Water Reuse and Pathogen Reduction
Part of the Solution or Part of the Problem?

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The Role of Process Water in Pathogen Reduction

The USDA's Pathogen Reduction/Hazard Analysis and Critical Control Point (HACCP) rule in July of 1996 required all meat and poultry slaughter plants to adopt a system of process controls to prevent food safety hazards. It contained four components: standard operating procedures (SOPs) for sanitation, HACCP plans, generic *E. coli* testing and *Salmonella* performance standards. With the implementation of this new rule, poultry processors quickly recognized that compliance would mean using more water, a lot more water.

Under the new HACCP rule, establishments were required to conduct generic *E. coli* testing to verify that process control systems are working as intended to prevent fecal contamination. Prior to the new rule the immersion chiller had been considered the primary means of pathogen reduction in the slaughter process. Afterwards, the pre-chill rinse cabinets were found to be an important key to compliance. Processors discovered very quickly that high volumes of pressurized water could physically rinse contaminants off the surface of the birds. At that point, the challenge became one of how to balance food safety with water conservation and still stay in business.

Also as part of the new rule FSIS set *Salmonella* performance standards to verify whether or not HACCP systems are effective in controlling contamination. These standards are based on post chiller sampling. Suddenly it was essential that the microbial load entering the chiller system be reduced as much as possible pre-chiller to provide a better opportunity for antimicrobials in the chiller to perform. The water used in the birdwashers, potable water with no chlorine demand, proved to be an excellent medium for the delivery of these antimicrobial agents.

As more fresh, chlorinated water came into contact with carcasses the contact time for antimicrobial agents such as chlorine, which require balanced CT values (concentration x time) for maximized disinfection, could be enhanced to improve disinfection levels. The down side was that water usage increased in some poultry plants by more than 50%, which immediately taxed, and in some cases overwhelmed, the existing water utility infrastructure.

USDA/FSIS acknowledged that more water was indeed a valid response to Zero Tolerance and began to consider extensive water reuse in the poultry industry for the first time. On October 20, 1999 the USDA released the Sanitation Performance Standards in the form of CFR 416.2. As a part of that document water reuse was addressed. Section (g)(3) states, "Water, ice, and solutions used to chill or wash raw product may be reused for the same purpose provided that measures are taken to reduce physical, chemical, and microbiological contamination so as to prevent contamination or adulteration of product."

This statement was considered to be ambiguous and created a tremendous number of questions from the poultry industry. In an effort to answer those questions the FSIS Technical Center issued the Water, Ice and Solutions Reuse Guidelines in January of 2000. The main intent was to create a set of guidelines that allowed for safe water reuse by providing a guideline to treatment with a published, measurable, repeatable standard. The guidelines relied upon a specific set of parameters and a series of "failsafe" mechanisms that are based on the National Primary Drinking Water Regulations of the Safe Drinking Act.

A Shift in Thinking Evolves Into a Change in Standards

In the past, water reuse had primarily been relegated to non-product contact applications such as vacuum pump cooling water, feather flume flushing, dock washing, etc. The ability to use reconditioned water for direct product contact changed the poultry industry's perception of reuse. The issuance of the USDA Sanitation Performance Standards, CFR 416.2(g), and the USDA/FSIS Water, Ice and Solutions Reuse Guidelines, effective date January 26, 2000, started the evolution of this change in thinking about water usage and water conservation. Under these guidelines poultry processors would now be allowed to utilize properly reconditioned water for direct product contact.

This update in standards provided a vehicle for the development of reuse systems that currently have the ability to reduce total water intake and discharge by more than 50% at most plants while providing pathogen free water that can safely be reused anywhere in the slaughter process to replace potable water. The guidelines have in effect allowed water to become an asset to the poultry processor instead of a detriment.

Over time CFR 416.2 (g) has been reinterpreted by some to mean that potable water can be replaced with water that does not meet any of the Water, Ice and Solutions Reuse Guidelines as long as it meets CFR 416.2(g). If the CFR is liberally interpreted, as written, that is true. Water from inside outside birdwashes and final rinse cabinets, after minimal treatment to "reduce physical, chemical and microbiological contamination" is now being reused upstream in the slaughter process to replace potable water. The door has been opened for the reuse of pathogen-laden reuse water on chicken carcasses. The short-term economic incentives for capturing a source of low-cost water are very attractive; however, the use of insufficiently treated reuse water carries important risks to processors as discussed below.

Has This Shift Gone Too Far?

A recent study by Scott M. Russell, Ph. D. at the University of Georgia demonstrated a significant level of cross-contamination risk with the reuse of pathogen-laden water. Dr. Russell states, "there is a clear danger to using process waters that have not been thoroughly disinfected. One of the primary purposes of process water is the physical removal of pathogens from the carcass. When pathogenic bacteria, such as *Salmonella*, are rinsed or washed from contaminated carcasses, the process water itself becomes contaminated. Even when steps are taken to reduce the contamination, treated process waters that contain any level of pathogens create a risk of cross-contamination when reintroduced upstream. In fact, 38 of 80 test birds were cross contaminated from 10 *Salmonella* tainted carcasses using a model of this type of reuse." (1)

The Importance of the Turbidity Measure in Reuse Water

A number of studies have been conducted related to the effect that turbidity has on chlorine efficiency. These studies have clearly demonstrated that, assuming a constant chlorine dose, an increase in turbidity from 1 NTU (Nephelometric Turbidity Units) to 10 NTU will result in an eightfold decrease in efficiency of disinfection. During one test coliforms in high turbidity water (13 NTU) were reduced to 20% of the initial count whereas coliforms in low turbidity water (1.5 NTU) were undetectable (2).

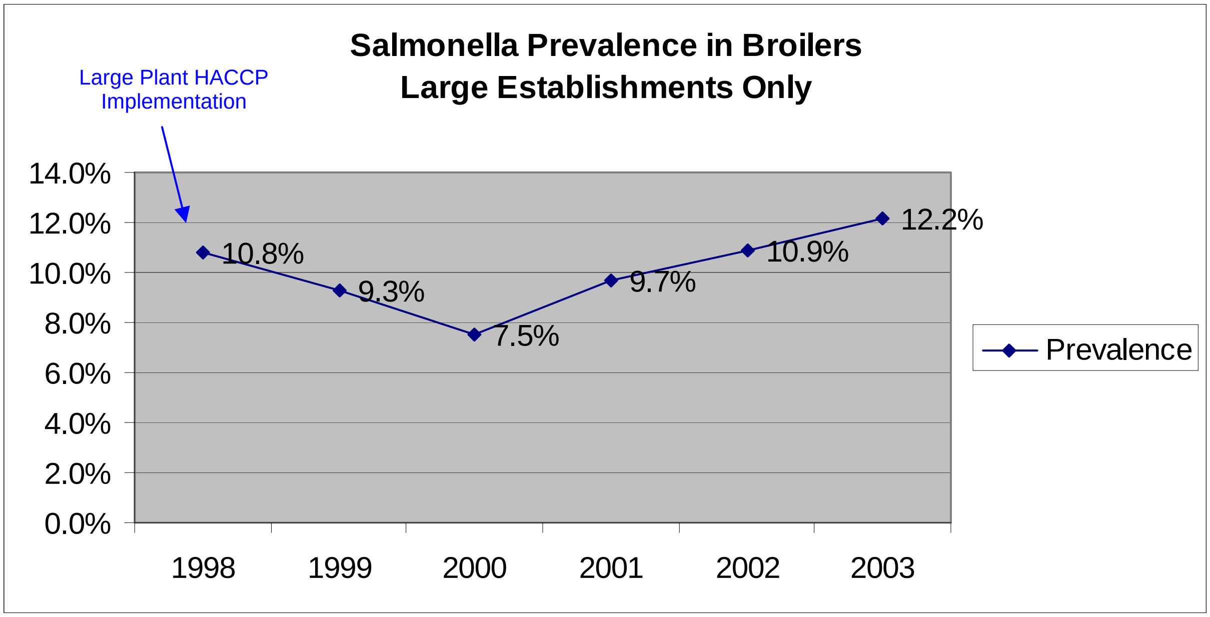
In a number of studies, turbid water samples were examined in an attempt to determine factors, which aid bacteria in surviving exposure to chlorine. Scanning electron photomicrographs demonstrated that some bacteria were either embedded in turbidity particles or appeared to be coated with amorphous material or both. Blending of chlorinated turbid water actually increased the number of standard plate count bacteria by as much as five times, indicating the physical separation of cells attached to common particles. If bacteria are embedded in suspended particles and chlorine is not able to come into contact with them, they will survive the disinfection process. This concept of bacterial attachment to solids has been well documented (3,4,5,6).

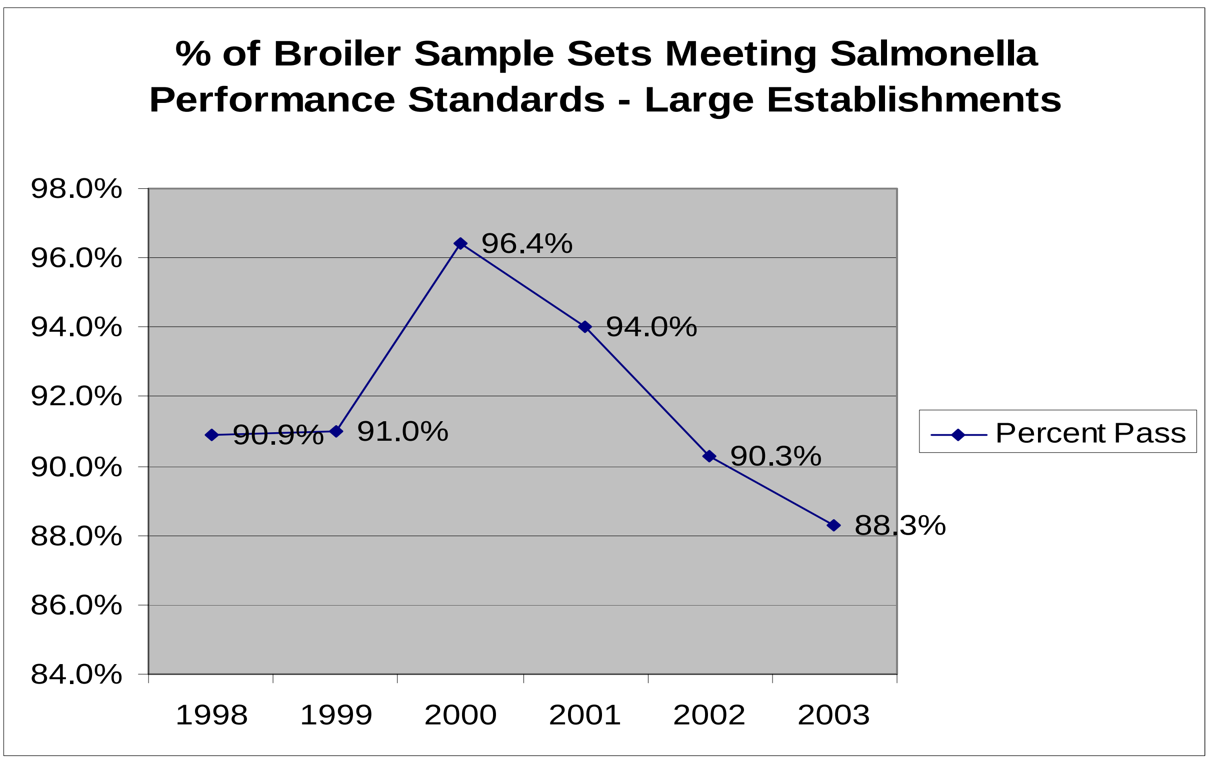
In summary, turbidity is an important indicator of potential problems with the disinfection process. The fact that bacteria can actually embed themselves in particles of material so that they are protected from chlorine is a core justification for the reduction of turbidity in reuse water as part of the reuse treatment process. If prior to reuse, process water has not been treated in accordance with USDA Water, Ice and Solutions Reuse Guidelines, which includes specific turbidity and pathogen levels, the potential for cross contaminating product is very real. Based on known science, reuse water should not be used to replace potable water in the slaughter process unless it has been thoroughly disinfected. High turbidity is an indicator that pathogens may exist in the water. The use of high turbidity reuse water from evisceration through final rinse poses significant risks to poultry processors.

USDA Progress Report on *Salmonella* Testing

In August of 2004 the USDA released "Progress Report on *Salmonella* Testing of Raw Meat and Poultry Products, 1998-2003", (Jan. 26, 1998 was the start of large plant HACCP programs). The results, for the poultry industry, were disconcerting to say the least. " While the regulatory prevalence of *Salmonella* across all seven product categories (broilers, market hogs, cows/bulls, steer/heifer, ground beef, ground chicken and ground turkey) continued to decrease in 2003, FSIS is concerned that the percentage of positive *Salmonella* tests (all sizes of establishments combined) increased slightly in all three poultry categories."

The graphs below, which represent the large broiler plants, show an increase in *Salmonella* prevalence that is currently even higher than pre-HACCP.


Salmonella Prevalence in Broilers
Large Establishments Only
Large Plant HACCP Implementation
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
10.8%
9.3%
7.5%
9.7%
10.9%
12.2%
1998
1999
2000
2001
2002
2003
Prevalence


% of Broiler Sample Sets Meeting Salmonella Performance Standards - Large Establishments
98.0%
96.0%
94.0%
92.0%
90.0%
88.0%
86.0%
84.0%
90.9%
91.0%
96.4%
94.0%
90.3%
88.3%
1998
1999
2000
2001
2002
2003
Percent Pass

Is the reuse of water that does not meet USDA Water, Ice and Solutions Reuse Guidelines the primary reason for this increase in Salmonella? Probably not. Is it a contributing factor? Very possibly. As shown in the University of Georgia study, there is a 48% chance of microbiological cross-contamination from reuse water that is not pathogen free (1).

If water from a birdwasher is merely screened, coarsely filtered and transferred upstream to another application point the maximum amount of contact time would conservatively be 60 seconds. This amount of time versus the concentration (CT value) of chlorine allowed (50 ppm maximum) is not sufficient to allow for total disinfection of water of this quality.

Treated to USDA Reuse Guidelines		Screened and Coarsely Filtered
NTU = 2.3		NTU = 85
COD = 53		COD = 331
TSS = 3		TSS = 84
FOG = 6		FOG = 77

OSHA

There is a genuine concern that reconditioned water that is used in the slaughter process that has not at minimum been reconditioned to be pathogen free may be in violation of Occupational Safety and Health Standards, 29 CFR 1910.141(b)(2)(iii) as stated below:

"Nonpotable water shall not be used for washing any portion of the person, cooking or eating utensils, or clothing. Nonpotable water may be used for cleaning work premises, other than food processing and preparation premises and personal service rooms: Provided that this nonpotable water does not contain concentrations of chemicals, fecal coliform, or other substances which could create unsanitary conditions or be harmful to employees."

Water Reuse Systems Designed to Treat Water to USDA Guidelines

Water reuse systems that are designed to recondition water to meet or exceed USDA Water, Ice and Solutions Reuse Guidelines for poultry processing plants are divided primarily into three types. These types are differentiated by water collection points, degree of treatment prior to reconditioning for reuse and USDA guidelines for reuse for direct product contact.

- **Type A**- This type of system collects water directly from individual sources inside the plant prior to being combined with other process water. These sources are considered to be raw water and have had no treatment prior to reconditioning for reuse. The fact that they are segregated and specifically identified allows them to be reconditioned through this process. Optimally the water sources selected for reconditioning in this type of system are among the cleanest in the poultry processing operation. These sources typically include the water from birdwashes and final rinses as well as other low load, higher volume water sources. Its limitation is that some plants need to reuse more water than is economically collectable with this type of system.

- **Type B**- This type of system is more inclusive in the water sources that are considered for reuse. This water can be collected further downstream in the process. This water is typically collected after pre-treatment through a dissolved air flotation system. Water for this type of system can contain no sanitation chemicals so proper process control and some physical separation is required for water that is collected to be treated. Much larger volumes are available for reuse with a Type B system as compared to a Type A system.

Both types of water reuse systems described above have basic similarities. The water targeted for reuse is:

1. Collected
2. Screened
3. Chemically treated (GRAS chemicals) for the removal of smaller suspended or emulsified solids
4. Passed through an air induced flotation system (solids removal)
5. Filtered to remove micron size particles (turbidity reduction)
6. Disinfected (pathogen removal)
6. Chlorinated (1 PPM) to prevent re-growth of microorganisms.
7. Stored and returned at a specific pressure and flow rate

Both of the systems described above fall under the same USDA reuse water guidelines:

Total Plate Count	500 cfu/mL or less
Total Coliform	Zero
Fecal Coliform	Zero
Turbidity	5 NTU or less

- **End of Pipe System: Type C** – This type of system collects water that has been biologically treated for direct discharge or land application (spray fields). Proper biological treatment removes dissolved organic material. This insures that the resulting water provided for reconditioning can be effectively treated to the guidelines listed below so that it can be utilized for direct product contact applications. This type of system also provides large volumes of water for reuse that can be collected from one source. The USDA guidelines for reuse water produced by this type of system are however more stringent than those listed for Types A and B as summarized below:

Total Aerobic Plate Count	500 cfu/mL or less
Total Coliform	Zero
E. coli	Zero
Total Organic Carbon (TOC)	100 mg/L or less
Turbidity	No more than 5% of samples analyzed can be greater than 1 NTU, by EPA nephelometry method or equivalent method No samples can be greater than 5 ntu
Heavy Metals	The reuse water should be tested for heavy metals a least once a year and meet the appropriate EPA Maximum Contaminant Levels (MCL's).
Potable Rinse	A final potable water rinse should be applied to any edible product and any equipment that contacts reuse water.
Human Waste	The establishment's advanced wastewater treatment system must not be treating human waste. Human waste must be kept separate from plant waste and not commingled at the advanced wastewater treatment facility

The water targeted for reuse from a Type C water reuse system as described above is:

1. Collected
2. Clarified (if required)
3. Chemically treated (GRAS chemicals) for the removal of smaller suspended or emulsified solids
4. Passed through an air induce flotation system (solids removal)
5. Filtered to remove micron size particles (turbidity reduction)
6. Disinfected (pathogen removal)
7. Chlorinated (1 PPM) to prevent re-growth of microorganisms.

8. Stored and returned at a specific pressure and flow rate

Reuse System Fail-Safe Design Features for Added Security

Similar in nature to municipal water treatment plants, the design and sequence of processes in all three types of water reuse systems mentioned above helps to insure that the maximum amount of suspended and dissolved material has been removed from the reconditioned water. This is essential in the effort to insure that the reconditioned water is pathogen free. Any particulate matter that remains in the reconditioned water would generate turbidity and could very possibly shield pathogens from chemical and physical disinfection. Suspended matter remaining in the reconditioned water would make it virtually impossible to guarantee complete disinfection.

Every one of the water reuse systems listed above employs failsafe features, which ensure that only water that has been completely disinfected is returned to the processing facility.

Turbidity – Each of the systems have been designed to monitor turbidity levels at several critical points in the process. If the turbidity of the reconditioned water is out of specification, the system has been designed to automatically shift into recirculation mode and stop sending water to the plant. In recirculation mode, the water will recirculate through the system until the turbidity limit has been satisfied. Once the turbidity limit has been satisfied the system leaves recirculation mode and returns to production mode. During recirculation mode, either stored reconditioned water or available municipal or well water will be used by the poultry plant processes until the water reuse system is back on line.

ORP – Each of the systems are provided with automated monitoring of Oxidation Reduction Potential (ORP), which is a measure of oxidizer in solution. To insure consistent disinfection, the systems are designed to maintain a specific ORP setpoint. If the ORP fails for any reason to reach setpoint, the reuse system will automatically switch to the recirculation mode until the ORP set-point has been achieved.

Case Studies

Plant I

This facility utilizes a Type A system as described above. This reuse plant has returned pathogen free water for direct product contact for over 5 years. Table 1 shows the sequential removal of contaminants from the water that allows for maximum efficiency of disinfection. Historical data in the plant showed a trend toward a direct reduction of pathogens related to the introduction of reuse water back into the process. Further testing has confirmed that the lower incidence rates are directly related to the addition of reuse water back into the process.

Plant II

This facility utilizes a Type C reuse system as described above. The water is collected from the point of permitted discharge. This reuse system has been on line for two years and the processing plant has acquired over 50% of its water requirements from the reuse water plant, thus reducing municipal water costs by a corresponding amount. This facility recently completed a set of USDA pathogen tests with extremely low incidence rates. The pathogen free reuse water delivered at constant pressure has been credited as a major contributor to the success of the plant's pathogen intervention program.

Table 1

	Plant I		**Plant II**	
Unit Operation	**TSS PPM**	**COD PPM**	**TSS PPM**	**COD PPM**
After Screening	100	75	1000	1000
After DAF	50	50	100	100
After Biological Treatment	N/A	N/A	100	40
After Primary Filtration	10	25	5	40
After Secondary Filtration	5	25	2	40
After Oxidation	5	20	2	30

The contaminant reductions are shown in Table 1. Note that Plant II shows a higher initial load than Plant I, but finished water quality is slightly better.

Conclusions

Reuse water can be a very effective tool for the efficient management of water in a poultry processing plant. Reconditioned water that meets USDA Water, Ice and Solutions Reuse Guidelines, that is low in turbidity and pathogen free, delivered at a constant pressure, with the appropriate fail-safes, has been proven over the last five years to be equal to or better than municipal or well water in reducing pathogens in poultry processing operations. Additionally, the ability to use more water on the evisceration line, as opposed to less water, allows for the maximization of contact time for water delivered antimicrobial agents such as chlorine. This provides more consistent removal of surface contaminants and more effective pathogen reduction.

On the other hand, research has demonstrated the increased risk of cross-contamination of chicken carcasses treated with pathogen-laden water. The use of insufficiently treated reuse water, especially in evisceration and rinse cabinets, pose significant product quality risks to poultry processors.

Water reuse in itself is an important intervention step in pathogen reduction in poultry processing plants as it allows plants to more thoroughly clean the product before introduction to the chiller tank. This can and is being done today with water reuse systems that comply with both CFR 416.2(g) and the USDA Water, Ice and Solutions Reuse Guidelines. Such water reuse systems are cost effective, have a positive impact on food safety and help to insure a safer worker environment.

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