REPORT on PHYSICO-CHEMICAL TREATMENT OF VEGETABLE WASH WASTEWATER

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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 VWW

Parameters	Test1	Test2	Average	Std	Analytical Methods
pH	7.53	7.45	7.49	0.06	pH meter
Alkalinity (mg $CaCO_3$/L)	300	296	298	3	Standard Methods (SM)
Turbidity (NTU)	259	276	268	12	Thermo Orion AQUA fast II
Particle size (µm, volume weighted mean)	98	100	99	1.4	MASTERSIZER 2000
Oxygen demand					
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	HM
Solids					
TSS (mg/L)	440	467	453	19	SM
VSS (mg/L)	407	400	403	5	SM
TDS (mg/L)	440	460	450	14	SM
Nitrogen					
(a) TN (mg N/L)	12	9	11	2	HM
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)
NH_3-N (mg N/L)	0	0	0	0	HM
(b) NO_3-N (mg N/L)	0.3	0.3	0.3	0.0	HM
(c) NO_2-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					
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		
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.

Table 2. Turbidity changes during VWW settleability test.

Time (min)	Turbidity (NTU)	Removal (%)
0	**375**	**-**
10	**94**	**75**
20	**55**	**85**
30	**61**	**84**
40	**54**	**86**
56	**41**	**89**
85	**42**	**89**

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 ($Al_2(SO_4)_3.18H_2O$), 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 l NTU were seen at alum dosages of 150 mg/L and greater.

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

Alum dosage (mg/L)	Jar 1 50	Jar 2 100	Jar 3 150	Jar 4 200	Jar 5 250	Jar 6 300
Initial pH			**7.04**			
Final pH	**6.9**	**6.8**	**6.7**	**6.56**	**6.47**	**6.38**
Initial Turbidity (NTU)	**357**	**371**	**358**	**371**	**369**	**374**
Final Turbidity (NTU)	**35**	**24**	**<1**	**<1**	**<1**	**<1**
Final TCOD (mg/L)	**91**	**N/A**	**64**	**59**	**53**	**54**

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	Supernatants of VWW treated with 150 mg/L alum			Target effluent quality	Removal (%)
		Test1	Test2	Average		
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.

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

	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)**	**-**

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.