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Project Summary

Multiple Water Reuse in Poultry Processing: Case Study in Egypt

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An industrial-scale multiple water reuse system was investigated for three years at a modern poultry processing plant in Alexandria, Egypt.

The system involved chlorination of cooling water from compressors and its successive reuse as feed water for the chiller, prechiller, washer and finally for makeup in the scalder. In all four units poultry carcasses are immersed in water.

Process waters in the prechiller and washer were purified alternatively by a pressure leaf filter.

Response-surface analysis demonstrated variable interacting effects of water rate, chlorine dosage and process time on the chemical and bacterial qualities of the processed carcasses, and water used in the immersion processes. Models were developed for prediction of the effect of operating conditions on poultry quality.

Long-term studies at the plant indicated that successive utilization of prechlorinated water in a multiple system did not result in significant buildup of contaminants (total and coliform counts) and organic pollutants (grease, nitrogen compounds, BOD and COD) in the immersion tanks.

The bacterial quality of the carcasses processed by the multiple reuse water was superior to the quality of the typical system which utilizes prodigious quantities of potable water in a once-through feed system without filtration and chlorination.

Filtration, when incorporated with the multiple system, enhanced the water and carcass quality with progressive elimination of the organic contaminants which would interfere with chlorination.

The study demonstrated a potential for substantial saving in water—an expensive commodity in arid areas of Egypt—through application of this multiple reuse system.

The conclusions and recommendations of this report are not directly applicable to poultry processing plants in the United States, since water use in those plants is regulated by the U.S. Department of Agriculture.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In Egypt, water supplies are limited for new poultry processing plants. The need for large quantities of processing water has forced the industry to develop water reuse systems.

In April 1976, a four-year joint project between Alexandria University and the United States Environmental Protection Agency (EPA) was initiated to develop, install, and evaluate a multiple reuse system at the Alexandria Poultry Processing Plant (APPP).

Conclusions

The following conclusions were drawn from this field investigation:

1. Multiple water reuse is a practical and viable option to conserve water

in poultry processing in Alexandria, Egypt.
2. Chlorination and filtration of the reused water were effective in reducing accumulation of pollutants and contaminants of the immersion water. The total aerobic and coliform counts of the carcasses were appreciably lower than those counts associated with carcasses treated in the normal once-through system, without chlorination.
3. In the Alexandria plant, optimum operation conditions for the multiple reuse system were achieved by using a water makeup rate of 20 m^3/d, while applying chlorine dosage of 20 mg/l, with filtration of the washer water in a closed loop.
4. Multiple water reuse reduced use of immersion water by 54% of the normal consumption in this plant.

Recommendations

Based on the results of the study, the following recommendations are proposed.

1. The poultry processing industry in Egypt should investigate multiple reuse of the existing once-through water systems in the carcass-cooling operation. Water flow to process units should be monitored.
2. Use of potable water for feather fluming, flushing of blood tunnels and cleanup operations should be replaced by reused water from other processes.
3. Coordination of activities between industry, regulatory agencies and research teams is necessary for development of efficient water conservation schemes.
4. Areas needing further investigation and evaluation are: long-term evaluation of cost, accumulation of contaminants, and operational problems of the continuous multiple water reuse system; development of further uses of byproducts; and use of specific sensing devices for monitoring of pollutants in the immersion water.

Description of the Multiple Reuse System

The normal operation of the APPP involves initial filling of the immersion tanks (chillers, washer and scalder) and introducing makeup with once-through fresh water in all tanks. Details of the operations, characteristics and flow of process effluents are described elsewhere.[1]

Figure 1 is a flowsheet of the multiple reuse system (MRS). The compressor's cooling water was used for initial filling and makeup in the immersion tanks. Makeup water was continuously pumped at a controlled rate to the chiller, and repumped at the same rate to the prechiller and washer, in a counter-current flow arrangement.

The overflow from the washer was diverted to the scalder as a replacement for part of the fresh water requirement during processing. Schematics of the flow for both normal operation (once-through makeup) and MRS are shown in Figure 2.

Modes of operation of the MRS system were as follows:

1. Treatment I. A gas chlorinator (Capital Control Co., USA) was installed on the subfeeding line to the immersion tanks. Metered chlorine dosages were injected into the line during initial filling (about one hour prior to startup). Chlorine dosages were controlled during the initial filling, and in makeup water. Chlorine dosages used were 10, 20 and 30 mg/l, and water makeup rates were 10, 20 and 30 m^3/d.
2. Treatment II. A high-pressure leaf filter was used for renovation of the wash water in a closed loop. The filter (Model 36H-805-4, Amafilter, Holland) has a net filtering area of 7.5 m^2, working pressure 4.5 Atm and an average capacity of 1000 L/hr filtered water. A local bentonite clay (equivalent pore size 0.8μ) was used for coating the leaves prior to filtration.
3. Treatment III. In this mode, the filter was connected to the prechiller rather than to the washer. Makeup water rates and chlorine dosages for treatments II and III were the same as those used in treatment I.

The ratio of makeup water used in the MRS and the normal nonreuse systems are given in Table 1.

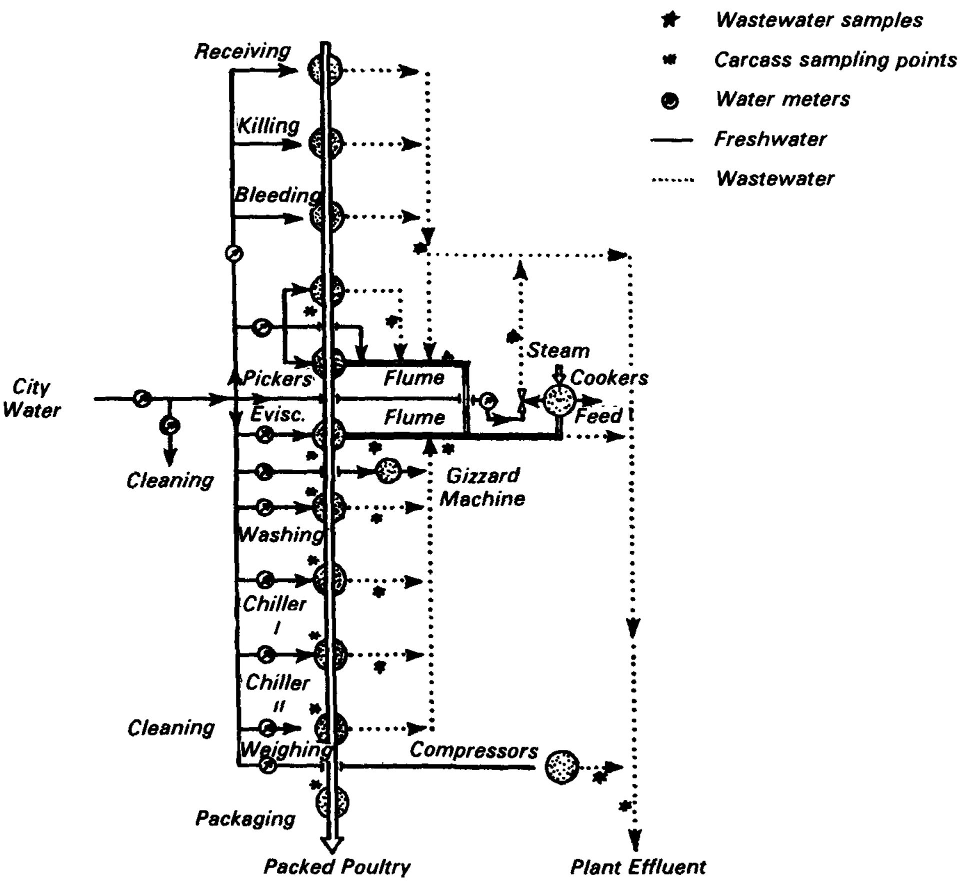


Figure 1. Multiple water reuse system at poultry processing plant, Alexandria, Egypt.

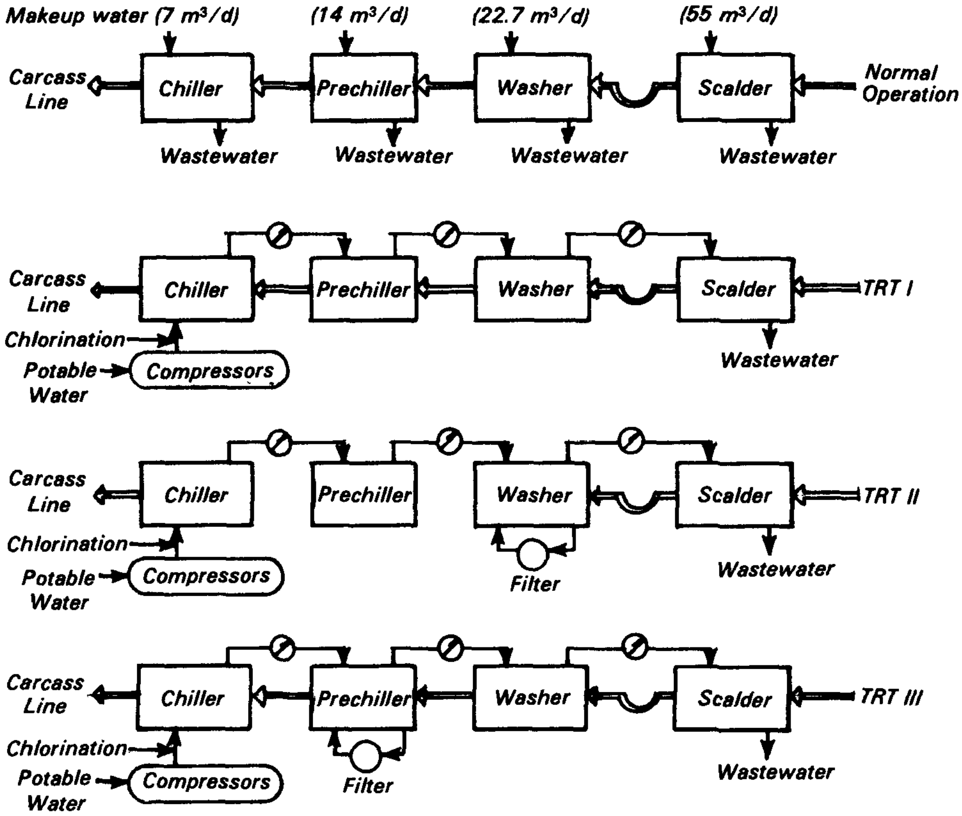


Figure 2. Schematics of normal operation and multiple reuse systems.

Table 1. Ratio of Makeup Water in the MRS and Normal Systems

Makeup (MRS) m^3/d	Chiller ($2.5^a + 7.0^b$)	Prechiller ($2.5^a + 14.0^b$)	Washer ($5.0^a + 22.7^b$)	Σ Operations ($10^a + 43.7^b$)
10	1.43	0.71	0.44	0.23
20	2.86	1.43	0.88	0.46
30	4.28	2.14	1.32	0.67

[a]Initial filling water, m^3/d.
[b]Makeup water in normal system, m^3/d.

Effect of Multiple Reuse on Chemical Characteristics of Process Water

As shown in Table 2, chlorination of water in the MRS (TRT I) reduced the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the washer and chiller waters in comparison with the normal once-through system. However, the BOD and COD of the scalder water were appreciably higher due to the near absence of residual chlorine and the significant accumulation of pollutants in wash water reused as makeup for the scalder.

Filtration of the chlorinated water in the MRS (TRTs II and III) further improved the quality of the washer water and chiller water as shown in Table 2. As anticipated, filtration of the washer water (TRT II) and chiller water (TRT III) produced noticeable reductions in the suspended residues (SR).

With minor exceptions, the accumulation of pollutants was decreased by increasing makeup rate and chlorine dosages in the MRS. The normal water-use scheme produced more accumulation of COD, Total Residue (TR), and Oil and Grease (O&G) in the washer and chiller. The use of 10 and 20 m^3/d in the MRS results in net saving of the immersion water of 77% and 54%, respectively (Table 1). Despite this appreciable reduction of water use, the quality of the washer and prechiller waters was better in the MRS as compared to the normal system, due to the influence of filtration and/or chlorination in reducing the accumulation of pollutants. The ANOVA reported in Table 3 indicates significant effects of the independent variables (treatments, date, time, and operating conditions [water rate and chlorine dosage]) on pollutants associated with the process water in the four immersion tanks. Interactions between the independent variables were significant in most cases. The dependent variables are COD, BOD, TR, volatile residual (VR), dissolved residual (DR) and O&G.

Effects of Multiple Reuse on Bacterial Counts of Water and Carcasses

Chlorination (TRT I) in conjunction with filtration (TRTs II and III) produced marked decreases in total aerobic count and coliform count of water and carcasses as compared with the normal system (Table 4). However, minor exceptions were observed.

Bacterial counts for water in the normal system were lower than the MRS (TRT I) when using chlorine dosage of 10 mg/l and water makeup rate of 10 m^3/d. However, increasing the water rate to 20 m^3/d and chlorine dosages to 20 and 30 mg/l produced marked decrease in bacterial counts of process water in the washer and chillers (Figure 3). On the other hand, as Figure 4 shows, bacterial counts on carcasses were consistently lower in the MRS compared to the normal system, even at the low water rate of 10 m^3/d and chlorine dosage of 10 mg/l.

The results reported in Table 4 indicate that the normal water system was less effective than MRS in removing bacteria from both water and carcasses. With minor exceptions, the MRS modes produced mean counts lower than the normal system.

The ANOVA of bacterial counts is reported in Table 5. In this case, most independent variables and their interactions produced significant effects on bacterial counts. The results generally agree with ANOVA reported in Table 3.

Table 2. *Effect of Treatment on Mean Concentrations of Pollutants in Process Water, mg/l*

Process	TRT	COD	BOD	TR	SR	O&G
Scalder	N	1574	1235	1700		91
	I	2145	1542	2627	1182	74
	II	1616	1156	1933	784	93
	III	1538	1419	2214	762	100
Washer	N	1434	1220	1744		242
	I	787	547	1842	523	126
	II	427	351	830	165	43
	III	485	396	1137	427	99
Prechiller	N	1883	1431	2119		244
	I	384	226	956	427	523
	II	402	311	826	386	102
	III	156	128	500	128	48
Chiller	N	1357	1020	1562		245
	I	326	218	671	229	75
	II	325	247	756	295	116
	III	179	154	505	256	85

N = Normal (once-through) system.
I = Chlorination of MRS water.
II = Chlorination of MRS and filtration of washing water.
III = Chlorination of MRS and filtration of prechiller water.
Data for TRTs I, II and III are pooled for makeup rates 10-20 m^3/day and chlorine dosage 10-30 mg/l.
Means of 8 experiments.

Table 3. *Effect of Treatment and Operating Conditions on Chemical Characteristics of Process Water*

	TRT (T)	OPCON (O)	T.O.	Date	Hours (H)	H.T.	H.O.	H.T.O.
Scalder								
COD	S	S	S	S	S	S	S	N
BOD	S	S	S	S	S	S	S	N
TR	S	S	S	S	S	S	S	S
VR	S	S	S	S	S	S	S	S
DR	S	S	S	S	S	S	S	S
O&G	S	S	S	N	S	S	N	S
Washer								
COD	N	S	N	S	S	S	S	S
BOD	S	N	N	S	S	S	S	S
TR	S	S	N	S	S	S	N	S
VR	S	S	N	S	S	S	N	S
DR	N	S	N	S	S	S	S	S
O&G	S	N	S	S	S	S	S	S
Prechiller								
COD	S	S	N	S	S	S	N	N
BOD	S	S	S	S	S	S	S	N
TR	S	S	N	S	S	S	S	N
VR	S	S	N	S	S	S	S	S
DR	S	S	N	S	S	S	S	S
O&G	N	S	S	S	S	S	S	S
Chiller								
COD	S	S	N	S	S	S	S	S
BOD	S	S	S	S	S	S	S	S
TR	S	S	S	S	S	S	N	S
VR	S	S	S	S	S	S	N	S
DR	S	S	S	S	S	S	N	S
O&G	S	S	S	S	S	S	N	S

OPCON (O) = 1 water makeup 10 m^3/d and Cl_2 dose = 10 mg/l
= 2 water makeup 20 m^3/d and Cl_2 dose = 20 mg/l
= 3 water makeup 20 m^3/d and Cl_2 dose = 30 mg/l
TRTs (T) I, II and III
Hours (H) 1, 2, 3, 4, 5 and 6
S Significant difference at the 5% level
N Not significant difference at the 5% level

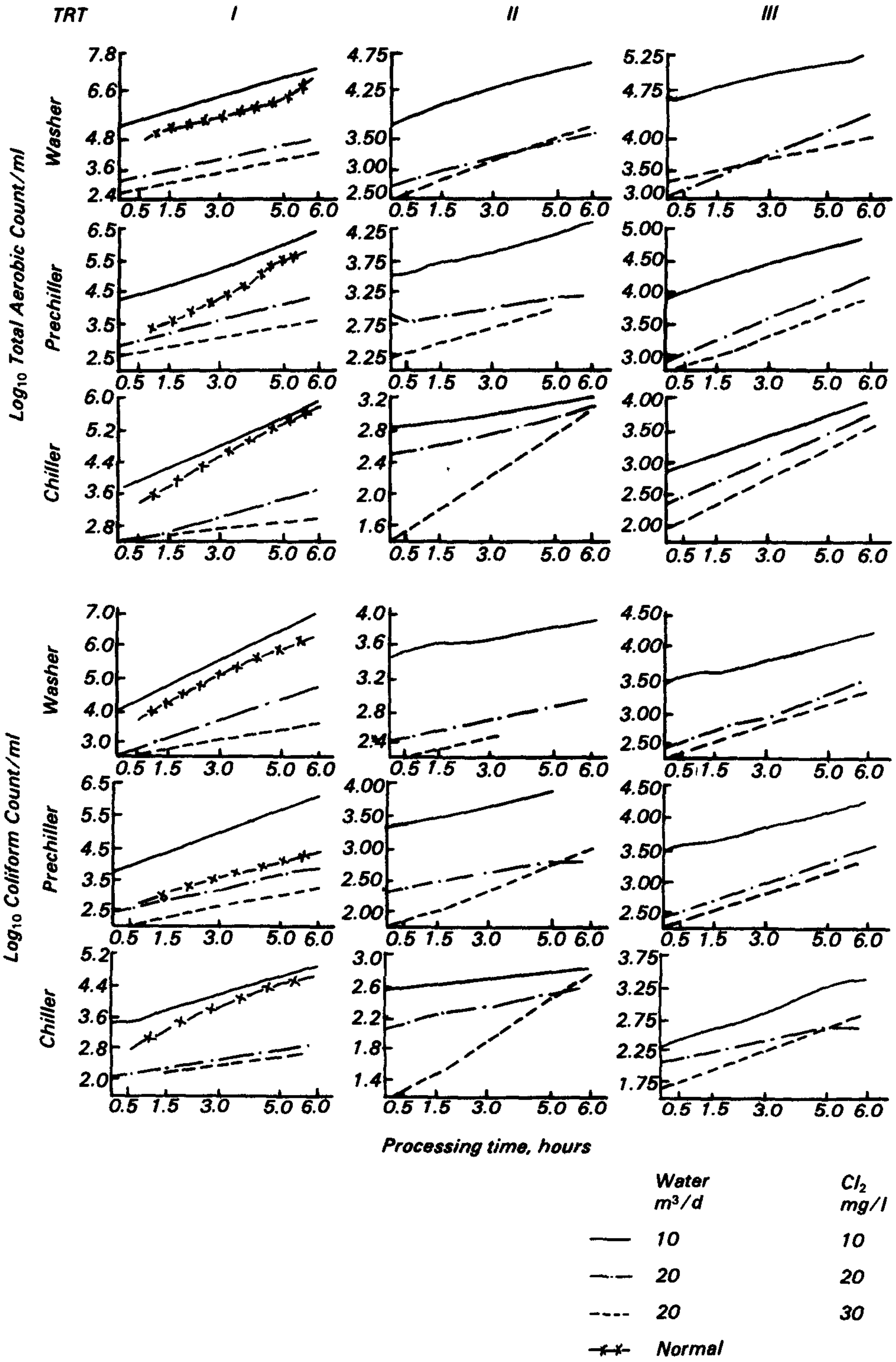


Figure 3. Effect of treatment on bacterial counts of process water.

Comparing the effects of TRT II and TRT III on the bacterial counts of the chilled carcasses shown in Table 4 and Figure 4 indicates that TRT II (filtering the washer water) produced a better quality of chilled carcasses. Since shelf-life is dependent on the bacterial quality of the carcasses in the last immersion process (chilling), it is recommended that the filter be used in conjunction with the washer in plants that use immersion washers so as to reduce bacterial levels most effectively.

Effect of Chlorination, Water Makeup Rate and Processing Time on Bacterial Counts of the Chiller

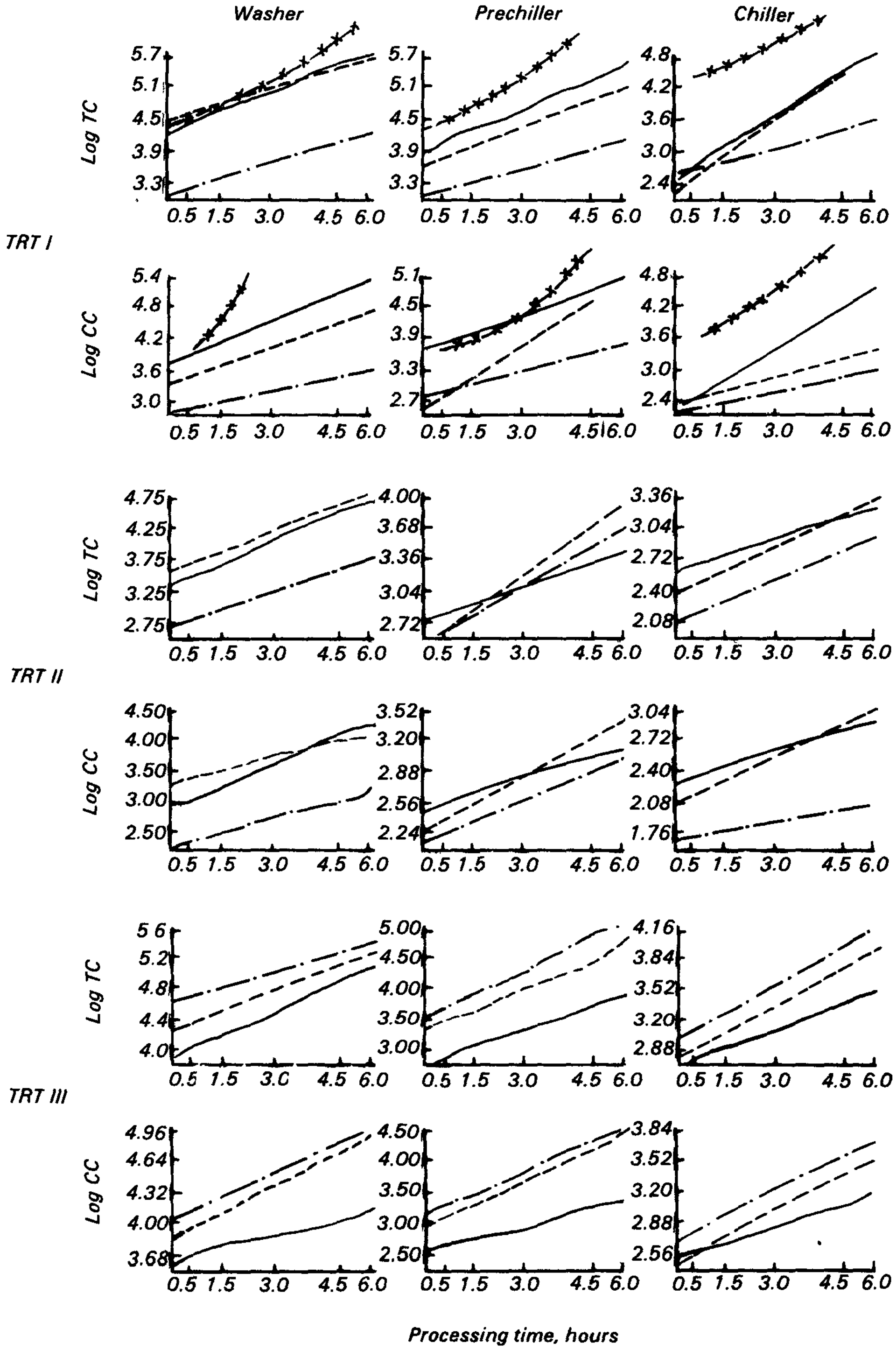
Contour plots *available in the full report* clearly demonstrate the favorable effect of chlorination on the bacterial quality of water and carcasses. Contours of relatively low bacterial counts were dominant when using chlorinated water, whereas the use of nonchlorinated water in the MRS was associated with higher total aerobic and coliform counts.

As processing time increased, bacterial counts also increased. However, toward the end of the operation, the chlorination controlled counts at lower levels than nonchlorinated water. The use of nonchlorinated water resulted in rapid increase in bacterial counts in the last stages of the operation period.

Although the effect of water makeup rate did not follow a uniform pattern, the contours for chlorinated water indicate an optimum water makeup rate of 20 m^3/d. The use of this water makeup rate in the MRS resulted in a net water saving of 54% compared to normal usage (Table 1).

Reference

1. Hamza, A., Saad, S. and Witherow, J., "Potential for Water Reuse in an Egyptian Poultry Processing Plant," Journal of Food Sci. 43, (1978).



Log TC = Log_{10} total aerobic count/Ca

Log CC = Log_{10} coliform count/Ca

	Water m^3/d	Cl_2 mg/l
——	10	10
—·—	20	20
- - -	20	30
-✱✱-	Normal	

Figure 4. *Effect of treatments on bacterial counts of carcasses.*

Table 4. *Effect of Treatments on Mean Logarithmic Counts of Carcasses and Water*

Process	TRT	Log TW	Log TC	Log CW	Log_{10} CC
Washer	N	5.00	8.30	3.30	6.90
	I	4.04	4.45	3.67	3.71
	II	3.40	3.73	3.01	3 28
	III	3.99	4.68	3.74	4.17
Prechiller	N	4.69	6.20	3.32	4.99
	I	3.59	4.08	3.25	3.61
	II	3.15	3.07	3.88	2.68
	III	3.65	3.78	3.29	2.37
Chiller	N	4.83	6.27	3.11	4.75
	I	3.17	3.29	2.76	2 77
	II	2.59	2.71	2.32	2.30
	III	2.93	3.21	2.57	2.88

Log TW = Log_{10} total aerobic count in water/ml.
Log CW = Log_{10} coliform count in water/ml.
Log TW = Log_{10} total aerobic count of carcasses.
Log CC = Log_{10} coliform count of carcasses.

Other conditions are similar to those of Table 2.

Table 5. *Effect of Treatments and Operating Conditions on Bacterial Counts of Carcasses and Process Water*

	TRT (T)	OPCON (O)	T.O	Date	Hours (H)	T.H	H.O	H.T.O
Scalder								
Log TW	S	S	N	S	S	S	N	N
Log CW	S	S	S	S	S	S	S	S
Log TC	S	S	S	S	S	S	S	S
Log CC	S	S	S	S	S	S	S	S
Washer								
Log TW	S	S	S	N	S	S	N	S
Log CW	S	S	N	S	S	S	S	S
Log TC	S	S	S	N	S	S	S	N
Log CC	S	S	S	S	S	S	S	S
Prechiller								
Log TW	S	S	S	N	S	S	N	S
Log CW	S	S	S	S	S	S	S	S
Log TC	S	S	S	S	S	S	S	S
Log CC	S	N	S	N	S	S	S	S
Chiller								
Log TW	S	S	S	N	S	S	N	S
Log CW	S	S	S	N	S	S	S	S
Log TC	S	N	N	S	S	S	N	N
Log CC	S	S	S	S	S	S	S	S

Log TW = Log_{10} total aerobic count in water/ml.
Log CW = Log_{10} coliform count in water/ml.
Log TC = Log_{10} total aerobic count of carcasses.
Log CC = Log_{10} coliform count of carcasses.

Other conditions are those of Table 3.

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The complete report, entitled "Multiple Water Reuse in Poultry Processing: Case Study in Egypt," (Order No. PB 83-156 760; Cost: $13.00, subject to change) will be available only from:

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