TREATMENT OF VEGETABLE WASH-WATER
TO PERMIT WATER RECYCLING

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Canadian Water Network

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WHY DID WE DO THIS RESEARCH?

Processing of fruit and vegetables requires high volumes of potable water for transporting produce, washing off soils, removing field-acquired contamination and for sanitation. In recent years the standards for water quality being released into the municipal system or environment have become increasingly more stringent. The solids generated during processing need to conform to the *Nutrient Management Act* of 2002[1] for land application to prevent excess levels of nitrogen and phosphates leaching into water courses. In addition, some fruit and vegetable processors are not linked to the municipal system, so they must transport water to and from the facility. Based on environmental concerns, cost and logistics there is a clear need to enhance water management by introducing, amongst other factors, wastewater treatment/recycling technologies. However, little is known about the physical and chemical characteristics of wastewater derived from different processing operations, and subsequently which technologies are most effective for each crop type.

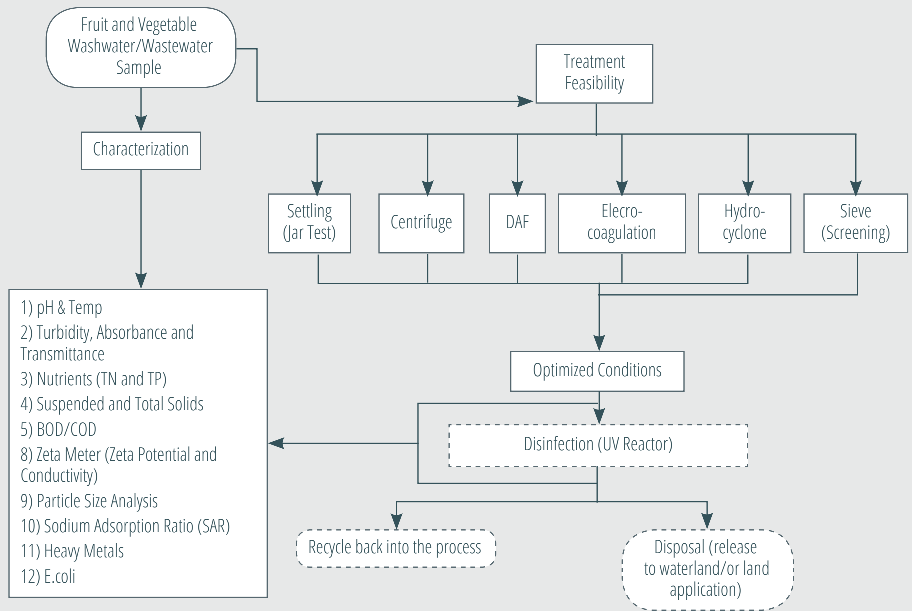

Figure 1: Wash-water characterisation and treatment tests

WHAT DID WE DO?

Working in collaboration with the end-users and their trade associations and with the assistance of OMAFRA, 13 growers who represent a wide variety of produce (ginseng, sweet potato, mixed vegetable, potato, carrot, apple and leafy greens) were selected for inclusion. Pre and post treatment wash-water samples were collected; most growers were sampled two to three times because of potential variability in the wash-water, while for a few crops the team sampled multiple sites, once per site, to assess the impact of differing site conditions such as soil type.

All wash-water samples were analyzed for the following suite of water quality parameters: pH, transmittance, turbidity, total solids, dissolved solids, total suspended solids, conductivity, nutrients nitrogen and phosphorous, total organic carbon, nitrite, nitrate, ammonia and chemical oxygen demand. Pre-treatment samples were used to complete the treatment feasibility tests (Figure 1) to assess which methods of treatment were most effective as a function of various factors, including produce type. These tests consist of settling, settling with coagulation, centrifuge, dissolved air flotation, electro-coagulation and hydro-cyclone, followed by disinfection with UV. Comparing the raw wash-water values to post treatment values allowed the team to assess treatment effectiveness and develop recommendations; based on these results, a preliminary decision matrix was developed to help producers select the ideal treatment technology.

Pilot scale work was also completed to optimize the operating conditions at a continuous wash-water recycling system for the processing of leafy greens at a commercial leafy green facility. The pilot scale system consisted of an initial coagulation step followed by filtration. After filtration, the water went through an ion exchange unit followed by UV disinfection. This project included the assessment of bacteria levels to determine the impact on food safety.

WHAT DID WE FIND?

The wash-water classification tests showed high variability in the water quality parameters (Table 1). The measured ranges were as follows: turbidity, 4 to 1000 NTU, SS, 43 to 12,750 mg/L, COD, ND to 12,100 mg/L, Total N, ND to 170 mg/L and TP, ND to 179 mg/L. The amount of sediment or suspended solids (SS) varies with the produce in that wash-water derived from root vegetable processing has higher solids compared to that from apple or leafy green facilities. Location (soil type) also influenced the nature of the wastewater. For example, wash-water for carrots grown in a sandy soil behaved differently than from carrots grown in the clay soils of the Holland Marsh area, the latter producing water with higher solids content. Likewise, there were wide ranges of the chemical oxygen demand (COD) parameter, which is of environmental concern because it can lower the oxygen level in streams and rivers. The variation in parameter values shows that one treatment approach does not work for every situation, and values change over time and location.

Overall, the trends in Table 1 show that additional factors beyond produce type need to be considered when selecting the appropriate water treatment technology leading to recycling. The importance of conducting a complete and thorough characterization study cannot be stressed enough before deciding which treatment technology should be considered.

TURBIDITY	SUSPENDED SOLIDS	COD	TOTAL N	TOTAL P
RVSW	RVSW	RVSW	RVSW	F
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	F	RVSW	F
RVSW	RVSW	RVSW	F	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	F
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	F
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	RVSW	RVSW
RVSW	RVSW	RVSW	F	RVSW
RVLG	RVLG	RVSW	RVSW	RVSW
RVLG	RVLG	RVLG	RVLG	RVSW
RVLG	RVLG	RVLG	RVLG	RVLG
RVLG	RVLG	RVLG	RVLG	RVLG
RVLG	RVLG	RVLG	F	RVLG
RVLG	RVLG	RVLG	RVLG	RVSW
RVLG	RVLG	RVLG	RVLG	RVLG
F	RVLG	F	RVLG	RVLG
RVLG	RVLG	RVLG	RVLG	RVLG
RVLG	RVLG	RVLG	F	RVLG
RVLG	F	RVLG	RVLG	RVLG
F	F	F	RVLG	RVLG
F	RVLG	F	RVLG	RVLG
F	F	RVLG	RVLG	RVLG
F	F	RVLG	RVLG	RVLG

Root Vegetables - Soil Washing: RVSW

Root Vegetables & Leafy Greens - minimal soil: RVLG

Fruit: F

Dark Blue: High Turbidity (over 300 NTU); SS and COD (over 1500 mg/L); TN and TP (over 45 mg/L)

Medium Blue: Medium Turbidity (100 to 299 NTU); SS and COD (500 to 1499 mg/L); TN and TP (10 to 44 mg/L)

Light Blue: Low Turbidity (0 to 99 NTU); SS and COD (0 to 499 mg/L); TN and TP (0 to 9 mg/L)

White: non detect

Table 1: Variability in Wash-water Characteristics

TREATMENT TRENDS

Feasibility testing showed that sieve treatment was only effective on wash-water that contained heavy level of sand, peels or other larger organic materials, and was ineffective for wash-waters containing clay and dissolved materials (leafy greens and apple). Further review of the treatability tests showed that simple settling can reduce suspended solids concentrations up to 80%. The exception was potatoes which had a removal rate of less than 50%. Soil type also played a large role. For example, loam soils took a long time to settle due to the fine and low density of the soil, compared to sand which settles quickly. To improve settling efficiency, the use of chemical aids (coagulation and flocculation (C & F)) can significantly increase the solid removal efficiencies for all types of wash-water. The coagulants help the smaller particles grow in size, making it easier for the solids to separate. The challenge lies in finding the correct coagulant for the vegetable and soil types.

Hydro-cyclone and centrifuge systems are considered to be mechanical in nature. The hydrocyclone worked well on sand solids, but poorly on the other types of solids. The centrifuge was generally very effective at removing solids to levels in excess of 95% without the need for coagulants. However, the centrifuge had low effectiveness for dissolved solids.

Dissolved air flotation (DAF) is a physical-chemical process. It works well for wash-water with floating material such as charged organic materials, and the process is enhanced by addition of low concentrations of coagulating agents. Electro-coagulation requires no addition of coagulating agents and precipitates organics via a combination of oxygen and aluminum oxides generated by the electrolysis reaction. The process worked well with leafy green water although water derived from potato operations resulted in excessive fouling to the electrode surface. The developed decision matrix for solids removal to help with the selection of appropriate technologies is given in Table 2.

PRODUCE	SETTLING	C & F	DAF	CENTRIFUGE	HYDRO-CYCLONE	SIEVE	ELECTRO-COAGULATION
POTATO	POOR	GOOD	GOOD	GOOD	POOR	POOR	FAIR
SWEET POTATO	FAIR	GOOD	GOOD	GOOD	POOR	POOR	GOOD
GINSENG	FAIR	GOOD	GOOD	GOOD	POOR	FAIR	GOOD
CARROT	FAIR	GOOD	GOOD	FAIR	POOR	FAIR	GOOD
MIXED VEG.	FAIR	GOOD	GOOD	GOOD	FAIR	FAIR	GOOD
LEAFY GREENS	FAIR	GOOD	FAIR	GOOD	POOR	FAIR	GOOD
APPLE	FAIR	GOOD	FAIR	FAIR	POOR	POOR	GOOD

Poor: < 50% reduction; Fair: 50 – 80% reduction; Good: >80% reduction

Table 2: Decision Matrix for Solids Removal (no Peeling)

The Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) were more problematic to remove due to the soluble nature of the contributing constituents. Some of the material which causes oxygen demand was removed through dissolved air flotation, electro-coagulation and coagulation, although it was apparent that biological treatment would be better suited (Table 3). The participating producers had some treatment systems in place which removed COD, such as sequential batch reactors (SBRs) employed by potato producers. These SBRs were able to produce adequate treatment of wash-waters having high COD levels.

PRODUCE	SETTLING	C & F	DAF	CENTRIFUGE	HYDRO-CYCLONE	SIEVE	ELECTRO-COAGULATION
POTATO	NA	GOOD	GOOD	FAIR	NA	NA	FAIR
SWEET POTATO	NA	GOOD	GOOD	GOOD	NA	NA	GOOD
GINSENG	NA	GOOD	GOOD	GOOD	NA	NA	GOOD
CARROT	NA	GOOD	GOOD	FAIR	NA	NA	FAIR
MIXED VEG.	NA	GOOD	GOOD	FAIR	NA	NA	FAIR
LEAFY GREENS	NA	POOR	POOR	POOR	NA	NA	POOR
APPLE	NA	POOR	POOR	POOR	NA	NA	FAIR

Poor: < 50% reduction; Fair: 50 – 80% reduction; Good: >80% reduction

Table 3: Decision Matrix for COD Reduction (no Peeling)

Table 4 shows the variation in nutrient removal (total nitrogen and phosphorus) for the various treatment technologies tested. Settling was not tested as it has minimal impact on the dissolved nature of the nitrogen and phosphorous. For the other treatments, the removal of nitrogen and phosphorous varies with the produce. Using the decision matrix results will help producers assess which process works well.

PRODUCE	SETTLING	C & F		DAF		CENTRIFUGE		ELECTRO-COAGULATION	
	TN & TP	TN	TP	TN	TP	TN	TP	TN	TP
POTATO	NA	P	G	F	G	P	F	F	G
SWEET POTATO	NA	G	G	F	F	G	F	G	G
GINSENG	NA	G	G	G	G	F	G	G	G
CARROT	NA	F	G	F	F	F	P	F	NA
MIXED VEG.	NA	F	G	P	G	P	F	P	G
LEAFY GREENS	NA	P	F	F	F	P	P	NA	F
APPLE	NA	P	G	P	G	P	P	F	F

Poor (P): < 50% reduction; Fair (F): 50 – 80% reduction; Good (G): >80% reduction

Table 4: Decision Matrix for N and P removal

In the disinfection component of the study, it was seen that most produce had *E. coli* in wash-water, ranging from nd to 6.56 log cfu/100 mL. No trends were observed as the data were highly variable. Based on these findings, disinfection will be required if water reuse is desired. For example, a successful disinfection system was optimized for a continuous wash-water recycling system for leafy green processing. The optimized system was comprised of an initial coagulation step followed by filtration, passage through an ion exchange followed by UV lamps treatment; this system achieved solids removal in excess of 90%, with a 2 log CFU (colony forming unit) reduction in bacterial counts. This successful treatment allowed the reuse of the water in the continuous wash system.

WHAT ARE THE IMPLICATIONS FOR DECISION MAKERS?

Completion of the study has led to the development of three decision matrices that help end-users and partners better understand which treatment technologies work best for various wash-waters. It is also possible for the end-users to integrate the various technologies to construct the water treatment system that works best for their operations. Using these simple tools will help with the selection of the appropriate treatment equipment, so that funds are spent on the appropriate equipment, keeping the grower competitive and protecting the environment.

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