Wash-water Treatment Systems

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Objectives of Research

- Develop decision matrix for wash-water options
  - Efficient
  - Cost effective
- Treatment levels
  - At a minimum, less than sewer discharge by-laws
  - PWQO
  - Meet NASM requirements
- Evaluate possibility of wash-water recycling
  - Maintain a high level of food safety

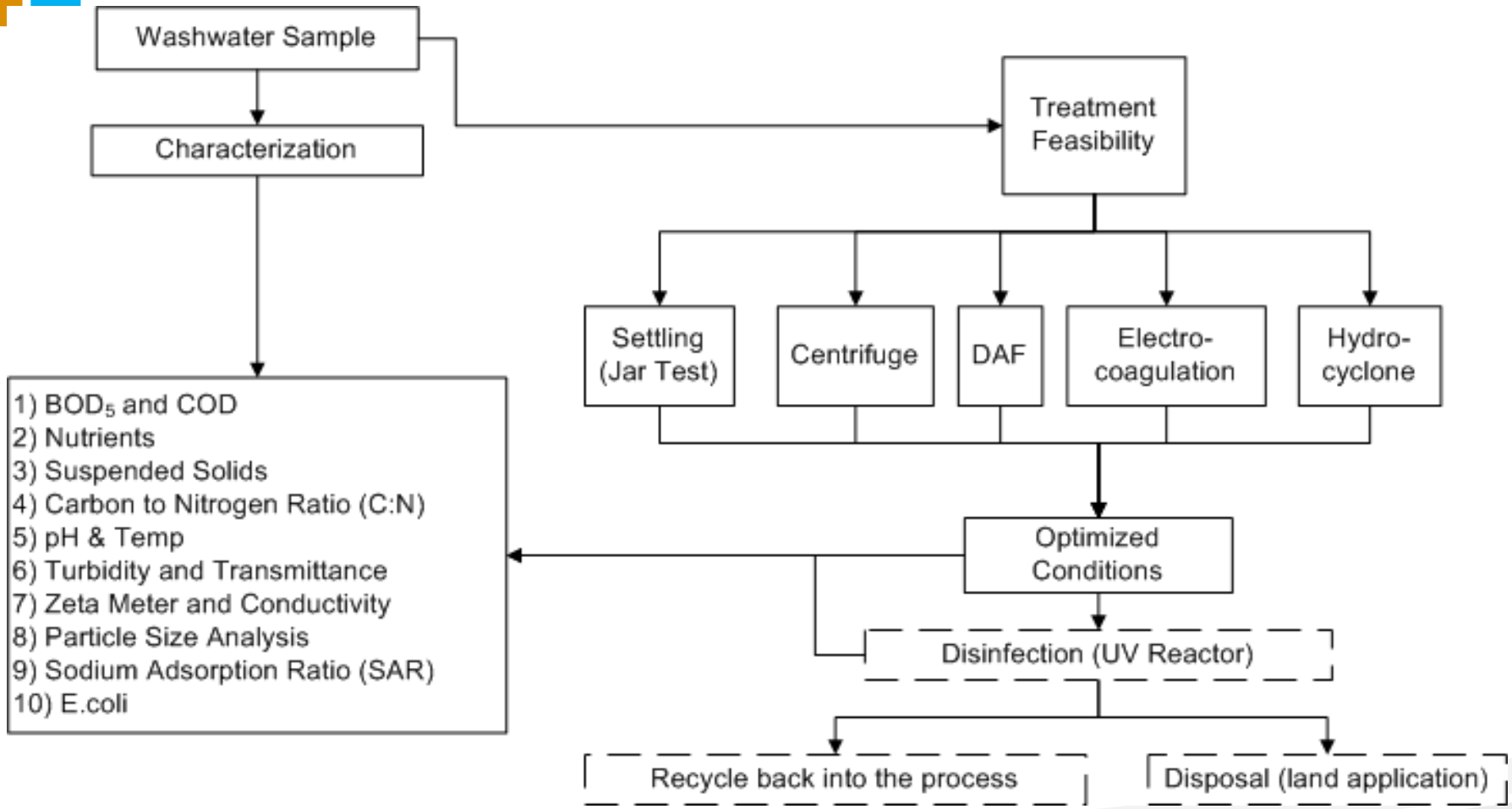
Types of Produce for Wash-water

- Carrots
- Potatoes
- Sweet Potatoes
- Mixed vegetable
- Ginseng
- Apple
- Leafy Greens

Assessment of Treatment Options

- Solids removal
  - Density (high – settle vs. low - float)
  - Size (large – easy to screen out)
  - Source (type of vegetable, soil, and processing)
- BOD (COD) reduction
  - Any indirect impact
- Pathogen elimination
  - Set targets for pathogens
  - Source (type of vegetable/fruit, soil, and processing)

Methodology



Wash-water Classification

Highest to lowest	Turbidity (NTU)		Suspended Solids (mg/L)		COD (mg/L)		Total N (mg/L)		Total P(mg/L)	
Root Vegetables; Soil Washing	Potato 3	1,000	Sweet Potato 2	12,732	Ginseng 2	12,103	Ginseng 2	170	Apple 1 - F1	179
	Potato 3	1,000	Ginseng 2	12,039	Potato 3	5,740	Potato 2	61	Potato 2	99
	Potato 3	1,000	Potato 3	7,794	Potato 3	5,340	Potato 3	53	Ginseng 2	76
	Potato 1	958	Potato 3	7,160	Apple 2	3,900	Potato 2	49	Apple 1 - F2	73
	Potato 1	830	Potato 2	4,706	Potato 2	2,104	Apple 2	35	Potato 3	53
	Potato 2	817	Potato 2	3,894	Potato 2	1,870	Mixed Vegetable 1	23	Potato 2	29
	Sweet Potato 1	803	Potato 1	2,846	Potato 3	1,115	Mixed Vegetable 1	22	Potato 3	26
	Sweet Potato 2	749	Potato 1	2,738	Potato 1	1,049	Potato 3	17	Apple 2	14
	Potato 1	745	Ginseng 2	2,392	Potato 1	1,000	Potato 2	13	Sweet Potato 2	11
	Carrot 2	700	Potato 2	1,772	Potato 1	867	Potato 3	11	Apple 1 - FR	10
	Potato 2	620	Potato 1	1,768	Sweet Potato 1	854	Potato 1	10	Potato 1	9
	Sweet Potato 1	600	Carrot 2	1,476	Potato 2	788	Ginseng 1	7	Potato 1	9
	Ginseng 2	595	Ginseng 1	1,055	Carrot 2	654	Potato 1	6	Potato 3	7
	Mixed Vegetable 1	589	Sweet Potato 1	900	Leafy Greens 1 (spinach)	583	Apple 1 - FR	4	Sweet Potato 1	7
	Ginseng 1	571	Sweet Potato 1	853	Ginseng 1	566	Potato 1	4	Potato 1	6
Root veg. & Leafy Green Veg.; Very minimal soil	Mixed Vegetable 1	530	Ginseng 1	699	Carrot 2	370	Sweet Potato 1	4	Ginseng 1	6
	Ginseng 1	448	Potato 3	698	Carrot 2	338	Ginseng 1	4	Ginseng 1	6
	Mixed Vegetable 1	347	Mixed Vegetable 1	638	Leafy Greens 1 (spinach)	294	Leafy Greens 1 (spinach)	3	Mixed Vegetable 1	5
	Sweet Potato 1	330	Mixed Vegetable 1	456	Ginseng 1	241	Carrot 2	3	Carrot 2	4
	Ginseng 1	124	Ginseng 1	312	Sweet Potato 1	173	Apple 1 - F1	3	Mixed Vegetable 1	4
	Carrot 2	123	Mixed Vegetable 1	306	Mixed Vegetable 1	168	Sweet Potato 1	3	Potato 2	3
	Leafy Greens 1 (spinach)	109	Sweet Potato 1	299	Mixed Vegetable 1	165	Leafy Greens 1 (spinach)	3	Leafy Greens 1 (spinach)	3
	Apple 2	108	Leafy Greens 1 (spinach)	215	Apple 1 - F1	143	Carrot 2	3	Ginseng 1	2
	Carrot 2	86	Carrot 2	206	Sweet Potato 1	131	Carrot 2	2	Sweet Potato 1	1
	Leafy Greens 1 (spinach)	66	Carrot 2	182	Ginseng 1	114	Apple 1 - F2	2	Carrot 2	1
	Leafy Greens 1 (spinach)	61	Apple 1 - F1	140	Mixed Vegetable 1	110	Ginseng 1	1	Carrot 2	1
Fruit	Apple 2	56	Apple 2	126	Apple 1 - FR	66	Sweet Potato 2	nd	Leafy Greens 1 (spinach)	1
	Apple 1 - F1	23	Leafy Greens 1 (spinach)	69	Apple 1 - F2	20	Ginseng 2	nd	Ginseng 2	nd
	Apple 1 - FR	17	Apple 1 - FR	51	Leafy Greens 1 (spinach)	nd	Sweet Potato 1	nd	Sweet Potato 1	nd
	Apple 1 - F2	4	Apple 1 - F2	43	Sweet Potato 2	nd	Mixed Vegetable 1	nd	Mixed Vegetable 1	nd

RESULTS To DATE

- Simple settling can reduce turbidity by up to >80%
  - Except for some root vegetables with post washing process
  - Soil types
- Chemical aids (coagulants) can significantly increase the solid removal efficiencies for all types of wash-water
  - >90%.
- Centrifuge can achieve reduction of >95% without any chemical aid.
  - Low effectiveness for dissolved solids

DAF

- Remove SS solids
  - Works well for high organic loading, i.e., wash-water from peeling processes.
  - Ineffective for high inorganic loading, i.e., wash-water with soils/sand.
- Some reduction in BOD (COD) levels
- Captures dissolved solids more effectively
  - Good potential for water reuse.

Electrolysis

- Short treatment times are effective at reducing turbidity of lettuce washwater.
- Able to reduce TSS by >90%
- Able to reduce BOD by ~95%

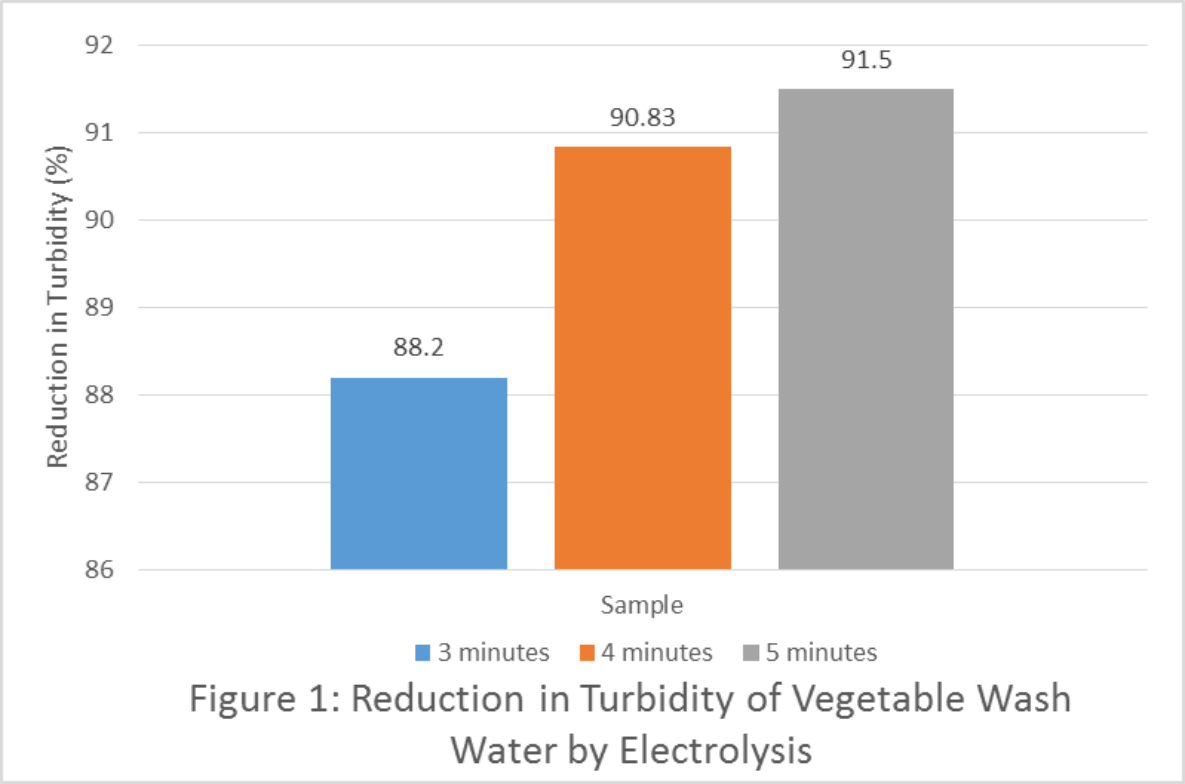
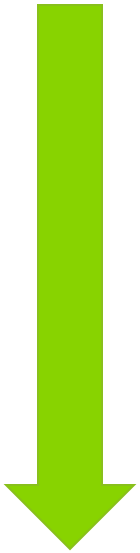


Figure 1: Reduction in Turbidity of Vegetable Wash Water by Electrolysis

Hydro-cyclone Results: Transmittance

1) Sweet potato & Mixed vegetable
2) Leafy greens
3) Potato
4) Carrot
5) Apple
6) Ginseng

Best Performance



Worst Performance

Ranked based on percent reduction averages.

SS and Transmittance (no peeling)

Vegetable/Fruit	Settling	DAF	Centrifuge	Hydro-cyclone	Sieve	Electro-coagulation
Potato	Good	Fair	Good	Poor	Poor	Fair
Sweet Potato	Good	Fair	Good	Poor	Poor	Good
Ginseng	Good	Fair	Good	Poor	Poor	Good
Carrot	Good	Fair	Fair	Poor	Fair	Good
Mixed Veg.	Good	Fair	Good	Fair	Fair	Good
Leafy Greens	Good	Fair	Good	Poor	Fair	Good
Apple	Poor	Fair	Fair	Poor	Poor	Good

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

Results to Date – TP and TN

- Settling and DAF
  - TP > 80%
  - TN – variable
- Electrocoagulation
  - Variable
- Centrifuge
  - TP - Fair (heavy solids) to Poor
  - TN - Poor
- Sieve and Hydro-cyclone
  - Not tested → negligible

Results to Date – E. coli

- All produce had E. coli in wash-water
  - Largest at 6.56 log cfu/100 ml
  - Lowest nd
- No trends as data all over the place
  - Ginseng varies from nd to 6.56 log cfu/100 ml
  - Apple varies from nd to 4.78 log cfu/100 ml
  - On-site pre and post treatment values
- Disinfection required if water reuse desired

Electrocoagulation: Lettuce Wash-water

Parameter	% Decrease
Turbidity	99%
BOD	29%
COD	46%
E. coli	1 log cfu*
Listeria	1 log cfu

*companion work with lettuce wash-water using membrane and UV, obtain 5 log removal

Effluent limits

- Producer and processors need to meet limits
- Regulations do not directly address limits
  - Per case basis
- Limits - reference
  - Drinking water – MOE
  - Release to surface water – PWQO
    - Rural producers
  - Sanitary and combined sewer – Municipality
    - Further treatment

Effluent Limits

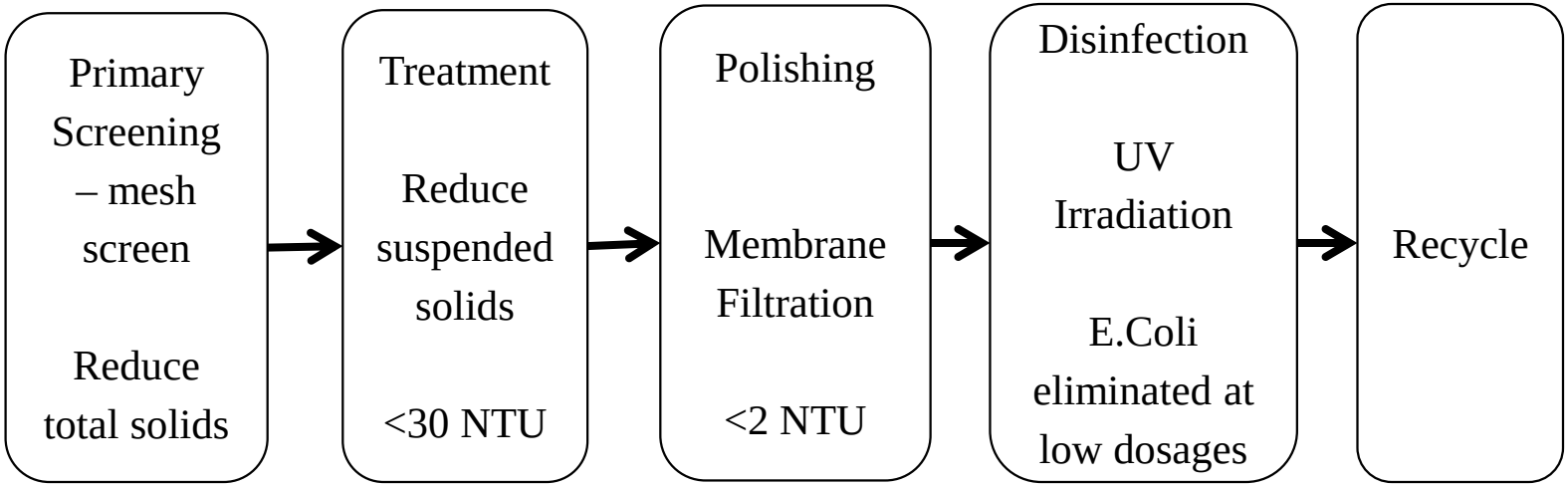
Parameter	Target concentration for drinking water (mg/L or ppm)	Target concentration for sanitary and combined sewer discharge (mg/L or ppm)	Provincial Water Quality Objectives[3] (mg/L or ppm)
Ammonia as N			0.02*
Nitrate as N	10		
Nitrite as N	1		
TKN		100	
Organic Nitrogen (TKN – Ammonia as N)	0.15		
Total Phosphorus	0.01	10	0.02
pH (Log_{10} $[H^+]$)	6.5 – 8.5		6.5 - 8.5
BOD		300	20[a]
COD			
TSS		350	25[a]
TDS	500		
Turbidity (NTU)	5		
Pathogens	not detectable		400 per 100 mL[a]
Hardness	80 – 100		
*Fats, Oil and Grease	Site specific	150	

[1]Data obtained from Supporting Document for Ontario Drinking water Quality Standards, Objectives and Guidelines, Tables 1, 2, and 4
[2]Data obtained from City of Toronto Sewer Discharge and Storm water Discharge Limits, Table 1
[3]Data obtained from Provincial Water Quality Objectives for Surface Water, some parameter are subjected to additional conditions
*See additional comments regarding parameter measurement in reference documents
[a] Limits for effluent discharged to receiving waters; Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments

Comparison of solid removal technologies

Type	Factors effecting treatment efficiency in addition to particle size, type, flow rates and retention time	Require chemical aid to operate	Cost	Footprint
Settling	settling tank dimensions	Yes and No	low	largest
Dissolved Air Flotation	saturation pressure and detention time	Yes, coagulant and flocculant	highest	large
Electrolysis	current demand; other parameters also removed	No	high	medium
Centrifuge	rotation speed	No	high	small
Hydro-cyclone	influent flow velocity	No	low	smallest

Water Recycling Quality



- Water quality equal to tap water
- Possible to close the loop and reduce water consumption

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Thank you

Questions