# <u>REPORT on PHYSICO-CHEMICAL TREATMENT OF VEGETABLE WASH</u> <u>WASTEWATER</u>

Prepared by

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#### 1. Analysis of Vegetable Wash Wastewater (VWW)

Samples were taken on Feb 17, 2015 and delivered to the Western wastewater laboratory on Feb 19. The samples were stored at 4 °C in a cold room prior to analysis. The detailed results of the analysis along with the analytical methods are presented in Table 1. VWW samples had pH 7.49, alkalinity 298 mg/L, turbidity 268 NTU, and an average particle size of 99 µm. Chemical oxygen demand (COD), and 5-day biochemical oxygen demand (BOD), as well as total nitrogen (TN), total phosphorous (TP) were analyzed for the unfiltered samples and the samples filtered through 0.45 micron filter paper. Parameters determined for the unfiltered samples are designated by total and those measured in the filtered samples are designated as soluble. Total and soluble COD i.e. TCOD and SCOD concentrations were 487 mg/L and 101 mg/L, respectively. Similarly, respective values of TBOD and SBOD were 52 mg/L and 33 mg/L. TBOD accounted for 11% of TCOD, while SBOD accounted for 33% of the SCOD, indicating low readily biodegradable fraction of the organics in the VWW. TSS (total suspended solids), VSS (volatile suspended solids), and TDS (total dissolved solids) concentrations were 453 mg/L, 403 mg/L, and 450 mg/L, yielding 89% VSS content of TSS and the TDS represented 50% of the total solids (TS). The TN concentration was 11 mg/L while the predominant form of nitrogen was particulate nitrogen with a small fraction of inorganic nitrogen at 3.6% of TN. Total phosphorus was present at 2.9 mg/L including 0.8 mg/L ortho-P.

Table 1. Characteristics of	f VWW
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pH         7.53         7.45         7.49         0.06         pH meter           Alkalinity (mg         300         296         298         3         Standard Methods (SM)           CaCOyL         2         276         268         12         Thermo Orion AQUA fast II           Particle size (µm, 98         100         99         1.4         MASTERSIZER 2000           volume weighted mean         7         50         53         52         2           SBOD (mg/L)         35         30         33         4         SM &HACH LBOD METER           SBOD (mg/L)         495         478         487         12         HACH LBOD METER           SCOD (mg/L)         118         84         101         24         HM           Solids         7         440         467         453         19         SM           VSS (mg/L)         440         460         450         14         SM         SM           Nitrogen         7         9         11         2         Galculation (a-b-c)         mg/L           (a) TN (mg N/L)         12         9         10         2         Calculation (a-b-c)         mg/L           NH_3-N (mg N/L)         0.3 <th>Parameters</th> <th>Test1</th> <th>Test2</th> <th>Average</th> <th>Std</th> <th>Analytical Methods</th>	Parameters	Test1	Test2	Average	Std	Analytical Methods
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	pH	7.53	7.45	7.49	0.06	pH meter
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Alkalinity (mg	300	296	298	3	Standard Methods (SM)
Particle size (µm, volume weighted mean)98100991.4MASTERSIZER 2000Oxygen demand	CaCO <sub>3</sub> /L)					
volume weighted mean         Image: Market mean         Imag	<b>Turbidity (NTU)</b>	259	276	268	12	-
mean         mean         mean         mean         mean           Oxygen demand $\mathbf{F}$ $\mathbf{F}$ $\mathbf{F}$ $\mathbf{F}$ TBOD (mg/L)         50         53         33         34         SM & HACH LBOD METER           SBOD (mg/L)         495         478         447         12         HACH method (HM)           SCOD (mg/L)         118         84         101         24         HACH method (HM)           SCOD (mg/L)         118         84         101         24         HACH method (HM)           SCOD (mg/L)         440         467         453         19         S         SM           TSS (mg/L)         440         466         450         14         SM         SM           TDS (mg/L)         412         9         11         2         Galuation (a-bcc)         SM           Nitrogen		98	100	99	1.4	MASTERSIZER 2000
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TBOD (mg/L)         50         53         52         2         SM &HACH LBOD METER SBOD (mg/L)           35         30         33         4         SM &HACH LBOD METER TCOD (mg/L)         495         478         487         12         HACH method (HM)           SCOD (mg/L)         118         84         101         24         HACH method (HM)           SOlids						
SBOD (mg/L)         35         30         33         4         SM &HACH LBOD METER           TCOD (mg/L)         495         478         487         12         HACH method (HM)           SCOD (mg/L)         118         84         101         24         HACH method (HM)           SCOD (mg/L)         118         84         101         24         HACH method (HM)           Solids             HACH method (HM)           SS (mg/L)         440         467         453         19         SM           TSS (mg/L)         440         466         450         14         SM           Nitrogen            SM         SM           Nitrogen             Galculation (a-b-c)           (a) TN (mg NL)         12         9         10         2         Calculation (a-b-c)           Sol TN (mg NL)         0         0         0         0         MM (STN seems to be less than 0.5           MH3-N (mg         0         0         0         0         MM (STN seems to be less than 0.5           NH3-N (mg NL)         0.3         0.3         0.0         HM (STN seems	•0	50	52	50	2	
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Solids         Image: second seco						
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VSS (mg/L) TDS (mg/L)         4407 440         400 460         403 450         5 14         SM           Nitrogen		440	A ( 8	450	10	
TDS (mg/L)         440         460         450         14         SM           Nitrogen			-			
Nitrogen         Image: Marking ML (a) TN (mg N/L)         12         9         11         2         General (a) TN (mg N/L)         12         9         11         2         Calculation (a-b-c)           Sol TN (mg N/L)         12         9         10         2         Calculation (a-b-c)           Sol TN (mg N/L)         0         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH <sub>3</sub> -N (mg N/L)         0.3         0.3         0.3         0.0         HM (STN seems to be less than 0.5 mg/L)           NH <sub>3</sub> -N (mg N/L)         0.3         0.3         0.3         0.0         HM           (b) NO <sub>3</sub> -N (mg N/L)         0.3         0.3         0.3         0.0         HM           (c) NO <sub>2</sub> -N (mg N/L)         0.09         N/A         0.09         HM           Phosphorus         Image: Colored (Colored (Col					-	
(a) TN (mg N/L)         12         9         11         2         Calculation (a-b-c)           KN (mg N/L)         12         9         10         2         Calculation (a-b-c)           Sol TN (mg N/L)         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH3-N (mg         0         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH3-N (mg         0         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH3-N (mg N/L)         0.3         0.3         0.3         0.0         HM           (b) NO3-N (mg N/L)         0.09         N/A         0.09         HM         HM           (c) NO2-N (mg N/L)         0.09         N/A         0.09         HM         HM           Phosphorus         Image: Color (mg P/L)         3.0         2.8         2.9         0.2         HM           Ortho-P (mg P/L)         0.8         0.7         0.8         0.1         HM           Ratios         Image: Color (mg/L)         0.8         0.2         Image: Color (mg/L)         Im	· · · · · ·	440	400	450	14	SIVI
TKN (mg N/L)         12         9         10         2         Calculation (a-b-c)           Sol TN (mg N/L)         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH3-N (mg         0         0         0         0         10         mg/L)           NH3-N (mg N/L)         0.3         0.3         0.3         0.0         Image: Comparison of the	0	12	0	11	2	TIM
Sol TN (mg N/L)         0         0         0         0         0         HM (STN seems to be less than 0.5 mg/L)           NH <sub>3</sub> -N (mg N/L)         0         0         0         0         0         10						
NH3-N (mg NL)         0         0         0         0         0         mg/L)           (b) NO3-N (mg N/L)         0.3         0.3         0.3         0.0         HM           (c) NO2-N (mg N/L)         0.09         N/A         0.09         HM         HM           Phosphorus         0.09         N/A         0.09         HM         HM           Phosphorus         0.09         N/A         0.09         HM         HM           Ortho-P (mg P/L)         3.0         2.8         2.9         0.2         HM           Mortho-P (mg P/L)         0.8         0.7         0.8         0.1         HM           PCOD/VSS          40.96         1         HM           PTF/NSS          0.96         1         1           PTP/VSS          0.03         1         1           PTP/VSS          0.22         1         1           TBOD/TCOD          46         1         1           TBOD/TN          5         1         1           TBOD/TN          5         1         1						
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N/L)              (b) NO <sub>3</sub> -N (mg N/L)         0.3         0.3         0.0          HM           (c) NO <sub>2</sub> -N (mg N/L)         0.09         N/A         0.09          HM           Phosphorus         0.09         N/A         0.09          HM           Phosphorus         0.0         0.8         2.9         0.2            TP (mg P/L)         3.0         2.8         2.9         0.2            Ortho-P (mg P/L)         0.8         0.7         0.8         0.1            Ratios         0         0.96           0.03            PCOD/VSS         0.022         0.005          0.022             TBOD/TCOD         0.11          46               TBOD/TN         5          166	NH2-N (mg	0	0	0	0	_
(b) NO3-N (mg N/L)       0.3       0.3       0.3       0.0       HM         (c) NO2-N (mg N/L)       0.09       N/A       0.09       HM       HM         Phosphorus       I       I       I       I       HM         Phosphorus       3.0       2.8       2.9       0.2       HM         Ortho-P (mg P/L)       0.8       0.7       0.8       0.1       HM         Ratios       I       I       I       I       I       IIII         PCOD/VSS       I       0.96       IIII       IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII		Ŭ	Ū	v	U	
(c) NO2-N (mg N/L)       0.09       N/A       0.09       HM         Phosphorus             TP (mg P/L)       3.0       2.8       2.9       0.2       HM         Ortho-P (mg P/L)       0.8       0.7       0.8       0.1       HM         Ratios            HM         PCOD/VSS        0.96          HM         PCOD/VSS         0.03		0.3	0.3	0.3	0.0	HM
Phosphorus         Image: Constraint of the system         Image: Constraint of the system <td></td> <td></td> <td>N/A</td> <td>0.09</td> <td></td> <td>HM</td>			N/A	0.09		HM
Ortho-P (mg P/L)         0.8         0.7         0.8         0.1         HM           Ratios                HM           PCOD/VSS           0.96						
Ratios         0.96           PCOD/VSS         0.96           PTKN/VSS         0.03           PTP/VSS         0.005           SCOD/TDS         0.22           TBOD/TCOD         0.11           TCOD/TN         46           TBOD/TN         5           TCOD/TP         166	-	3.0	2.8	2.9	0.2	HM
PCOD/VSS       0.96         PTKN/VSS       0.03         PTP/VSS       0.005         SCOD/TDS       0.22         TBOD/TCOD       0.11         TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	Ortho-P (mg P/L)	0.8	0.7	0.8	0.1	HM
PTKN/VSS       0.03         PTP/VSS       0.005         SCOD/TDS       0.22         TBOD/TCOD       0.11         TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	Ratios					
PTP/VSS       0.005         SCOD/TDS       0.22         TBOD/TCOD       0.11         TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	PCOD/VSS			0.96		
SCOD/TDS         0.22           TBOD/TCOD         0.11           TCOD/TN         46           TBOD/TN         5           TCOD/TP         166	PTKN/VSS			0.03		
TBOD/TCOD       0.11         TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	PTP/VSS			0.005		
TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	SCOD/TDS			0.22		
TCOD/TN       46         TBOD/TN       5         TCOD/TP       166	TBOD/TCOD					
TBOD/TN5TCOD/TP166						
TCOD/TP 166						
	TBOD/TP			18		

## 2. VWW treatment with Alum Addition

### **2.1 Simple settling test**

In order to explore the settleability of VWW, 1 L sample was transferred to a beaker and settleability of particles was monitored over time. Efficiency of this gravitational settleability was measured through regular reading of turbidity of supernatant during the test as shown in Table 2. In 20 min, turbidity decreased to 15% of the initial value.

Time (min)	Turbidity (NTU)		Removal (%)	
(		375		-
1(		94	75	5
20		55	85	5
3(		61	84	4
4(		54	80	6
56	j l	41	89	9
85	5	42	89	9

Table 2. Turbidity changes during VWW settleability test.

## 2.2 Jar test

Jar testing was conducted to investigate the optimal alum dose for VWW treatment. Six jars were used each filled up with 1 L sample each. By adding different aliquots of alum stock solution (Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>.18H<sub>2</sub>O), six jars had different alum concentrations ranging from 50 mg/L to 300 mg/L with an interval of 50 mg/L. The procedure after alum addition included fast mixing at 100 rpm for 1 min, slow mixing for 15 min at 30 rpm, and settling for 20 min. After settling, pH, turbidity, TCOD of supernatant were immediately measured as presented in Table 3. Low turbidities of less than 1 NTU were seen at alum dosages of 150 mg/L and greater.

	Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
Alum dosage (mg/L)	50	100	150	200	250	300
Initial pH			7.	04		
Final pH	6.9	6.8	6.7	6.56	6.47	6.38
Initial Turbidity	357	371	358	371	369	374
(NTU)						
<b>Final Turbidity</b>	35	24	<1	<1	<1	<1
(NTU)						
Final TCOD (mg/L)	91	N/A	64	59	53	54

Table 3. Jar test results (final values are from supernatant).

Since the performance at 150 mg/L alum dose showed better than cases at lower doses and similar to results at higher dosage, further analysis of supernatant from Jar 3 was conducted. Results are shown in Table 4. Turbidity, TSS, and TP removal efficiencies were >97%. Similarly, TCOD and TN removal also showed greater than 87% while TBOD removal was 56%.

Table 4. Characteristics of samples treated with alum 150 mg/L	

Parameters	Raw VWW	-		of VWW 150 mg/L alum Average	Target effluent quality	Removal (%)
pH	7.49	6.70	-	6.70	-	-
Turbidity (NTU)	268	<1	-	<1	-	>99
TBOD (mg/L)	52	22	23	23	25	56
TCOD (mg/L)	487	65	63	64	-	87
TSS (mg/L)	453	7	7	7	30	>99
TDS (mg/L)	450	513	503	508	-	-
TN (mg N/L)	11	<0	2	<1	-	>90
TKN (mg N/L)	10	<0	2	<1	2	>90
TP (mg P/L)	2.9	<0.1	<0.1	<0.1	0.5	>97

Solids removal using alum 150 mg/L was estimated using solid mass balances (Table 5). On a mass basis, TSS distribution in supernatant and settled fraction showed that 98% of the initial TSS mass was found in the settled sludge.

	Raw VWW	Supernatant	Settled	Supernatant + settled
TS (mg/L)	1070	515	32820	-
TSS (mg/L)	453	7	-	-
Volume (L)	1	0.981	0.019	-
TS (g)	1.07	0.51	0.62	1.13
TS fraction (%)		45 (=0.51/1.13×100)	55 (=0.51/1.13×100)	-
TSS (g)	0.45	0.01	0.44 (=0.45-0.01)	-
TSS fraction (%)		2 (=0.01/0.45×100)	98 (=0.01/0.454×100)	-

Table 5. Mass distribution of solids after treatment with alum 150 mg/L.

## **Summary and Conclusions**

Based on the completed testing and characterization of the sample received, it appears that chemical coagulation, flocculation, and sedimentation can readily achieve the required TSS, TKN, and TP effluent requirements of 30, 2, and 0.5 mg/L, respectively. The successful closure of the TSS mass balance verifies the accuracy of the observed results. Although the treated wastewater BOD averaged 23 mg/L, slightly below the 25 mg/L effluent requirement, the margin of safety is too low for scale-up. Accordingly, further testing of a large number of samples that reflect the range of pollutant concentrations experienced in real life is warranted.