USING INNOVATIVE WATER REUSE SYSTEMS TO MEET WATER CONSERVATION GOALS IN GEORGIA'S POULTRY PROCESSING INDUSTRY

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Abstract In 2007, Georgia poultry processors slaughtered over 1.3 billion broilers (14.4% of U.S. production) in 21 processing plants across the state. Commercial broiler processing plants use an average of 6.9 gallons of potable water per bird, with most plants falling in the 5-10 gallon range. Thus in 2007 alone, Georgia poultry processors used approximately 9 billion gallons of water. Much of this water is used for scalding, chilling, bird washing, and plant sanitation. The water is also the primary means by which offal (inedible solids) is transported out of the various processing areas for collection and separation from wastewater. Recent severe drought conditions in Georgia and the adoption of the Georgia Statewide Comprehensive Water Plan (with subsequent development of the Water Conservation Implementation Plan) have placed new emphasis on water conservation by traditional industrial users. To meet these new demands while maintaining or in many cases increasing production, Georgia poultry processors have turned to innovative water reuse systems that maximize water use efficiency while maintaining strict food safety requirements. Current systems utilized by poultry processors are presented with advantages and disadvantages of each explored. A case study is presented showing the decision making process employed by the plant management team in water reuse technology selection. Results and impact of the water reuse system are also presented.

INTRODUCTION

In 2007, the USDA reported that U.S. poultry processing plants slaughtered over 9.0 billion chickens with a total live weight of 49.8 billion pounds. The state of Georgia is the nation's top-ranked poultry producer accounting for 1.3 billion chickens or 14.4 percent of U.S. production (NASS, 2008). The U.S. poultry industry has seen a phenomenal rate of growth that started in the 1940s and continues today at an annual rate of approximately five percent (Kiepper, 2003). This rapid growth rate is 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. From 1960 to 1998 the U.S. annual rate of young chickens or 'broilers' slaughtered increased 525 percent from 1.5 billion to 7.9 billion birds (Ollinger et al., 2000).

The poultry processing industry has responded to this growing demand with larger plants, faster processing line speeds, and more employees. During the past 30 years, the average slaughter plant has increased in capacity from approximately 60,000 to over 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).

However, the growing demand for more poultry products has also resulted in an ever-increasing demand for potable water by poultry processing plants. Commercial broiler processing plants use an average of 6.9 gallons of potable water per bird processed (gpb); with most plants falling in the 5-10 gpb range (Northcutt, 2003). Thus in 2007 alone, Georgia poultry processors used approximately 9 billion gallons of potable water. A typical poultry processing plant that slaughters over 200,000 birds per day can easily use 1.0-2.0 million gallons of potable water.

Traditionally, food processing industries have viewed water as an endlessly abundant and inexpensive resource. Water has been, and continues to be, used in large quantities in food processing plants for cleaning and sanitization, as a heat transfer medium in heating and cooling systems, and for transporting wastes. However since the inception of the 1972 Clean Water Act, municipal water and sewer costs have grown from under $1.00 per 1000 gallons in the 1970s to over $11.00 per 1000 gallons in some areas of Georgia today.

By 1968, the basic automated poultry slaughtering process in use today was established (Bugos, 1992). Within this highly automated system, water plays an intricate role in poultry processing most important task: food safety. Food safety can be defined as the steps taken to reduce or eliminate the potential for foodborne illness that can occur from contamination that can be introduced to a foodstuff from agricultural production to the consumer's table (Wabeck, 2002). Currently, the Hazard Analysis Critical Control Point (HACCP) and Zero Tolerance for fecal materials programs dominate food safety protocols within poultry processing plants. In addition to these programs, the USDA Food Safety and Inspection Service (FSIS) mandates *Salmonella* and *E. coli* testing requirements, and Standard Operating Procedures (SOP) for sanitation (Wabeck, 2002).

One solution the poultry processing industry has implemented to help meet these food safety mandates has been increased water consumption. Many industry experts report a 20 to 50 percent increase in water consumption at slaughter plants following the implementation of HACCP programs (Northcutt, 2003). Multiple inside-outside bird washing (IOBW) cabinets and more frequent cleanings have joined the traditional large water consumption processing functions of scalders and chiller tanks. The process steps of scalding, chilling, carcass washing, and the cleaning and sanitation of equipment and floors account for the majority of water consumed during poultry processing.

There is little published data regarding water consumption by poultry processing facilities. In 2002, Kiepper and Sellers produced a report for USPOULTRY that included survey information on water consumption from 45 U.S. broiler slaughter facilities. The average number of chickens processed daily at the surveyed plants was 205,587. The average daily water use from the same plants was 1.46 MGD. Using the traditional gpb calculation the average gallons of water used per bird processed was 7.1. The least amount of water consumed on a daily basis was 0.377 MGD by a plant processing 55,000 chickens each day (6.85 gpb), while the maximum consumption rate was 4.5 MGD by a facility processing 600,000 birds per day (7.5 gpb).

WATER SUPPLY RESTRICTIONS

In October of 2007 in response to chronic drought conditions in Georgia, Governor Sonny Perdue directed the Georgia Environmental Protection Division (EPD) to modify current surface water and groundwater withdrawal and drinking water permits to achieve a 10 percent reduction in withdrawals for permit holders in 61 North Georgia counties covered under a Level 4 drought designation. Permit holders were required to reduce water withdrawals by 10 percent compared to the permit holder's water usage of the previous winter season (beginning of December 2006 through the end of March 2007). The revised permit modifications began taking effect on November 1, 2007 and continue until further notice from EPD. The EPD intends to enforce permit restrictions and impose fines for noncompliance.

In November 2008, Dr. David Stooksbury, Georgia State Climatologist, reported that drought conditions continued to grow harsher across north Georgia, the center of the state's poultry production. Water levels in reservoirs and streams were at or near record lows across most of the state. Lake Lanier, which serves as a primary water source for metro Atlanta, was at a record low for mid-November. Other Georgia lakes (Hartwell, Russell and Clarks Hill) in the Savannah River basin were also at record low levels. Stooksbury reported that even with normal seasonal rains, it's was doubtful that Lanier, Hartwell, Russell or Clarks Hill lakes would fully recover over the ensuing winter.

Major rivers that were at record low flows for mid-November included the Etowah River at Canton, the Chattahoochee River near Cornelia, Chestatee River near Dahlonega, the Middle Oconee River at Athens, the Broad River near Bell, the Little River near Washington, the Oconee River at Dublin and the Altamaha River near Baxley. Because of the extremely low stream flows, many counties in north Georgia had their drought level classifications changed to a more intense level. Exceptional drought (the most severe drought level) were set for counties north and east of a line running through Lincoln, Wilkes, Olgethorpe, Oconee, Barrow, Gwinnett, Hall, Forsyth, Cherokee, Pickens, Gilmer and Fannin counties. This region includes many major poultry production areas.

Extreme drought conditions were declared in Columbia, Richmond, McDuffie, Glascock, Taliaferro, Warren, Hancock, Greene, Morgan, Walton, Gwinnett, north Fulton and Cherokee counties (Stooksbury, 2008).

GEORGIA'S STATEWIDE WATER PLAN

In January, 2008, the Georgia state legislature ratified the Georgia Comprehensive State-wide Water Plan (GCSWP). As stated in the plan, Georgia's current approach to water management has evolved in a piecemeal fashion over several decades, mainly through reactions to federal legislative mandates and localized and immediate water issues such as droughts. However, as the population and economy of the state grow and the demands on water resources increase, a comprehensive approach to water management is necessary.

The purpose of this plan is to guide Georgia in managing water resources in a sustainable manner to support the state's economy, to protect public health and natural systems, and to enhance the quality of life for all citizens. The plan lays out statewide policies, management practices, and guidance for regional water basin-based planning. The provisions of this plan are intended to guide river basin and aquifer management plans and regional water planning efforts statewide in a manner consistent with current EPD regulations (EPD, 2008a).

Subsequent to the GCSWP, in December 2008, the EPD released for public comment the draft of the state's Water Conservation Implementation Plan (WCIP). The goal of the WCIP is to provide guidance to assist Georgia's 7 major water use sectors effectively implement water conservation state-wide. The major water use sectors include: agricultural irrigation, electric generation, golf courses, industrial/commercial, landscape irrigation, domestic/non-industrial public uses, and state agencies.

Each sector-specific chapter of the WCIP details water conservation goals, benchmarks, best practices and implementation actions designed to reduce water waste, water loss, and, where necessary, water use. The goals are presented as aspirations for water use and efficiency, and should help guide water users no matter how much investment has previously been made in conservation efforts (EPD, 2008b).

The institution of the GCSWP and WCIP, along with sustained drought conditions in Georgia has led many poultry processors to explore alternative methods of sustaining current production levels while reducing their demand for potable water.

INDUSTRIAL WATER REUSE

To accomplish water conservation goals, poultry processors typically employ traditional water conservation practices. These traditional practices include reducing in-pipe water pressure to isolated areas or the entire plant, reevaluating and optimizing dry cleanup procedures, and replacing high volume with new engineered high-pressure, low-flow (HPLF) nozzles.

Once these traditional water conservation practices are implemented and optimized, poultry processors are often faced with the need to further reduce water use. In response to this demand, poultry processors are utilizing water reuse systems. Industrial Water Reuse (IWR) can be defined as the capture and reutilization of water within industrial processes with the intent of reducing total water use or increasing production while maintaining current water use levels.

The 3 general types of IWR are water reuse with no treatment, water reuse with limited or targeted treatment, and water reuse with advance or full treatment. In IWR systems with no treatment, water used for one plant operation is able to subsequently be used of another operation without any treatment measures being utilized. Although not common in food processing plants, these systems are sometimes applicable for non-contact applications (i.e. water does not contact food) (Metcalf and Eddy, 2007).

The most popular form of IWR is limited or targeted treatment. These IWR systems are often referred to as reclamation or regeneration. Targeted treatment means that single or multiple points of water flow are isolated and collected for treatment and reuse in a facility. The type and level of treatment is dictated by the intended end use of the reclaimed water. Typical single-point to single-point applications in poultry processing facilities are systems that collect effluent from chillers, reconditioned that water and it is reutilized in the chiller again. A typical multiple-point to multiple-point application would be a system that collects chiller and IOBW effluent to be reconditioned and utilized in the upstream scalder and feather picking operations (Mann and Liu, 1999).

The final IWR systems are advanced or full treatment in which the entire effluent from a poultry processing plant is captured, treated and reutilized by the plant as a potable water source. These systems are often referred to as zero liquid discharge or ZLD. These systems are by nature the most capital intensive to construct and maintain and are restrictive in that all water must be treated to potable water standards regardless of intended reuse (Mann and Liu, 1999; Metcalf and Eddy, 2007).

The major water reuse concerns for any type of system are cross-contamination of pathogenic organisms, corrosion of infrastructure, scaling deposits, biological fouling, and the accumulation of persistent wastewater constituents.

CASE STUDY

Mar-Jac Poultry, Inc., located in Gainesville, Georgia is the 20th ranked broiler integrator company in the U.S. producing a weekly average of 7.2 million pounds of RTC (Ready-to-Cook) product. Mar-Jac slaughters an average of 2 million broilers per week at an average live weight of 4.4 lbs per bird (Thornton, 2008). Once primary processing is complete, 80 percent of the whole carcasses are cut-up for foodservice and institutional customers. Thirty (30) percent of the cut-up product is then deboned. The average weekly production rates for Mar-Jac during 2006 and 2007 are shown in Table 1.

Table 1. Mar-Jac Production Rates

Weekly Average	*2006*	*2007*	*Increase*
No. of Birds	1.85 Million	2.00 Million	8.1%
Live Wt. Lbs.	7.95 Million	8.80 Million	10.7%
RTC Lbs.	6.36 Million	7.20 Million	13.2%

In 2002, Mar-Jac embarked on a comprehensive water conservation plan with the primary objective of reducing the overall potable water used within the plant. The first task completed was a water audit which established baseline values for water use in all the major operations areas of the facility. Similar to most poultry slaughter plants, Mar-Jac found the greatest water use occurred from in the operations starting with scalding and ending when carcasses exit the chiller. In particular, the wide array of carcass washes and rinses on both equipment and carcasses as well as the many IOBWs (inside, outside bird washers) were water use intensive.

Mar-Jac's water conservation team determined that the most efficient and timely approach to water use reduction would be to concentrate efforts in these areas. Initial water conservation efforts included replacing current nozzles on spray guns and spray cabinets with nozzles with more restrictive orifices, adding water flow restrictor plates on goosenecks and shower heads, instituting new dry cleaning procedures, and reducing overall plant water pressure. These initial water conservation efforts resulted in water use at the facility decreasing from over 5 GPB to 3.9 GPB.

The water conservation team then decided to begin exploring water reuse as a subsequent step to reduce potable water use. The team established their first objective of deciding between pursuing full treatment (i.e. total plant water, end-of-pipe, zero discharge) reuse systems versus partial treatment (i.e. single-point, multiple-point, specific internal plant flows) reuse systems.

Although closed-loop full treatment systems offered the greatest reduction in potable water demand and produced the greatest reuse water volumes, Mar-Jac found that these systems required a relative high capital investment and the team had specific concerns about the possible buildup of potential contaminants in the system over time. Conversely the team found that partial treatment systems where less expensive to install and maintain, provided the opportunity to treat water only to the level required for the end use, and allowed the team greater flexibility in reaching their water conservation goals. Thus, the Mar-Jac team made the decision to embark on what they refer to as a "piecemeal" approach versus the "all-in-one" option.

Initial investigations revealed the water resulting from the IOBWs and overflow from the plant's pre-chillers were the optimum locations to capture water for reuse due to the ease of recovery and volume of relatively clean water produced in these areas. Mar-Jac began by recovering water from one IOBW and the overflow from one pre-chiller. This allowed Mar-Jac staff to focus data collection for food safety testing in a limited area at a minimum expense in equipment.

Once it was determined that these initial systems met both the requirements for water reuse quality and food safety standards, all 3 of the facility's IOBWs and both pre-chillers were scheduled to receive water reuse systems. The installation of the 5 systems took place over several months. This allowed for equipment to be purchased as needed and allowed time for equipment re-alignment to make room for the new system components. This "piecemeal" approach also had the additional benefit of allowing each system to be tested independently.

The recovery phase of the water reuse systems is accomplished using sets of internal-rotary horizontal screens in series with static-vertical fine-screen filters designed to remove solids. Mar-Jac purchased the internal rotary screens from an outside vendor and manufactured their own vertical filters in-house.

The rotary screens work much like traditional offal (i.e. inedible poultry by-products) recovery screens in which water enters a horizontal rotating drum that allows the screened water to fall through to perforated surface the bottom of the cabinet where it is pumped to the next filter. The captured solids are augered out the back of the drum and conveyed to offal.

The horizontal filters are cleaned on a continuous basis using high pressure backwash sprays mounted in the drum cabinets. The vertical filters are cleaned at shift change and lunch breaks manually by pulling the screen out and rinsing it with high pressure water. The vertical filters can also be automatically backwashed in place. Both screening systems are broken down during the daily sanitation shift for a more thorough cleaning.

The screens use expanded metal mesh with 200-250 micron (~0.008-0.010 inch) gap openings. Once the recovered water passes through the series of filers it is pumped to a centralized recirculation tank. Gaseous chlorine is injected into the recirculation tank for disinfection. Reclaimed water is then pumped to a common manifold where water is sent to multiple plant locations for reuse. All pumps are equipped with pressure/backflow valves.

One pump is dedicated to this gaseous chlorine injection feed line to ensure continuous flow and pressure to the chlorinator. Mar-Jac believes that the use of gaseous chlorine has produced the added benefit of lowering the pH in the reclaimed water to about 6.8, which aids in the disinfection process.

During the testing phase as each new unit of the reuse system was installed, influent and reclaim/chlorination effluent water samples were tested for Total Plate Count (TPC), *E. coli* Count (ECC), *Salmonella* presence, and solids content (Total Suspended Solids or TSS).

This initial testing was conducted for a period of 3 to 4 weeks prior to bringing the filter system "on-line" and using the reclaimed water. Data shows that TPCs are routinely less than 300 cfu/ml, ECC is routinely <10, *Salmonella* is absent, and TSS is routinely <25 ppm during the setup phase for each set of screens.

Once it was established that a set of screens met USDA food safety guidelines, the testing was reduced to *E. coli* counts and *Salmonella* presence on a daily basis on both production shifts. While this level of testing was more than required and did increase the probability of not meeting the guidelines, the Mar-Jac team believed it was necessary to build a history that justified not including this process as a critical control point (CCP) in the plant's HACCP plan.

The overall data collection design and goal of the testing was to show a statistically significant reduction in both TPC and *E. coli* to drive the argument that the reclaimed water posed no significant food safety risk. *Salmonella* presence or absence was treated as a percentage of samples positive for the purposes of before and after comparisons.

As summarized in Table 2, the water reuse systems installed at Mar-Jac have resulted in reduced water use from 3.90 to 2.85 GPB. This reduction equates to a savings of $86,384 when compared to the projected costs in 2008 using 3.9 GPB. This savings is based upon a cost per thousand gallons of $9.50. However, Mar-Jac's water costs have recently increased to $10.198/Kgal, so additional cost saving continue to accumulate.

Table 2. Fiscal Impact of Water Reuse Systems at Mar-Jac, Inc, Gainesville, Georgia

	Birds/ Month	*Gal/ Bird*	*Gal/ Month*	*Water Cost/ Month*
2002 (actual)	7.144 Million	3.90	27.86 Million	$160,215
2008 (@3.9 GPB)	8.660 Million	3.90	33.77 Million	$320,853
2008 (actual)	8.660 Million	2.85	24.68 Million	$234,469
Savings	-	1.05	9.09 Million	$ 86,384

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