.ascusc.org/jcmc/vol4/issue3/sheehan.html. Accessed in January 2003.

Sincero, A. P. and G. A. Sincero, 2003. Physical-Chemical Treatment of Waste and Wastewater. CRC Press, New York, New York.

Singh, S. P., R. L. Wesley, and E. A. Budd, 1973. Characteristics of Poultry Processing Effluents. Poultry Science 52:1478-1481.

Smith, R., 1996. Wastewater Treatment System Upgrade at a Processing Plant. In: Proceedings of the 1996 National Poultry Waste Management Symposium. P. H. Patterson and J. P. Blake (Editors). Auburn University Printing Service, Auburn, Alabama. pp. 282-284.

Stadelman, W. J., V. M. Olson, G. A. Shemwell, and S. Pasch, 1988. Egg and Poultry-Meat Processing. Ellis Horwood, Ltd., Chichester, England.

Starkey J., 2000. Vice President for Environmental Programs, U.S. Poultry & Egg Association, Tucker, Georgia. Personal Communication.

Steel, G. D. and J. H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, New York.

Strikland, J., 1998. Development and Application of Phosphorus Removal from Wastewater Using Biological and Metal Precipitation Techniques. Journal of the Chartered Institute of Water Environment Management 12(1):30-37.

Swan, J. E., D. E. Epley, and W. L. Burns, 1980. Can Follow-up Response Rates to a Mail Survey Be Increased By Including Another Copy of the Questionnaire? Psychological Reports 47:103-106.

Tarver, F. R., Jr., G. C. McGee, and O. E. Goff, 1956. The Rate of Cooling and Water Absorption of Poultry Held in Various Mediums. Poultry Science 35:905-910.

Teletzke, G. H., 1961. Chicken for BBQ, Wastes for Aerobic Digestion. Wastes Engineering 32:135-139.

Tookos, I., 1982. Pilot Plant Experiments on the Physio-Chemical Treatment of Meat Processing Effluents. Effluent and Water Treatment Journal 22(11):421-427.

Truell, A. D. and J. E. Bartlett, 2002. Response Rate, Speed, and Completeness: A Comparison of Internet-Based and Mail Surveys. Behavior Research Methods Instruments & Computers 34(1):46-49.

Tusseau-Vuillemin, M. H., 2001. Do Food Processing Industries Contribute to the Eutrophication of Aquatic Systems? Ecotoxicology and Environmental Safety 50:143-152.

Tyagi, P. K., 1989. The Effects of Appeals, Anonymity and Feedback on Mail Survey Response Patterns from Salespeople. Journal of the Academy of Marketing Science 17:234-241.

Uhlmann, D. and H. Klapper, 1985. Protection and Restoration of Lake and Reservoirs in the German Democratic Republic – Case Studies. In: Proceedings of the International Congress on Lake Pollution and Recovery, Rome, Italy. pp. 262-271.

U.S. Congress, 1972. Federal Water Pollution Control Act Amendments of 1972. PL 92-500, 92nd Congress, S. 2770, 18 October 1972. U.S. Congress, Washington, D.C.

USDA, 1981. USDA Policy Book. Labeling Policy Book. Food Safety Inspection Service. Meat and Poultry Inspection Technical Services, Standards and Labeling Division, U.S. Department of Agriculture, Washington, D.C.

USDA-FSIS, 1991. Meat and Poultry Inspection Program: Statistical Summary for 1990. FSIS-14. Food Safety Inspection Service. U.S. Department of Agriculture, Washington, D.C.

USDA-NASS, 2003. Poultry Slaughter – 2002 Annual Summary. Pou 2-1(03). National Agricultural Statistics Service. U.S. Department of Agriculture, Washington, D.C.

USEPA, 1975. Development Document for Proposed Effluent Limitations, Guidelines and New Source Performance Standards for the Poultry Segment of the Meat Product and Rendering Process Point Source Category. EPA 440/1-75-1031b, Group I, Phase II. U.S. Environmental Protection Agency, Washington, D.C.

USEPA, 1996. Environmental Indicators of Water Quality in the United States. EPA 841-R-96-002. Office of Water (4503F), U.S. Environmental Protection Agency, Washington, D.C.

USEPA, 2002. Effluent Limitation Guidelines and New Source Performance Standards for the Meat and Poultry Products Point Source Category; Proposed Rule – Part II. Federal Register, 40 CFR Part 432. U.S. Environmental Protection Agency, Washington, D.C.

Vickers, Z. and M. C. Bourne, 1976. Crispness in Foods – a Review. Journal of Food Science 41:1153-1157.

Vincon-Leite, B., X. Gayte, G. Balvay, P. Blanc, J. C. Druant, J. C. Fontvieille, and B. Tassin, 1999. Interannual Variability of Phytoplankton Dynamics in Lake Bourget (Savoie, France) During Two Successive Years (1995-1996). In: Proceedings of the 8th International Conference on the Conservation and Management of Lakes, Copenhagen, Denmark. pp. 117-129.

Walsh, K. M., 1993. Screening Your Options. Water Environment & Technology 5(10):16.

Wang, P. L. and F. A. Gardner, 1979. Microbiological Characterization of Effluent Samples from Turkey Processing Plants. Poultry Science 58:1119.

WEF, 1998. Design of Municipal Wastewater Treatment Plants. Volume 2 & 3. 4th Edition. Manual of Practice No. 8. Water Environment Federation, Alexandria, VA.

Welch, E. B. and T. Lindell, 1992. Ecological Effects of Wastewater: Applied Limnology and Pollutant Effects. Second Edition. Chapman & Hall, New York, New York.

Wessels, J. P., 1972. A Study of the Protein Quality of Different Feather Meals. Poultry Science 51:537-541.

Westerman, P. W., W. L. Hankins, and L. M. Safley, 1989. Nitrogen Availability from Poultry Processing Plant DAF Sludge. Transactions of the ASAE 32(4):1287-1294.

Whitehead, W. K., 1976. Monitoring Poultry Processing Wastewater with Total Organic Carbon. Poultry Science 55:679-684.

WPCF, 1977. Water Treatment Plant Design, 9-10. Water Pollution Control Federation. American Society of Civil Engineers, Washington, D.C.

Woodard, F. E., O. J. Sproul, and M. W. Hall, 1972. Treatment of Poultry Processing Wastes using DAF and Chemical Coagulants. Journal Water Pollution Control Federation 44:1909-1915.

Woodard, F. E., M. W. Hall, O. J. Sproul, and M. M. Ghosh, 1977. New Concepts in Treatment of Poultry Processing Wastes. Water Research 11(10):873-877.

Zwiercon, G. A., 1974. Case of the Weeping Pies (and Others). Food Engineering 46:79-81.

APPENDIX A

SURVEY OF WASTEWATER TREATMENT PRACTICE AND EXPERIENCE IN THE POULTRY PROCESSING INDUSTRY

U.S. Poultry & Egg ASSOCIATION

A Survey of Wastewater Treatment Practice and Experience in the Poultry Processing Industry

— 1785 —

U.S. Poultry and Egg Association
Department of Biological and Agricultural Engineering, The University of Georgia

Introduction

The U.S. Poultry and Egg Association, in conjunction with the Biological and Agricultural Engineering Department at the University of Georgia, is conducting a survey of the poultry (chicken, turkey, duck, and other fowl) processing industry, in an effort to establish baseline wastewater data. The information collected by this survey will be used to determine the range and average production rates, water usage, wastewater generation, treatment and disposal methods utilized by the poultry processing industry. Financial data collected will be used to characterize the economic impact of water use and wastewater generation on the industry. The U.S. Poultry & Egg Association thanks you for your participation.

Instructions for Completing the Survey

1. The person(s) with the most knowledge of the plant's present wastewater system should complete this survey.
2. The survey has been prepared in an attempt to make it applicable to various poultry processing operations; therefore, not all of the information requested will apply to each facility.
3. Every effort should be made to complete all applicable items.
4. If exact data is not available to answer a particular question, please provide your best engineering estimates.

Statement of Confidentiality:

The information provided in this survey will be used to develop ranges and averages of wastewater systems at typical types of poultry processing operations. Individual plants and company data will be viewed and compiled internally by specified U.S. Poultry & Egg Association and University of Georgia staff only. Reports and other information generated as a result of this survey will contain only cumulative data presented by poultry processing operation type. No individual plant or company data will be released.

Should you have any questions concerning the completion of the survey, please contact:

Brian Kiepper
Engineering Outreach program
The University of Georgia
Phone: 706-542-6907
Fax: 706-542-8806
E-mail: bkiepper@engr.uga.edu

Returning the Survey

Please complete the survey and return it to the address below by **Friday, March 16, 2001:**

Brian Kiepper
Driftmier Engineering Center
The University of Georgia
Athens, GA 30602

Note: Please make a copy of this survey for your files, prior to mailing. Information gathered for this survey will be useful in the preparation of future environmental regulatory questionnaires, such as the upcoming scheduled survey from the United States Environmental Protection Agency.

Survey Questions

1. Plant Information:

Name of Plant/Facility: ____________________

Location Address: ____________________

____

Years Plant in Operation: ________

Contact Person: ____________________

Title: ____________________

Telephone: ____________________

Fax: ____________________

Email: __________@__________

2. Plant Operations (check all that apply):

Type	*Operations*
1st ____	Slaughter ____ Chill-pak ____ Other ____________________ Cut-up ____ ____________________
2nd ____	Debone ____ Portion Control ____ Other ____________________ Marination ____ MSC/MDM ____ ____________________ IQF ____ ____________________
3rd ____	Cooking/Breading ____ Par fry ____ Other ____________________ Fully Cooked ____ BBQ ____ ____________________ Breading ____ ____________________
4th ____	Rendering ____ Other ____________________

3. Plant Capacity and Actual Operations:

Type	*Operations*	*Production Levels Per DAY*	*Avg. Maximum Plant Design Capacity*	*Average Actual Throughput*
1st	Slaughter:	IN: Birds Processed		
		and/or Lbs. Live Weight		
		OUT: Lbs.		
	Cut-up:	IN: Lbs.		
		OUT: Lbs.		
	Chill-pak:	Lbs.		
	Other: ________	Lbs.		
	________	Lbs.		
2nd	Debone:	IN: Lbs.		
		OUT: Lbs.		
	Portion Control:	IN: Lbs.		
		OUT: Lbs.		
	Marination:	Lbs.		
	IQF:	Lbs.		

Type	Operations	Production Levels Per DAY	Avg. Maximum Plant Design Capacity	Average Actual Throughput
2nd (cont.)	Other: ______	Lbs.		
	______	Lbs.		
	______	Lbs.		
3rd	Cooking/Breading:	Lbs.		
	Fully Cooked:	Lbs.		
	Breading:	Lbs.		
	Par Fry	Lbs.		
	BBQ	Lbs.		
	Other: ______	Lbs.		
	______	Lbs.		
	______	Lbs.		
4th	Rendering:	IN: Lbs. Offal Processed		
		Lbs. Feathers Processed		
		OUT: Lbs. Oil		
		Lbs. Poultry Meal		
		Lbs. Feather Meal		

4. Other Plant Information

Number of production employees: ______

Number of total employees: ______

Days of operation (circle): M T W T F S S

Weekly operating hours: ______ (7 days/week, 24 hours/day = 168 hours)

Number of production shifts: ______

Number of sanitation shifts: ______

5. Water usage:

Total plant water usage per day: ______________

Water usage during production shift(s): 1st: __________ 2nd: __________

Water usage during sanitation shift: ____________

Water cost: $ ________ per: 1000 gallons _____, 100 ft^3 ____, Other: ________

Major water usage areas: On the process flow sheets corresponding to your operation (see attached Figures 1, 2, and 3), please enter actual or estimated water usage in each of the major process areas. Please cross out any operations that are not applicable to your plant. If the flow diagrams provided cannot be used to accurately represent your process operations, please provide a flow diagram with the requested information.

6. Wastewater Treatment Operations:

Wastewater system: On-site treatment with direct disposal – to surface water ______

- to land application ______

On-site pretreatment with indirect disposal to public sewer system ______

No on-site pretreatment with disposal to public sewer system ______

Other: ____

____

Cost of wastewater treatment: Total Cost = $ __________ per __________

Cost for on-site treatment = $ _______ per _______

Cost for public sewer service = $ _______ per _______

Wastewater treatment personnel: No. of State Licensed Operators ______

No. of Other Operators ______

7. Wastewater Characteristics:

Parameter	*Permitted (Y or N)*	*Permitted Level (mg/l or lbs./day)***	*Actual Discharge Level Range (mg/l or lbs/day)#*	*Sampling Frequency*
BOD5*	Y N		--	
COD*	Y N		--	
TSS*	Y N		--	
FOG*	Y N		--	
TKN*	Y N		--	
AN*	Y N		--	
NN*	Y N		--	
P*	Y N		--	
OP*	Y N		--	
pH	Y N		--	
	Y N		--	
	Y N		--	
	Y N		--	
	Y N		--	
	Y N		--	

* BOD5 – Biochemical Oxygen Demand
FOG – Fat, Oil and Grease
NN – Nitrate and Nitrite Nitrogen
COD – Chemical Oxygen Demand
TKN – Total Kjeldahl Nitrogen
P – Total Phosphorus
TSS – Total Suspended Solids
AN – Ammonia Nitrogen
OP – Ortho-phosphate

** Please enter units for each permitted level given
\# Please enter units for each actual discharge level given and provide the typical range of test results

8. Wastewater Treatment Processes:

Please check each of the wastewater treatment processes your plant uses and provide detailed information requested:

Process:	*Additional Information:*
Screening	Types & sizes: ______
DAF	Volume of solids per day, % moisture: ______
Anaerobic Digestion	Volume: ______
Activated Sludge (i.e., SBR)	Type & volume: ______
Aerated Lagoon	Number of ponds & volume: ______
Facultative Lagoon	Number of ponds & volume: ______
Packed Tower	Volume: ______
Final Clarifier	Volume: ______
Filtration	Types & filter sizes: ______
Polishing Ponds	Number of ponds & volume: ______
Disinfection	Type(s) & volume of disinfectant used: ______
Land Application	Acres & application rate: ______
Public Sewer Discharge	Volume per day: ______
Other:	______
	______

Further description of treatment process: On the process flow sheet(s) corresponding to your treatment operation(s) (see attached Figures 4 and 5), please indicate the essential operating data for each process. For example, for biological processes, information of interest would include, but not be limited to, flow rate, basin volume, influent and effluent composition, and dissolved oxygen concentration. For dissolved air flotation operations, information of interest would include, but not be limited to, flow rates, tank volume, influent and effluent composition, pressure at which air is injected, pH, and chemical dosages. Please cross out any operations that are not applicable to your treatment system. If the flow diagrams provided cannot be used to accurately represent your treatment system, please provide a flow diagram with the requested information.

9. Process Control:

Please list the operating parameters that are regularly monitored and/or controlled to ensure proper wastewater treatment plant operation. In effect, these are the parameters you would use to diagnose an operational problem when one is encountered. This information will provide information on the process control strategy and will be correlated to the wastewater treatment problems that your plant has experienced.

Parameter	*Sample Point*	*Frequency*	*Target Level*	*Check if automated:*	
				Monitoring	*Control*
DO*	Aeration				
SVI*	Clarifier				
pH	Digester				
pH	DAF tank				

* DO – Dissolved Oxygen
SVI – Sludge Volume Index

10. Wastewater Treatment Operational Problems:

Please list and describe any problems that you have encountered in the operation of your wastewater treatment plant, as well as any measures you have taken to remedy the problem.

Activated sludge bulking	
Poor DAF sludge separation	
Phosphorus Removal	
Sour anaerobic digester	
Others:	

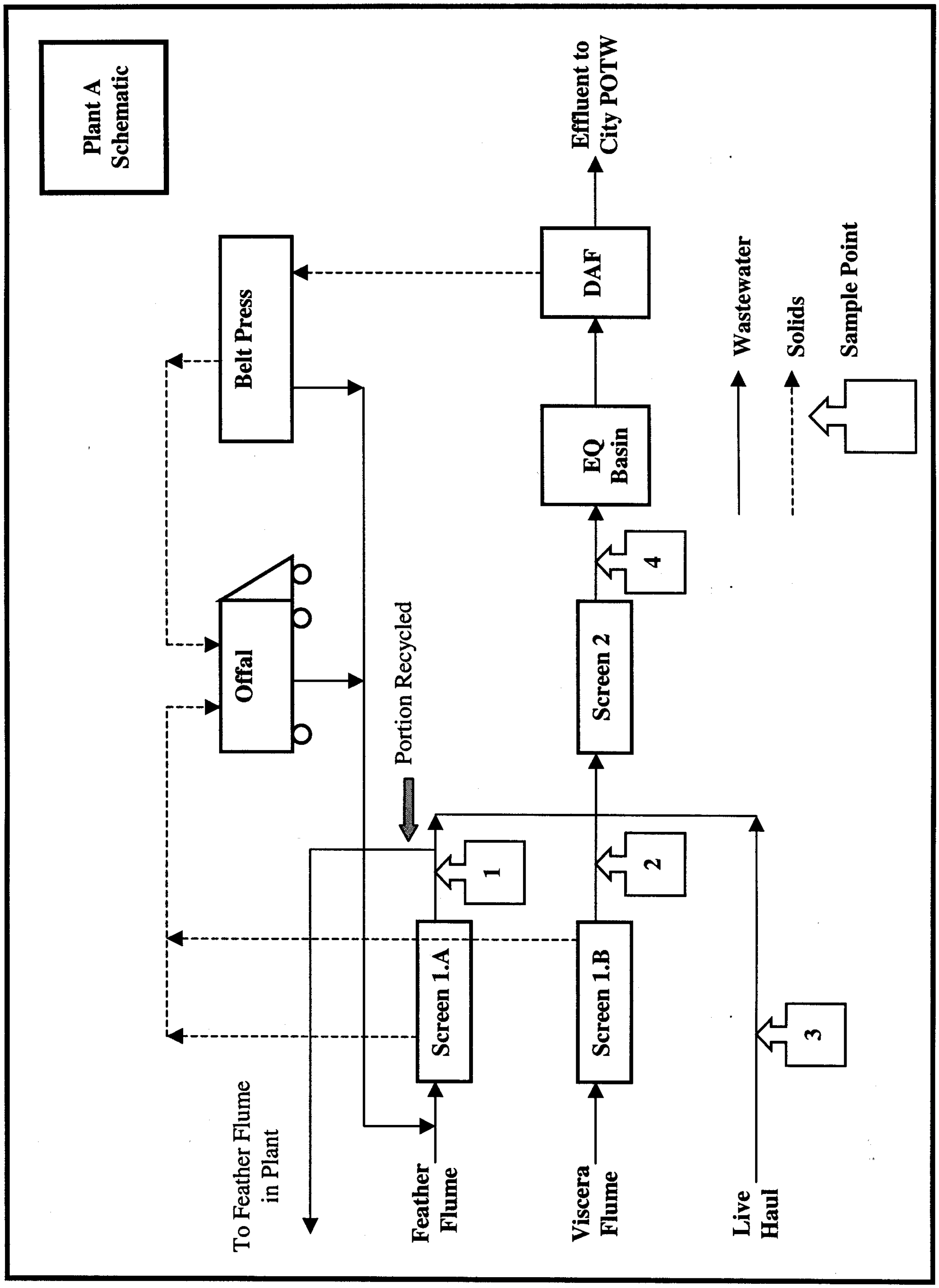
11. Wastewater Treatment Residuals:

Please list any residuals generated in your wastewater treatment operation, indicating the source or point at which they are generated, the generation rate, and their final disposal method.

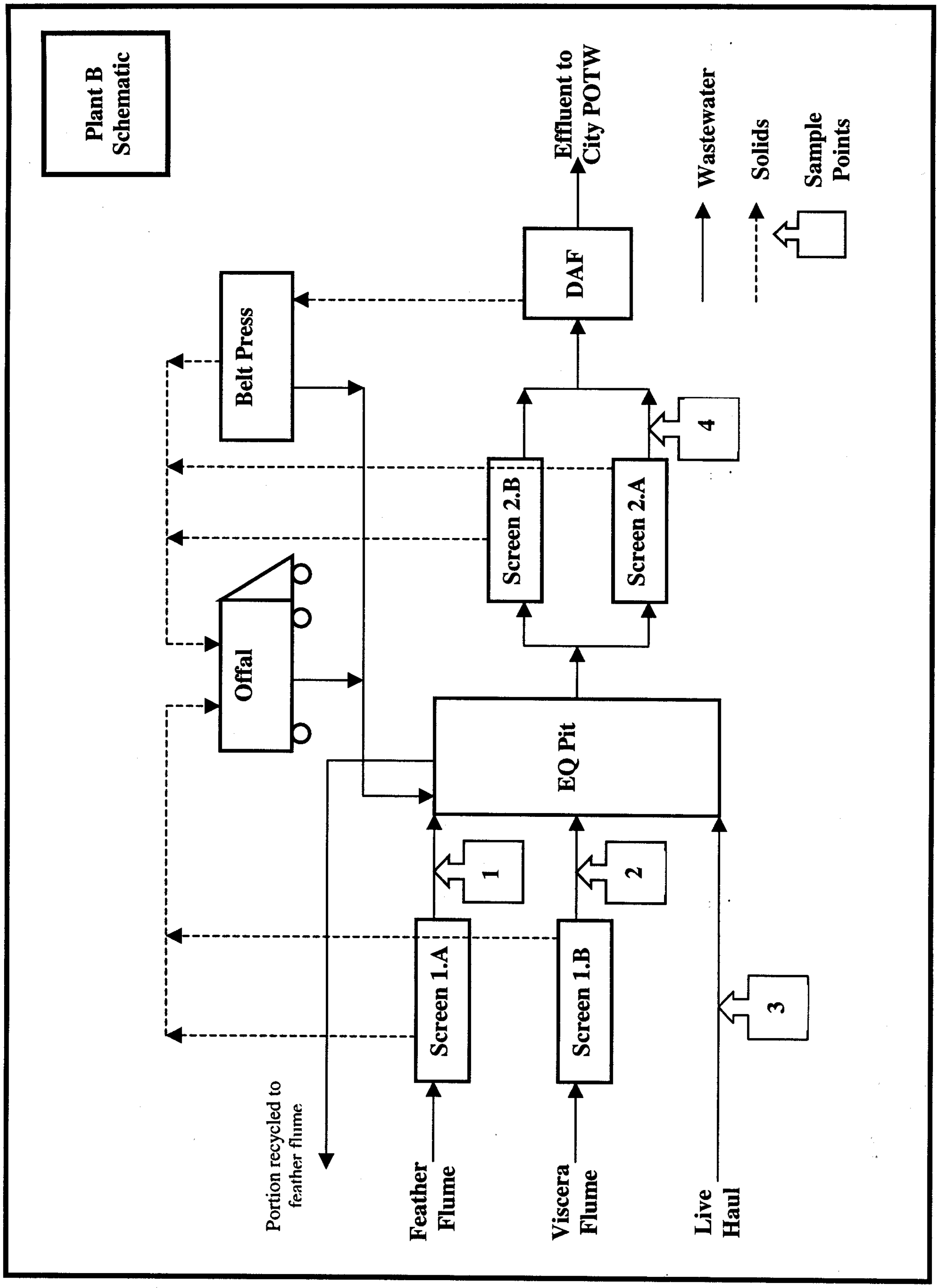
Residual	*Source*	*Generation Rate*	*Final Disposal*
Screenings			
DAF sludge			
Waste activated sludge			
Treated effluent			
Other:			

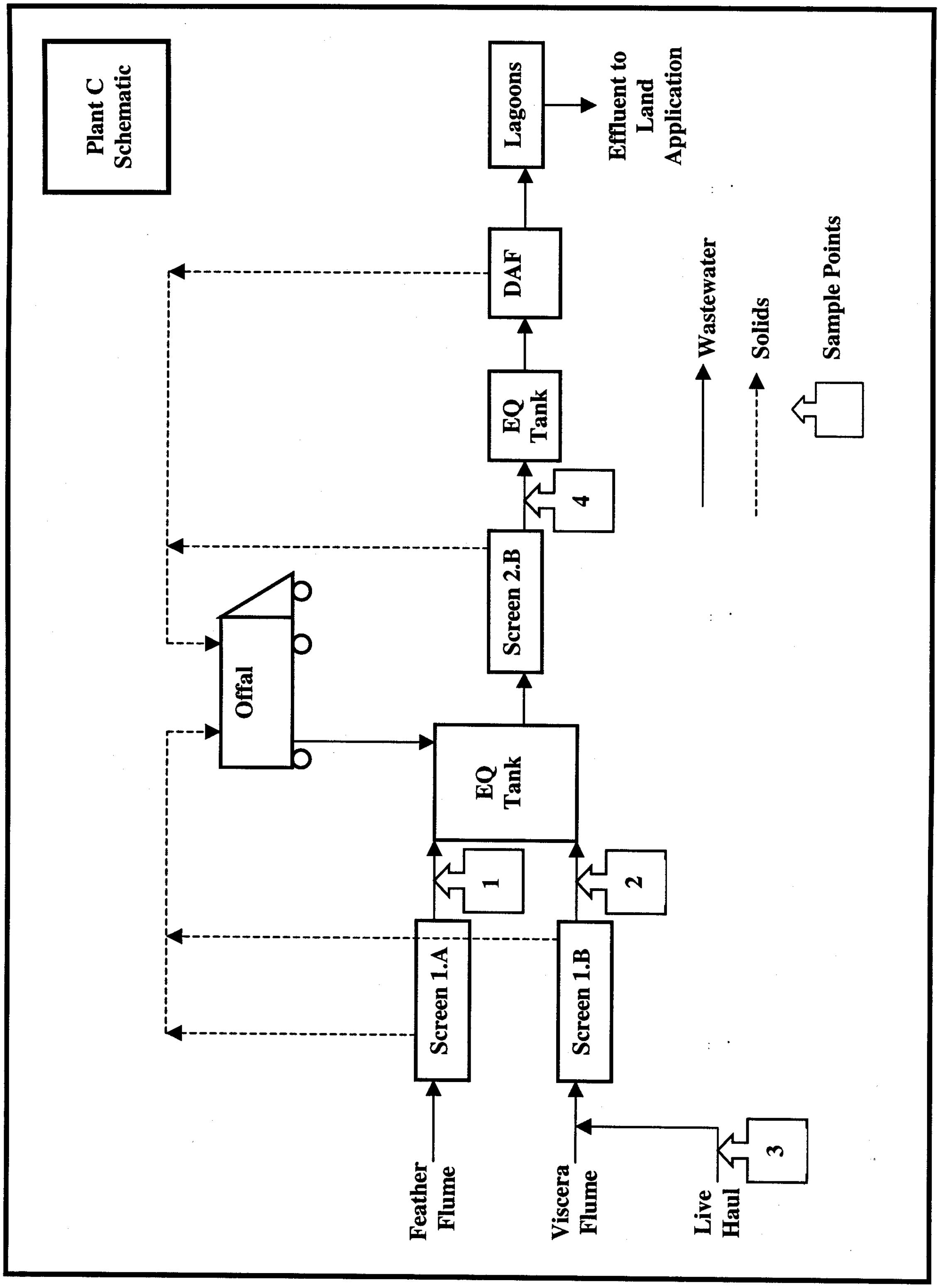
APPENDIX B

WASTEWATER FLOW SCHEMATICS OF NUTRIENT DISCHARGE SAMPLED POULTRY PROCESSING PLANTS

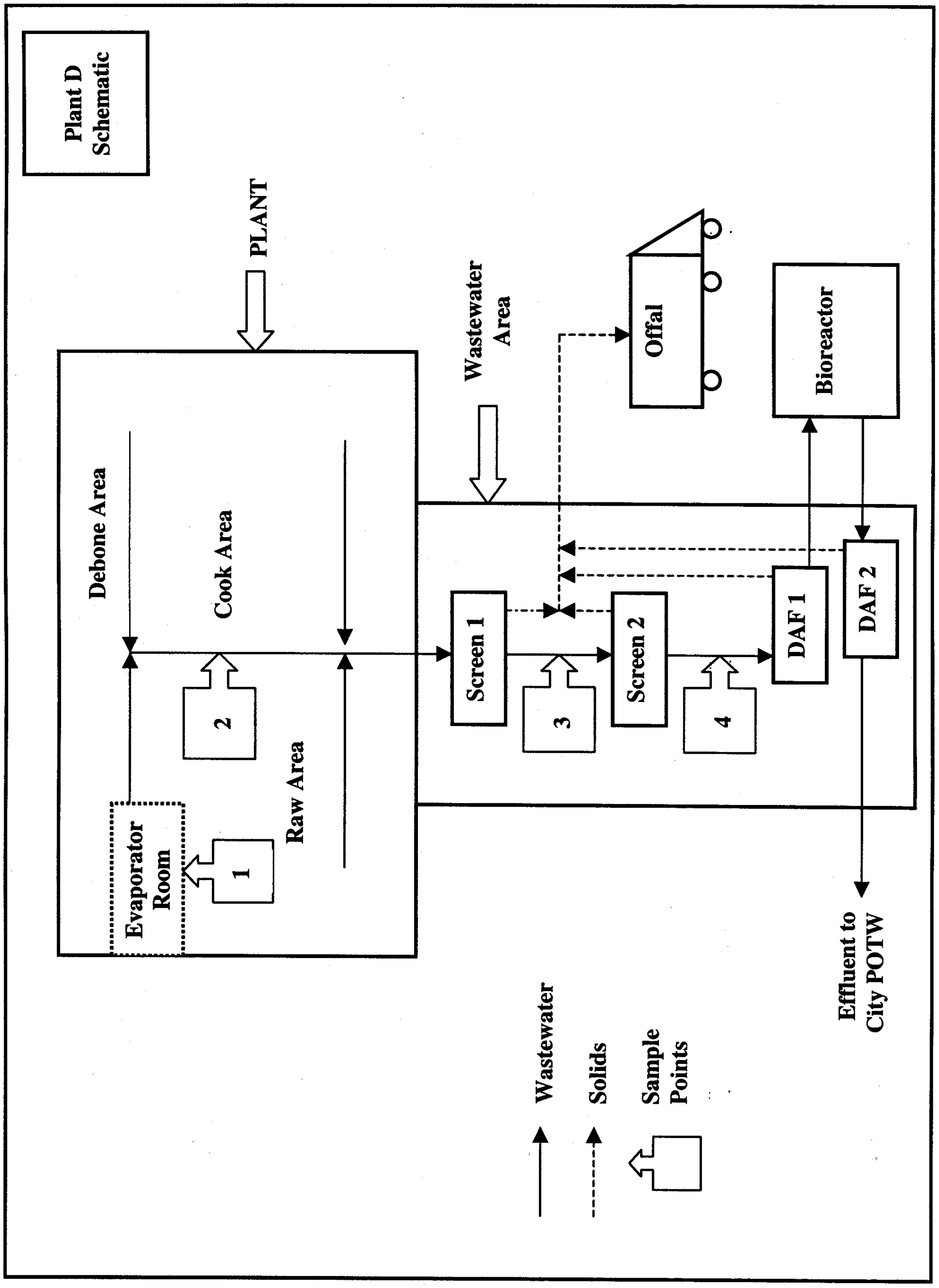


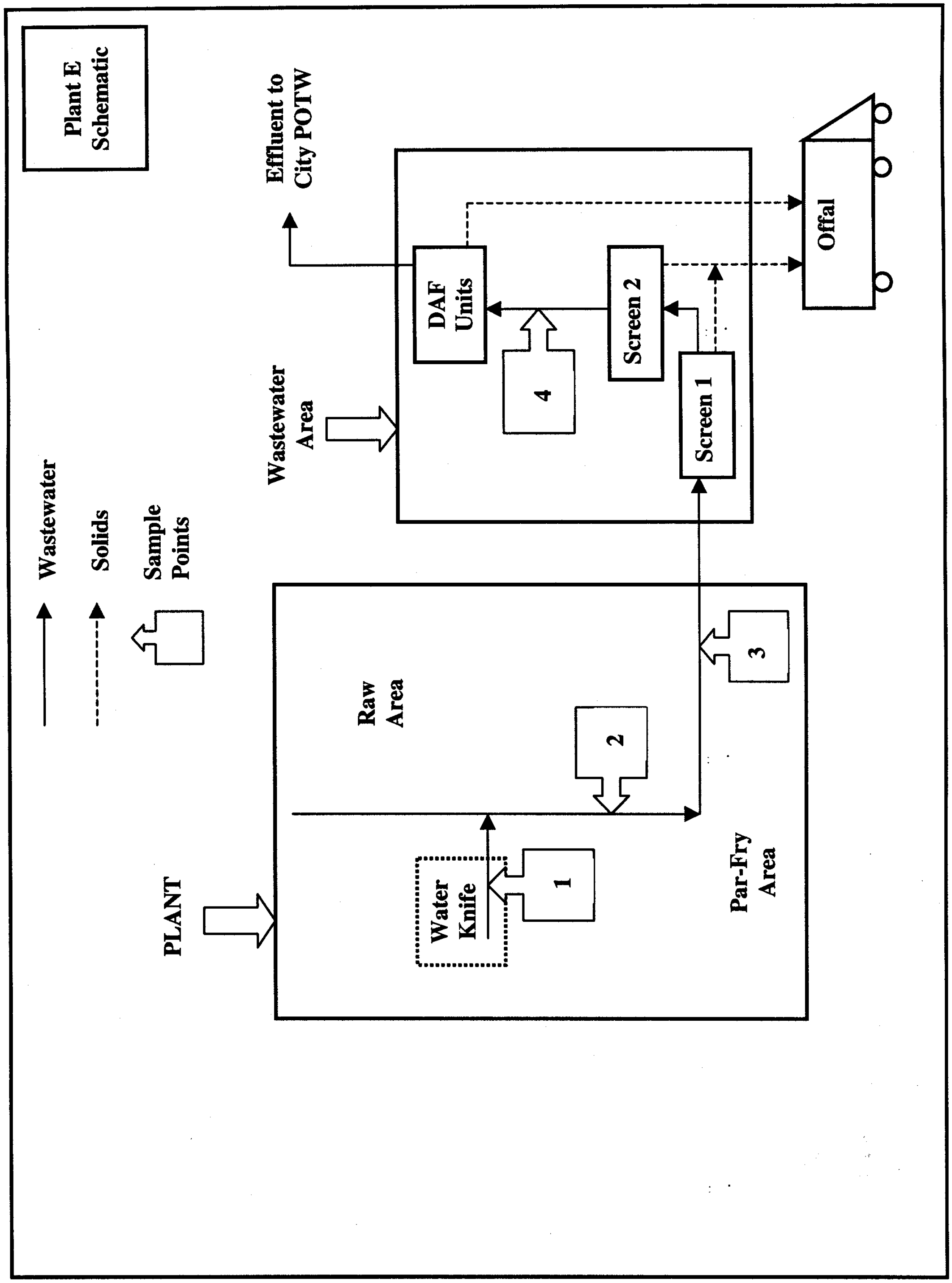
Plant A Schematic
Belt Press
Offal
Portion Recycled
DAF
EQ Basin
Screen 2
Screen 1.A
Screen 1.B
Effluent to City POTW
To Feather Flume in Plant
Feather Flume
Viscera Flume
Live Haul
1
2
3
4
Wastewater
Solids
Sample Point

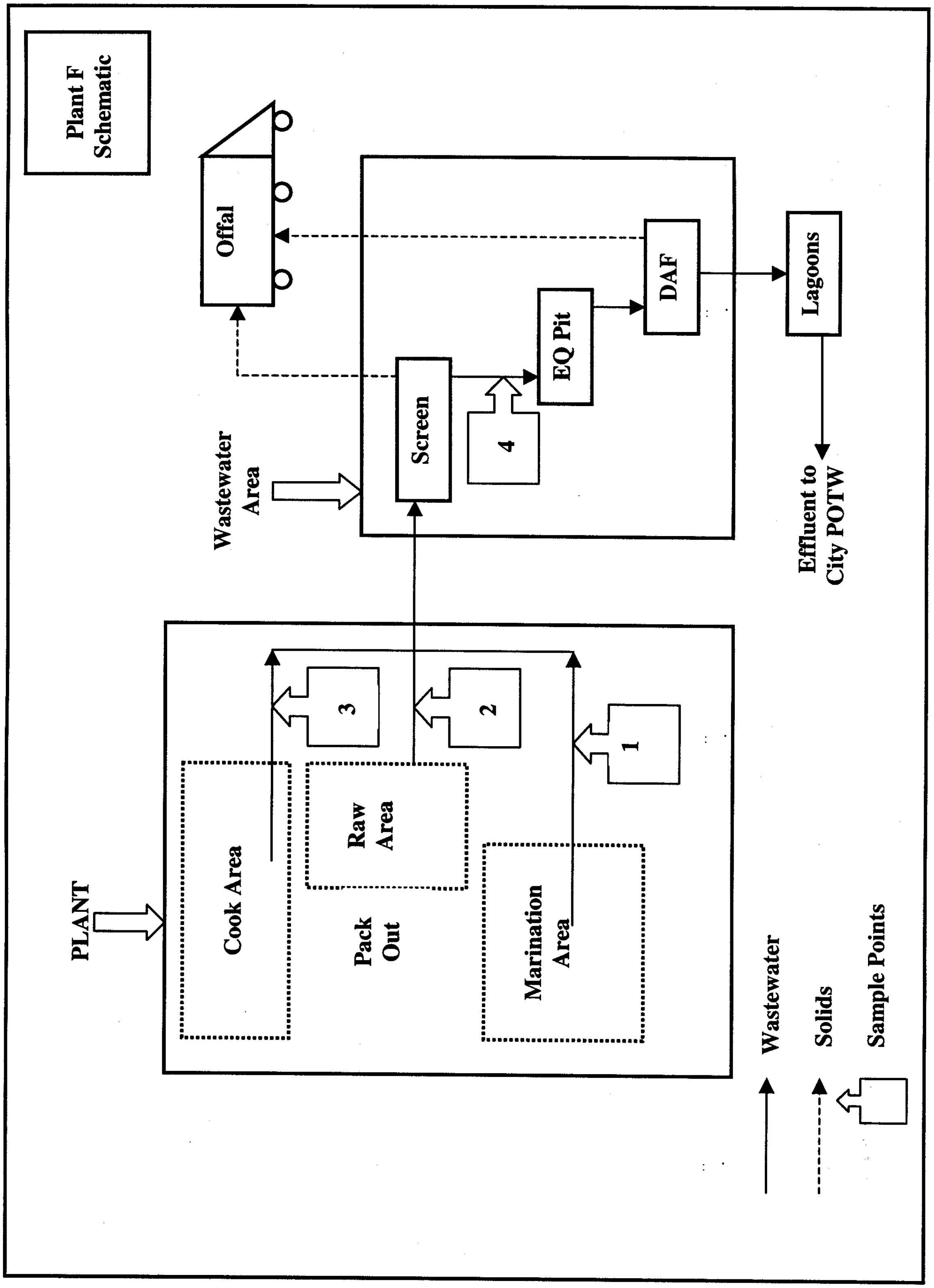

Plant B Schematic
Effluent to City POTW
Wastewater
Solids
Sample Points
DAF
Belt Press
Screen 2.B
Screen 2.A
Offal
EQ Pit
Screen 1.A
Screen 1.B
1
2
3
4
Portion recycled to feather flume
Feather Flume
Viscera Flume
Live Haul



Plant C Schematic
Feather Flume
Viscera Flume
Live Haul
Screen 1.A
Screen 1.B
1
2
3
EQ Tank
Offal
Screen 2.B
4
EQ Tank
DAF
Lagoons
Effluent to Land Application
Wastewater
Solids
Sample Points


Plant D Schematic
PLANT
Wastewater Area
Offal
Bioreactor
Debone Area
Cook Area
Raw Area
Evaporator Room
1
2
3
4
Screen 1
Screen 2
DAF 1
DAF 2
Effluent to City POTW
Wastewater
Solids
Sample Points


Plant E
Schematic
Wastewater
Solids
Sample
Points
Effluent to
City POTW
Wastewater
Area
DAF
Units
Screen 2
Screen 1
4
Offal
PLANT
Raw
Area
Water
Knife
1
2
3
Par-Fry
Area


Plant F
Schematic
Offal
Wastewater
Area
Screen
EQ Pit
DAF
Lagoons
4
Effluent to
City POTW
PLANT
Cook Area
Raw
Area
Pack
Out
Marination
Area
3
2
1
Wastewater
Solids
Sample Points