FINAL PROJECT REPORT

Project Title: Analysis of packinghouse preventive controls for dump tank water

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Cooperators:

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Five WA apple packing facilities
Biologics Resources, LLC
Pulse Instruments

Other funding sources: None

Total Project Funding: $94,000

Budget History:

Item	**Year 1: 2014**	**Year 2: 2015**
Salaries	$28,000	$33,750
Benefits	$5,600	$5,600
Wages		
Benefits		
Equipment		$6,279.44
Supplies		
Travel	$142.36	$3,031.56
Plot Fees		
Miscellaneous		$11,596.64
Total	$33,742.36	$60,257.64

As part of the Food Safety Modernization Act (FSMA), the recently enacted Current Good Manufacturing Practice and Hazard Analysis and Risk-Based Preventive Controls (HARPC) for Human Food (the Preventive Controls Rule) focuses on preventive standards for the manufacturing and processing of food for human consumption. Data on food safety practices for the produce industry were last recorded by the USDA's National Agricultural Statistics Service (NASS) in 1999. Without data documenting current practices, it may be challenging for industry to implement FSMA rules that require scientific evidence for food safety practices (Perez, 2015). To meet the Preventive Controls Rule's validation requirements, Washington tree fruit packinghouses will be required to demonstrate that their preventive practices (i.e., sanitizer use in dump tank water) are effectively controlling for microbial contamination. Facilities that use water in their packing systems will be required to prepare and implement preventive controls using a food safety plan (HARPC) that includes hazard identification and evaluation, preventive control implementation for identified hazards, preventive control monitoring, verification of monitoring including process validation, corrective action procedures if preventive controls are not properly implemented, and a recall plan if contaminated food is released into the supply chain. To date, there has not been a study conducted for the tree fruit industry correlating microbial water testing data to preventive controls for dump tank water.

OBJECTIVES

1. **Collect industry data: As part of their previous work, IDS has collected individual company water, environmental and product test data from third-party laboratories for apples, pears and cherries. In addition IDS has worked with individual companies to obtain and analyze actual packing line monitoring data. In 2014 IDS proposes extending the data collection efforts to other packinghouses.**
2. **Data Analysis: Correlate dump tank water monitoring parameters (e.g. temperatures, pH, ORP readings, sanitizer levels and exposure by fruit and variety) to microbial levels. To the extent possible, examine how various sanitizers perform given the fruit and environmental conditions. Examine critical limits for critical control points, how they were determined, and how frequently they are exceeded.**
3. **Review HACCP plans: Based on the data analysis, develop a dump tank decision tree for packinghouse use. Recommend appropriate parameters for dump tank water in tree fruit packinghouse HACCP plans.**

SIGNIFICANT FINDINGS

- Over the two-year project, 368 total coliform (TC) tests and 74 generic *E. coli* tests were conducted (36 samples for TC testing and 8 samples for generic *E. coli* testing were lost by FedEx). Total coliform was present in 19% of dump tank water samples containing chlorine and in 35% of water samples containing PAA. In dump tank water containing either chlorine or PAA, generic *E. coli* was present 17% of the time.

- In dump tank water containing chlorine, ORP was the only predictor found to be significantly correlated to TC detection ($r^2 = 0.3924$; $p < 0.0001$); as ORP increased, TC concentration decreased. These findings suggest that maintaining a higher ORP would reduce TC concentration. Interestingly, chlorine concentration (measured using either strips or a ChlordioX) was not found to be a significant predictor for TC concentration. ORP, pH, water use duration, and conductivity were collectively strong predictors for generic *E. coli*.

- For facilities using chlorine as a dump tank water sanitizer, pH levels were maintained largely within the ideal range of 6.5 and 7.0.

- At facilities using chlorine as the water sanitizer, ORP, pH, and temperature were collectively found to be significantly correlated with free chlorine measurements ($r^2 = 0.475$; $p < 0.0001$). Individually ORP was not found to be a strong predictor of free chlorine concentration. When pH was within the optimal range for free chlorine formation (6.5 - 7.0), individually ORP was still not a strong predictor for chlorine levels ($r^2 = 0.2740$; $p < 0.0001$; $\beta = 0.096$).

- In PAA-containing dump tank water, PAA concentration, pH, conductivity, turbidity, water use duration, and ORP collectively were found to be significant predictors of TC concentration ($r^2 = 0.384$; $p < 0.0001$). High turbidity and conductivity measurements were positively associated with increases in microbial concentration. Only ORP was found to be a significant predictor for generic *E. coli* ($r^2 = 0.323$; $p = 0.0011$) with decreases in ORP associated with increases in generic *E. coli* concentration.

- At facilities using PAA, increases in turbidity and conductivity were found to be associated with an increase in PAA, probably due to more sanitizer typically being added as debris increase in the tank. Increases in water use duration, pH, and ORP were associated with a decrease in PAA concentration.

- Among all four facilities using PAA, levels ranged between 0 and 120 ppm during the sampling period. Sixty samples (17.9%) were measured at levels greater than the FDA's 80 ppm limit for wash water; 18.3% of these had levels greater than 100 ppm. ORP was observed between 246 and 685 mV while PAA was in use.

- All companies reported having HACCP plans; however, in response to the question of whether the dump tank was considered a critical control point (CCP) in their plan, one company said it was, one company said it was did not, and the other three did not answer the question. Based on the data analysis, sanitizer concentration, ORP, water pH and temperature, and microbial levels need to be measured for an entire dump tank water cycle (i.e., when tank is filled with clean water prior to fruit entry until water is drained from tank) when validating the HARPC/HACCP plan for a dump tank system. A diagram (Figure 1) illustrating operational areas to be considered when developing and validating a HARPC/HACCP plan are provided at the end of the report.

RESULTS & DISCUSSION

Sampling was conducted in six visits at five Washington apple packing facilities for a total of 177.5 operational hours. Prior to each site visit, companies were asked to fill out a 70-question questionnaire covering their HACCP plan, equipment, dump tank cleaning and sanitation, cleaning frequency, cleaning verification, unloading mechanism, apple variety and harvest information, chemical exposure, dump tank water, dump tank operations and monitoring, instruments used for measurements, instrument calibration, and microbial testing.

IDS tested physicochemical parameters on site. ORP, pH, temperature, and conductivity were measured using an Ultrameter II (Myron L Company, Model 6PFC). Turbidity was measured using a Compact Turbimeter (Palintest, Model CT12). Free chlorine was measured using a ChlordioX Plus (Palintest) and colorimetric strips (Water-Works, Free Chlorine High). PAA was measured using a hydrogen peroxide and peracetic titration kit (LaMotte) and colorimetric strips (Lamotte Insta-Test Analytic, Peracetic Acid).

Water samples were tested for total coliform and generic *E. coli*. Total coliform testing measures biologic pollution in water, includes all coliform species found in animal's intestines, soil, water and vegetation, and is usually associated with fecal polluted water. Generic *E. coli* tests specifically for bacterial species found in intestinal tract and are an indicator for contamination due to enteric pathogens (EPA, 2002).

For both total coliform and generic *E. coli* concentration, 100 millimeter (mL) water samples were collected and shipped overnight on ice to Biologic Resources, LLC in Portland, Oregon. TC samples were tested according to Method 9221B and generic *E. coli* samples were tested according to Method 9221F. Water samples for generic *E. coli* tests were collected at the beginning and nearest to the end of each operating day as possible. Water samples collected for TC tests were collected every hour.

PAA and chlorine in the form of calcium hypochlorite were the sanitizers used in the sampled facilities (Table 1). In three of the facilities, either chlorine or PAA was used based on the fruit variety and/or the condition of the fruit arriving from the orchard. Two of the facilities use PAA or chlorine in the dump tank water, regardless of fruit variety and condition. Due to a limited number of project participants packing pears and cherries, data included in this report is from dump tank water used in apple packing only.

At each facility, dump tank water parameters were measured during normal operations throughout two dump tank water cycles. The first sample was taken in clean water before product entered the dump tank. Thereafter, sampling/measuring (in duplicates) continued at 30 minute intervals until water was discharged from the tank. The number of days the dump tank water was used prior to discharge varied by facility and was dependent on factors such as apple variety, appearance of the water, and fruit inventory. Data is summarized in Table 1.

Pearson correlations and step-wise multiple regressions were completed using Stata 12. One step-wise regression was completed for each variable. If the regression for the variable was individually found to be statistically significant (significance for inclusion in the model was set at $p < 0.015$), it was included in the regression model.

Table 1. Facilities visited and dump tank use.

Packinghouse	Line type	Tank ID	Days of use	Total water use time (hrs/tank)	Sanitizer	From Storage (S) or Orchard (O)
A	Commit to pack	A1	1	6.9	Chlorine	S
	Commit to pack	A2	1	7.7	Chlorine	S
B	Commit to pack	B1	3	33.1	Chlorine	S
	Commit to pack	B2	3	32.1	Chlorine & PAA	O
C	Commit to pack	C1	1	8.6	PAA	O
	Commit to pack	C2	2	17.5	PAA	S
D	Commit to pack	D1	2	20.7	Chlorine	O
	Commit to pack	D2	2	20.8	PAA	O
E	Commit to pack	E1	2	18.8	PAA	S
	Pre-size	E2	1.5	11.3	Chlorine	S

Each facility had separate measures and targets for maintaining their system (Table 2). Three of the four companies that used chlorine as a water sanitizer use ORP readings for monitoring sanitizer efficacy. ORP target level ranged from 800 to 1,000 mV and acceptable readings varied among companies. Companies using PAA directly measured sanitizer concentration and did not rely on ORP readings for monitoring sanitizer efficacy. Target concentrations for PAA ranged between 50 to 80 ppm (80 ppm is the maximum concentration allowed by the FDA).

Table 2. Dump tank controls as reported in the questionnaire and visits.

Packinghouse	A	B	C	D	E
Parameters measured for sanitizer target level	Cl: FC ppm	Cl: ORP	PAA: ppm	Cl: ORP PAA: ppm	Cl: ORP PAA: ppm
Target sanitizer concentration	Total Cl: 40-60 ppm FC: 20-30 ppm	NA	PAA: 60-80 ppm	PAA: 50-70ppm	FC: 50-100 ppm PAA: 0-80 ppm
ORP target for Cl	900-1000 mV	800 mV	-	800 mV	920 mV
ORP acceptable readings for Cl	>750 mV	800 mV	-	675-900 mV	755-920 mV

Cl = Chlorine sanitizer; FC = Free chlorine; PAA = Peracetic acid; ORP = Oxidation Reduction Potential; T = Temperature; NA = not answered

Table 3 displays violations for each company when measurements were outside the company's acceptable readings. Packinghouse A had only 2 measurements outside of their ORP acceptable readings and did not have any positive tests. Of the 18 measurements outside of Packinghouse B's acceptable readings, all but one was below the minimum of 750 mV. Packinghouse C, using PAA, had a number of measurements exceeding their target maximum concentration of 80 ppm. No positives for either TC or generic *E. coli* were found when PAA was above 80 ppm; however when the concentration was below the target concentration range (60-80 ppm), 33% of the water samples tested for TC were positive. While using PAA as the sanitizer, Packinghouse D never reached their target concentration (50-70 ppm). When using chlorine as the sanitizer, Packinghouse D's readings never exceeded the upper limit (900 mV) of their acceptable ORP readings. However, when ORP was below the minimum acceptable reading of 675 mV, 100% of TC samples were positive. Packinghouse E had no ORP violations when chlorine was in use and 34 violations when PAA was in use, 33 of which were higher than the maximum acceptable reading (920 mV). However, no samples tested positive for TC or generic *E. coli*.

Table 3. Dump tank controls performance.

Packinghouse	A	B*	C	D	E
<u>Chlorine – ORP (mV)</u>					
Total samples† outside of acceptable ORP readings	2	18	N/A	12	0
No. of samples tested for TC outside of acceptable ORP readings (percent TC-positive)	2 (0)	12 (75%)	N/A	6 (100%)	0 (0)
No. of samples tested for GE	2 (0)	4 (50%)	N/A	4 (50%)	0 (0)

Packinghouse	A	B*	C	D	E
outside of acceptable ORP readings (percent GE-positive)					
<u>PAA concentration (ppm)</u>					
Total samples outside of target concentration	N/A	No range provided	65	86	34
No. of samples tested for TC outside of target concentration (percent TC-positive)	N/A	No range provided	21 (10%)	48 (90%)	18 (0)
No. of samples tested for GE outside of target concentration (percent GE-positive)	N/A	No range provided	6 (0)	8 (75%)	2 (0)

†Includes readings at time points when TC and GE were not measured.

*Packinghouse B – Target and acceptable ORP range was reported as 800 mV, assumed acceptable range was 750-850 mV; N/A = not applicable, GE = generic *E. coli*

<u>Calcium hypochlorite (chlorine)</u>

In dump tanks using calcium hypochlorite (chlorine) as the sanitizer (Table 4), all water samples that tested positive for generic *E. coli* also tested positive for TC. Generic *E. coli* was detected in six samples (3 duplicates), at an average concentration of 89 MPN/100mL (range: 4-170 MPN/100mL). For these generic *E. coli*-positive samples, the average TC concentration was 1,334 MPN/100mL (range: 4->1,600 MPN/100mL). Two of the six samples were at the maximum detection limit of 1,600 MPN/100mL total coliforms and three exceeded it. When samples tested positive for generic *E. coli*, the average ORP, pH, and free chlorine readings were 486 mV, 6.9, and <0.02 ppm, respectively.

Table 4. Microbial testing results when chlorine sanitizer was in use.

Packinghouse	Tank ID	Total Coliform			Generic *E. coli*		
		Number of tests	Positive tests	Percent positive	Number of tests	Positive tests	Percent positive
A	A1*	16	-	-	4	-	-
	A2	16	0	0	4	0	0
B	B1	58	5	9%	12	4	33%
	B2	32	12	38%	4	0	0
D	D1	40	16	40%	8	2	25%
E	E2	28	0	0	8	0	0
Total		174	33	19%	36	6	17%

* Tank A1 microbial results are not included as the microbial samples were lost by FedEx.

Thirty-three samples contained detectable levels of TC with an average concentration of 534 MPN/100mL (range: 2->1,600MPN/100mL). The average ORP, pH, and chlorine measurements for TC-positive samples were 608 mV, 7.1, and 12 ppm, respectively. Of the 33 TC-positive samples, five contained levels exceeding the 1,600 MPN/100mL detection limit. The average ORP, pH, and chlorine for TC-positive samples were 358 mV, 6.8, and <0.02 ppm, respectively.

Dump tank parameter measurements varied among facilities. Variations were also seen within each packinghouse data set with the greatest fluctuations in chlorine levels (the intra-packinghouse spread for free chlorine measurements averaged 53 ppm). In general, pH levels, controlled by adding various pH stabilizers (e.g., citric acid, sulfuric acid, or sodium hydroxide) were maintained largely within the ideal range of 6.5 and 7.0. However, two facilities (Packinghouse A and D) had mean pH readings (7.2 and 7.7, respectively) above ideal conditions for sanitizer efficacy (pH 6.5 − 7.0). Of the 84 water samples taken from tanks with a pH within the 6.5 − 7.0 optimal range, 11% had detectable TC levels versus 27% of the 90 water samples collected when pH was outside of the optimal range.

Pearson correlations were completed for all measured parameters. Measurements of free chlorine using chlorine strips and the ChlordioX were significantly correlated ($r = 0.881$, $p < 0.001$) however, differences between each of the two chlorine measurement methods and additional dump tank water parameters were found (see Table 5).

Table 5. Pearson correlations of each parameter for chlorine-containing dump tank water.

	†FC (C)	**†FC (S)**	**TC**	**G. *E. coli***	**ORP**	**pH**	**Turb.**	**Cond.**	**Temp.**	**WU**
FC(C)	1.000									
FC (S)	0.881**	1.000								
TC	-0.264*	-0.267*	1.000							
G. *E. coli*	-0.372*	-0.406	0.713**	1.000						
ORP	0.336**	0.385**	-0.626**	-0.384*	1.000					
pH	0.549**	0.674**	-0.015	-0.170	-0.108*	1.000				
Turb.	-0.061	0.086	-0.031	-0.192	0.223**	-0.352**	1.000			
Cond.	0.452**	0.588**	-0.004	-0.345*	0.047	0.543**	0.389**	1.000		
Temp.	0.377**	0.486**	0.161*	0.011	-0.278**	0.438**	0.254**	0.589**	1.000	
WU	-0.105	-0.078	-0.004	-0.292	0.166*	-0.370**	0.914**	0.438**	0.301**	1.000

FC (C) = Free chlorine measured using the Chlordiox; FC (S) = Free chlorine measured using strips; TC = Total coliform; G. *E. coli* = Generic *E. coli*; ORP = Oxidation Reduction Potential; Turb. = Turbidity; Cond. = Conductivity; Temp. = Temperature; WU = Water use duration in hours

† When calcium hypochlorite is added to dump tank water, the chlorine dissolves and takes multiple forms. In solution, chlorine (or total chlorine) can take either of two paths that determine its effectiveness: it can form the antimicrobial agent, free chlorine or it can lose its antimicrobial properties by reacting with organic compounds to form combined chlorine. Dump tank conditions that favor the formation of free chlorine are essential for minimizing pathogens.

*Significance of $p < 0.05$

**Significance of $p < 0.001$

In order to estimate the free chlorine levels collected with the ChlordioX, a stepwise multiple regression was conducted using the other water physicochemical properties. ORP, pH, and temperature were collectively found to be significantly correlated with free chlorine measurements ($r^2 = 0.475$; $p < 0.0001$). When modeled individually, ORP was not found to be a strong predictor of free chlorine concentration despite current industry use of ORP as a surrogate measurement for sanitizer efficacy. Even when pH was within the optimal range for free chlorine formation (6.5 and 7.0), individually ORP was still not a strong predictor for chlorine levels ($r^2 = 0.2740$; $p < 0.0001$; $\beta = 0.096$).

A second stepwise multiple regression was completed in order to estimate free chlorine levels using measurements collected with colorimetric strips (commonly used by industry). ORP, conductivity, water use duration, and turbidity explained up to 75% of the variability observed in chlorine concentration measured with strips ($r^2 = 0.752$; $p < 0.0001$). Colorimetric strips are not considered to be very accurate measurers of free chlorine due to oxidizing agents in water that may alter readings. In addition there is limited variability in chlorine readings using colorimetric strips due to set increments in concentration. However, if used in conjunction with pH measurements, colorimetric strips may be a useful method for verifying free chlorine measurements taken with handheld instruments or inline probes.

An additional stepwise regression was completed in order to assess the relationship between dump tank water parameters and microbial content. ORP was the only parameter found to be a significant predictor of TC levels ($r^2 = 0.3924$; $p < 0.0001$); the analysis showed that as ORP increases, TC levels would be expected to decrease. These findings suggest that maintaining a higher ORP would reduce TC concentration. Interestingly, chlorine concentration (measured using either strips or a ChlordioX) was not found to be a significant predictor for TC concentration.

Peracetic acid

IDS used two methods to measure PAA: colorimetric strips and a titration kit. The colorimetric strips and titration kit tests are significantly correlated ($r^2 = 0.792$; $p < 0.001$; Table 7). However, the PAA strip method and titration kit method were not as highly correlated as one would expect. The difference may be due to the objectivity of reading the tester identifying colors and then determining where the strip falls on scale. The same color (or result) may be interpreted differently by different testers or the same tester at a different time. In addition, the scale provided is incremental and therefore the PAA level may match a color but theoretically the real value is lower or higher. The titration method, although requiring more technical expertise, is less likely to vary between users.

In dump tanks using PAA as a sanitizer, all water samples that tested positive for generic *E. coli* were also positive for TC (Table 6). All five samples containing detectable levels of generic *E. coli* were collected from Tank D2 and had an average concentration of 1,340 MPN/100mL TC. Four of the five *E. coli*-positive samples exceeded the TC detection limit of 1,600 MPN/100mL. Forty-three dump tank water samples contained detectable TC. When samples were TC-positive, the average ORP and pH readings were 319 mV and 6.3 and when samples were TC-negative 460 mV and 3.9, respectively. Tank D2 accounted for the majority (77%) of TC-positive tests.

Table 6. Microbial testing results when PAA sanitizer was in use.

Packinghouse	Tank ID	Total Coliform			Generic *E. coli*		
		Number of tests	Positive tests	Percent positive	Number of tests	Positive tests	Percent positive
B	B2	28	10	36%	6	0	0
C	C1	20	1	5%	4	0	0
	C2	20	2	10%	4	0	0
D	D2	48	43	90%	8	5	63%
E	E1	42	0	0	8	0	0
Total		158	56	35%	30	5	17%

Among all four facilities using PAA, levels ranged between 0 and 120 ppm during the sampling period. Sixty samples (17.9%) were measured at levels greater than the FDA's 80 ppm limit for wash water; 18.3% of these had levels greater than 100 ppm. ORP was observed between 246 and 685 mV while PAA was in use.

Table 7. Pearson correlations of each parameter for PAA-containing dump tank water.

	PAA tit.	**PAA strips**	**TC**	**G. *E. coli***	**ORP**	**pH**	**Turb.**	**Cond.**	**Temp**	**TU**
PAA tit.	1.000									
PAA strips	0.792**	1.000								
TC	-0.497**	-0.547**	1.000							
G. *E. coli*	-0.383*	-0.428*	0.707**	1.0000						
ORP	0.687**	0.451**	-0.507**	-0.568*	1.000					
pH	-0.704**	-0.572**	0.532**	0.505*	-0.930**	1.000				
Turbidity	0.121*	0.020	0.020	0.163	0.143*	-0.116*	1.000			
Conductivity	0.532**	0.213**	-0.218*	-0.177	0.686**	-0.644**	0.187**	1.000		
Temp	-0.195**	-0.172*	0.260**	0.424*	-0.352**	0.246**	0.083	-0.167*	1.000	
WU	-0.429**	-0.342**	0.164*	0.262	-0.263**	0.118*	0.479**	-0.121*	0.364**	1.000

PAA tit. = PAA measured using a titration kit, PAA strips = PAA measured using strips, TC = Total coliform, G. *E. coli* = Generic *E. coli*, ORP = Oxidation Reduction Potential, Turb. = Turbidity, Cond. = Conductivity, Temp. = Temperature, WU = Water use duration in hours
*Significance of $p < 0.05$
**Significance of $p < 0.001$

A multiple step-wise regression was completed in order to predict PAA concentration. It was found that water use duration, turbidity, pH, conductivity, and ORP are collectively significant predictors for PAA concentration ($r^2 = 0.715$; $p < 0.0001$) and were thus included in the model. Increases in turbidity and conductivity were found to be associated with an increase in PAA, probably due to more sanitizer typically being added as debris increase in the tank. Increases in water use duration, pH, and ORP were associated with a decrease in PAA concentration.

Additional step-wise regressions were completed in order to assess the relationship between microbial content (both TC and generic *E. coli)* and observed dump tank water parameters. PAA concentration, pH, conductivity, turbidity, water use duration, and ORP were found to be significant predictors of TC concentration ($r^2 = 0.384$; $p < 0.0001$). Increases in turbidity and conductivity were found to be associated with an increase in TC concentration and with increases in PAA and ORP, one would expect there to be a decrease in TC. Only ORP was found to be a significant predictor for generic *E. coli* ($r^2 = 0.323$; $p = 0.0011$) with decreases in ORP associated with increases in generic *E. coli* concentration.

Observations:

While testing, several observations were made regarding operating practices. They are:

Bin washing - All five participating facilities used bin-immersion dump tanks. Three of the five facilities used wood bins in the line sampled by IDS; one facility only used plastic bins and another used a combination of wood and plastic bins. Some bins (both wood and plastic) were visibly muddy. Wooden bins were occasionally lined with a plastic liner that was manually pulled out of the tank as the apples submerged. One facility used a hose to wash mud off bins as they were exiting the dump tank resulting in a large amount of mud being transferred from the bin back into the dump tank. In addition, water spray from the hose and subsequent splashing had contact with the fruit as it exited the dump tank. Bin condition was also variable: plastic bins were usually visually cleaner than wooden bins. However, bins were not tested for bacterial content, and the amount of visible mud seemed to depend on where the produce was harvested and the harvesting practices utilized in the orchard and not bin type.

Bin labeling - Bins were labeled with stickers for tracking purposes. Prior to entering the dump tank, stickers were removed from the bins by hand. At most facilities, stickers were removed using a metal spatula. At one facility, an employee climbed up each stack of bins by stepping on the lower bins in order to remove the sticker by hand, potentially introducing contamination to each bin before it entered the dump tank.

Debris - At each facility, employees are responsible for removing plant debris from the dump tank water and putting it in designated trash bins. At some facilities, trash bins containing plant debris were removed immediately while other facilities frequently allowed debris to accumulate in trash bins. Excessive debris accumulation in trash bins may provide a place for pest harborage and increase the contamination risk in the facility.

Employee practices - Employee clothing practices varied among facilities. Hair nets and gloves were not required at all facilities. Most facilities used tools to avoid animal intrusion (i.e. mouse traps near doors and/or electrical discharge insect control systems).

Employee Training - All five facilities verified the dump tank water sanitizer concentration by manually testing at varying time increments. However, lack of employee training for performing measurements was observed on at least one occasion. An employee measuring PAA sanitizer level using a titration kit did not properly follow the manufacturer's instructions. As a result of adding multiple reagent drops at once, the employee detected 40 ppm when IDS measurements using two different methods showed zero PAA was present. It is critical that employees are trained in using verification test equipment and methods, and supervisors/other employees should review employee measurements on a routine basis.

Food contact surfaces – Some tools (e.g., items used to move apples) used in the dump tank were not treated as food contact surfaces.

Pest control – Pest control is a challenge for facilities. Fruit fly swarms and rodents were observed on several occasions.

Probes - Each facility's dump tank water system is equipped with probes for automated readings (typically for pH and ORP). Based on the results, adjustments are made by adding water or chemicals in order to maintain sanitizer efficacy. If the probes are not maintained properly or are located in a region where the sanitizer is unevenly mixed, inaccurate readings may occur. At several facilities, the probes were located in the debris filter and often were covered in leaves and dirt. Line employees sporadically shook the probes to remove debris, which also may result in inaccurate ORP and pH readings.

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Figure 1. Questions to Consider for Dump Tank Water HARPC/HACCP Plan

Product

- When was the fruit harvested?
- What is the fruit condition?
- Was the fruit pre-sized?
- Has the fruit been in storage? And if so, for how long?

Microbial testing

- What organism(s) is the dump tank water tested for?
- How often is your dump tank water tested?
- Where do you sample?
- What volume of water do you sample?
- What threshold have you set for microbial levels?
- What are your actions in the event that levels exceed your threshold?

Water

- What is the source of the dump tank water (e.g. city water, well water, etc.)?
- What is the volume of water in the dump tank?
- How often is the water in the dump tank changed?
- What is the fresh water make-up rate?

Chemical use

- What chemicals do you use in your dump tank water (e.g., sanitizer, pH stabilizers, etc.)
- What concentration is targeted? (This could be an ORP target and/or a chemical target.)
- What is the range of the actual sanitizer concentration readings in the dump tank throughout a routine day?
- What is the set point for the system to add more sanitizer chemical?
- When the sanitizer chemical falls below the target concentration and sanitizer is added, how long does it take for the concentration to return to the target concentration?
- When the system is shutdown, is the sanitizer system still operating?
- Where is the sanitizer injected into the tank?
- Where is the sanitizer concentration monitored?

Monitoring equipment

- Is water monitoring equipment automated?
- How often does the automated system record measurements?
- How often are measurements taken to verify the automated system readings?
- For manual measurements, are they documented on paper records and/or in a database?
- What instruments (i.e.., type - e.g., hand-held device, strips; manufacturer and model) are used to make the measurements?
- How often are the automated system instruments calibrated?
- How often are the hand-held instruments calibrated?
- What are the corrective actions if the instruments are not in calibration?

EXECUTIVE SUMMARY

The study objectives were to collect dump tank monitoring data, correlate monitoring parameters (e.g. temperatures, pH, ORP readings, sanitizer levels and exposure by fruit and variety) to microbial levels, and use the findings to refine or inform development of dump tank water preventive controls as part of HARPC requirements or HACCP plans.

Sampling was conducted in six visits at five Washington apple packing facilities for a total of 177.5 operational hours. IDS tested the water's physicochemical parameters – sanitizer concentration (chlorine and peracetic acid (PAA)), ORP, pH, temperature, turbidity and conductivity on site. PAA and chlorine in the form of calcium hypochlorite were the sanitizers used in the sampled facilities. At each facility, dump tank water parameters were measured during normal operations throughout two dump tank water cycles. The first sample was taken in clean water before product entered the dump tank. Thereafter, sampling/measuring (in duplicates) continued at 30 minute intervals until water was discharged from the tank. For microbial testing (total coliform (TC) and generic *E. coli*), 100 millimeter (mL) water samples were collected and shipped overnight on ice to Biologic Resources, LLC in Portland, Oregon. Water samples were collected for TC tests every hour and for generic *E. coli* tests at the beginning and nearest to the end of each operating day as possible.

Over the two-year project, 386 TC tests and 74 generic *E. coli* tests were conducted. TC was present in 19% of dump tank water samples containing chlorine and in 35% of water samples containing PAA. In dump tank water containing either chlorine or PAA, generic *E. coli* was present 17% of the time.

In dump tank water containing chlorine, ORP was the only predictor found to be significantly correlated to TC detection ($r^2 = 0.3924$; $p < 0.0001$); as ORP increased, TC concentration decreased. These findings suggest that maintaining a higher ORP would reduce TC concentration. Interestingly, chlorine concentration was not found to be a significant predictor for TC concentration. ORP, pH, water use duration, and conductivity were collectively strong predictors for generic *E. coli*. ORP, pH, and temperature were collectively found to be significantly correlated with free chlorine measurements ($r^2 = 0.475$; $p < 0.0001$). Individually ORP was not found to be a strong predictor of free chlorine concentration. When pH was within the optimal range for free chlorine formation (6.5 - 7.0), individually ORP was still not a strong predictor for chlorine levels ($r^2 = 0.2740$; $p < 0.0001$; $\beta = 0.096$). Dump tank water pH levels were maintained largely within the ideal range of 6.5 and 7.0.

In PAA-containing dump tank water, PAA concentration, pH, conductivity, turbidity, water use duration, and ORP collectively were found to be significant predictors of TC concentration ($r^2 = 0.384$; $p < 0.0001$). Only ORP was found to be a significant predictor for generic *E. coli* ($r^2 = 0.323$; $p = 0.0011$) with decreases in ORP associated with increases in generic *E. coli* concentration. High turbidity and conductivity measurements were positively associated with increases in microbial concentration. Increases in turbidity and conductivity were found to be associated with an increase in PAA, probably due to more sanitizer typically being added as debris increase in the tank. Increases in water use duration, pH, and ORP were associated with a decrease in PAA concentration.

Among the four facilities using PAA, levels ranged between 0 and 120 ppm during the sampling period. Sixty samples (17.9%) were measured at levels greater than the FDA's 80 ppm limit for wash water; 18.3% of these had levels greater than 100 ppm. ORP was observed between 246 and 685 mV while PAA was in use.

All companies reported having HACCP plans; however, in response to the question of whether the dump tank was considered a critical control point (CCP) in their plan, one company said it was, one company said it was did not, and the other three did not answer the question. Based on the data analysis, sanitizer concentration, ORP, water pH and temperature, and microbial levels need to be measured for an entire dump tank water cycle (i.e., when tank is filled with clean water prior to fruit entry until water is drained from tank) when validating the HARPC/HACCP plan for a dump tank system.