

Introduction

Because the retention time of the CleanB® (10 minutes) is a small fraction compared to conventional practices, like digestion (30-40 days), nutrients and solids are not allowed time to solubilize and very high capture rates are obtained within the dewatered biosolids. Increased capture rates lead to a multitude of benefits, including, but not limited to; 1) increased front-end capacity (less air and retention times needed for nitrification/denitrification), 2) decreased effluent concentrations of total solids (TS), nitrogen (TN), and phosphorus (TP), 3) reduced costs by eliminating the need for chemical precipitation of phosphorus, and 4) reducing struvite formation due to a high orthophosphate return.

The following data and comparisons are illustrated in this document:

- Typical capture rates of TN, TP and TS utilizing CleanB®
- CleanB® vs Aerobic Holding– nutrients and solids capture rates
- CleanB® vs Anaerobic Digestion – nutrients capture rates

Typical Capture Rates Utilizing CleanB®

The following example illustrates the results from Raw, Treated, and Centrate samples taken from a CleanB® operation at Spencer's WWTF (Clay County, FL). Seven sets of samples were collected in 2015 within a period of two weeks. These lab analyses were conducted by Pace Analytical®. Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorous (TP) were measured. The data in red signify outliers and were not considered in the average calculations.

The key major conclusions from this work effort are:

- 1) There is some solubilization of the TSS within the CleanB® process, roughly 7% of the TSS is solubilized,
- 2) The majority of the TN mass is retained within the biosolids (97%) with only 3% returned to the plant via the centrate, and
- 3) The majority of the TP mass is also retained within the biosolids (95%) with only 5% returned back to the plant via the centrate.

A summary of the data obtained and analyzed is illustrated below:

Spencer WWTF Filtrate Testing & Mass Balance (CleanB®):

	TSS mg/L	TN mg/L	TP mg/L
Raw	9010	589	306
Trtd	8450	599	288
Filtrate	50	10.7	96.3
Raw	10700	8.2	18.4
Trtd	10400	34.4	46.9
Filtrate	50	11.2	18
Raw	8760	555	242
Trtd	8220	537	234
Filtrate	63	12.2	13.1
Raw	8700	599	241
Trtd	8100	611	243
Filtrate	76	7.2	14
Raw	5300	447	339
Trtd	5820	423	319
Filtrate	56.9	13.8	13.1
Raw	8580	577	47.8
Trtd	7500	555	45.4
Filtrate	90	15.8	11.6
Raw	9970	585	217
Trtd	8180	540	217
Filtrate	74	14.6	10.9
Averages*			
Raw	8717	558	269
Trtd	8095	544	260
Filtrate	65.7	12.38	13.82

X

indicates questionable data (outliers)

*

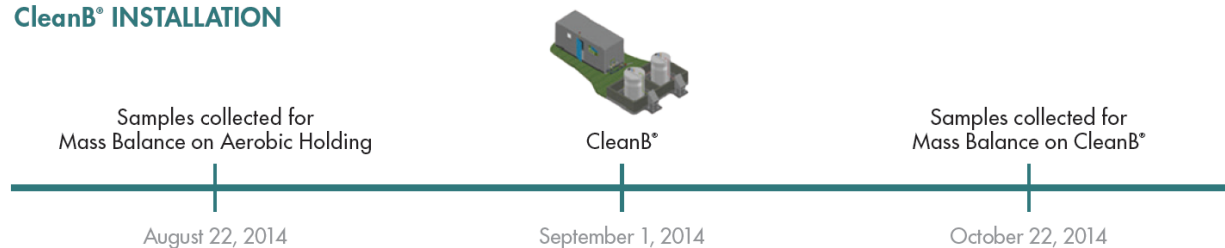
Averages exclude outliers

CleanB® Compared to Aerobic Holding

In September of 2014, a CleanB® system was installed at the Ft. Pierce, FL WWTF. Before the CleanB® installation, the plant wasted to a Dissolved Air Flotation (DAF) unit for thickening and held sludge in an aerobic holding tank prior to contract dewatering and landfill disposition. After installation of the CleanB® system, the plant started wasting directly from the clarifier to the CleanB® unit and centrifuge dewatering.

The following chart illustrates the timing of sample collections and CleanB® installation. Differences in nutrients leaving the clarifier were noted and were attributed to the timing of the samples. The capture rates of solids and nutrients after installation of the CleanB® show a substantial improvement when compared to the previous practice. Percent capture of Nitrogen went from 25.9% with DAF thickening and aerobic holding to 92.9% with CleanB® treatment. Percent capture of Phosphorous went from 21.1% to 83.1% with CleanB® treatment.

CleanB® INSTALLATION



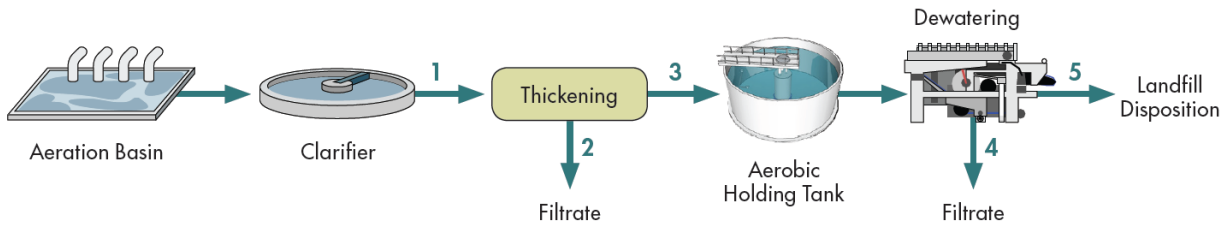
The key conclusions from this work effort are:

1. Solids return via centrate was reduced by 70% (76 tons/year)
2. %TS on dewatered biosolids improved by 21% (52 less Truckloads/year)
3. Total Nitrogen return via centrate was reduced by 92% (45 tons/year)
4. Total Nitrogen leaving with the biosolids was increased by 182% (35 tons/year)
5. Total Phosphorous return via centrate was reduced by 66% (9 tons/year)
6. Total Phosphorous leaving with the biosolids was increased by 476% (20 tons/year)

AEROBIC HOLDING MASS BALANCE

The following is a mass balance for the aerobic holding process while treating 2.6 DT/day. Using the results provided by the lab analyses, a complete mass balance was calculated around the Aerobic holding process at the Ft. Pierce WWTF. The balance was done by simultaneously solving equations to calculate the filtrate and dewatered biosolids flow by using the *Thickener Inflow %TS*, *Thickener Outflow %TS*, *Thickener Filtrate %TS*, *Dewatered Centrate %TS*, and *Dewatered Biosolids %TS*. The mass balance represents a 952 DT/yr facility operating 7 days a week. Since surface aerators were used at Ft. Pierce with a short SRT, their aerobic holding process did not achieve a volatile solids reduction.

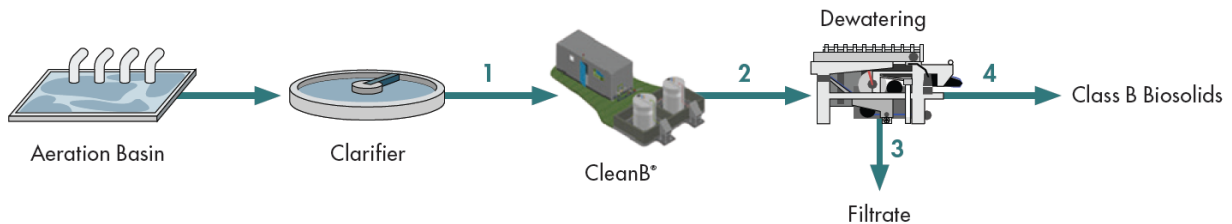
Summary of Nutrient and Solids Capture Rates Utilizing CleanB®



Process Stream	Stream #	Total Solids [%]	Flow [gpd]	Wet Solids [lbs/day]	Dry Solids [lbs/day]	Total Nitrogen [lbs/day]	Total Phosphorous [lbs/day]
Thickener In	1	0.80	88,091	734,678	5,892	410	109
Thickener Filtrate	2	0.06	75,588	630,404	366	182	47
Thickener Out	3	5.30	12,503	104,273	5,526	228	62
Dewatered Filtrate	4	0.41	8,927	74,450	307	122	39
Dewatered Biosolids	5	17.50	3,576	29,823	5,219	106	23

CleanB® MASS BALANCE

The following is a mass balance for the CleanB® process while treating 2.6 DT/day. Using the results provided by the lab analyses, a complete mass complete balance was calculated around the dewatering device following CleanB® treatment. A basis of 952 DT/yr operating 7 days a week was used.



Process Stream	Stream #	Total Solids [%]	Flow [gpd]	Wet Solids [lbs/day]	Dry Solids [lbs/day]	Total Nitrogen [lbs/day]	Total Phosphorous [lbs/day]
WAS in	1	0.62	104,706	873,244	5,405	322	160
CleanB® Treated	2	0.62	104,706	873,244	5,405	322	160
Dewatered Filtrate	3	0.02	101,886	849,733	186	23	27
Dewatered Biosolids	4	22.20	2,819	23,511	5,219	299	133

MASS BALANCE COMPARATIVE

The table below summarizes the results of lbs of nutrients returned to the plant via centrate and the solids concentration of dewatered biosolids requiring disposal:

Summary of Nutrient and Solids Capture Rates Utilizing CleanB®

	Units	Aerobic Holding	CleanB®	Tons of filtrate removed/yr	Percent Improvement
Dry Solids (filtrate return)	[lbs/DT]	228.5	68.8	76	70%
TN (filtrate return)	[lbs/DT]	103.1	8.5	45	92%
TP (filtrate return)	[lbs/DT]	29.1	10.0	9	66%
%TS Biosolids	[%]	17.5%	22.2%	N/A	27%
Lbs Wet/DT	[lbs/DT]	11,429	9,009	N/A	21%
Truckloads Hauled*	[TL/yr]	247	195	N/A	21%

*Truckload = 44,000 wet lbs

It should be noted that the filtrate returns were summed for aerobic holding (thickening and dewatering) and then compared to the filtrate return for the CleanB® process (dewatering). The total nitrogen return on a dry ton basis with their aerobic holding was 103.1 lbs, whereas the CleanB® showed 8.5 lbs return per dry ton, or a 92% reduction. The high capture rate of nitrogen in the biosolids reduces 45 tons of nitrogen being returned to the head works per year for this size facility (952 DT/yr). Total phosphorous returned via the centrate is smaller, 66%, reduction or 9 tons per year, but still is significant.

The CleanB® produced a much drier dewatered sludge cake; there was an observed 27% increase in cake solids (17.5% to 22.2% cake solids) for the dewatered biosolids. The change in cake solids equates to a 21% reduction in wet weight. When considering this facility produces 952 DT/year, the facility can now expect to decrease the number of truckloads hauled per year by 52 (assuming 44,000 lbs per truckload), or a 21% decrease in hauling.

CleanB® Compared to Anaerobic Digestion

Dewatering filtrate from a belt filter press was collected and analyzed to assess and compare nutrient returns. Table 1 summarizes data obtained from St. Petersburg's Southwest WRF (SWWRF) anaerobic digestion facility in November of 2011 and is compared to a CleanB® demo at the same plant in October of 2011. Alum was added to chemically precipitate the phosphorous at the anaerobic digestion facility and was not added during the CleanB® demonstration.

Table 1. Summary of Anaerobic Digester Filtrate and CleanB® Treated Filtrate at SWWRF

Treatment Type	WAS TS	TOTAL PHOSPHORUS		TOTAL NITROGEN	
		SLUDGE	FILTRATE	SLUDGE	FILTRATE
	[% w/w]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
AD	1.61%	560	77.2	1130	663
AD	1.71%	524	68.7	1100	603
AD	1.62%	504	73.3	1100	689
AD	1.59%	500	83.7	1040	761
AD	1.67%	532	82.9	1120	731
AD	1.67%	476	77.8	1090	774
CleanB®	2.65%	568	49.9	1920	98.7
CleanB®	2.25%	572	62.5	1860	113



Summary of Nutrient and Solids Capture Rates Utilizing CleanB®

CleanB®	2.55%	588	48.7	1980	119
CleanB®	2.35%	527	57.7	1770	118
CleanB®	2.45%	559	42.1	1840	100
CleanB®	2.35%	532	53.4	1760	97.5

Using the values in Table 1, an assessment was made to determine the percent of nutrients that returned to the headworks via filtrate. The following basis was used to perform this assessment:

WAS Flowrate: 100 GPM
WAS Density: 8.34 lbs/gal
Cake TS: 20%

Table 2 shows the lbs/min of both Total Phosphorus and Total Nitrogen in the sludge and in the dewatering filtrate. At SWWRF, the percentage returned to the WWTP using the anaerobic digester was 14.0% and 60.1% for TP & TN, respectively. During the CleanB® demonstration, the percentage returned was 8.5% and 5.2% for TP & TN, respectively. This data demonstrates the enhanced nutrient retention of CleanB® treated biosolids, limiting nutrient loading to the WWTP. On average, TN capture rate was improved by 137% - similar to the results found comparing CleanB® to aerobic holding. On average, TP capture rates improved by 6% when comparing anaerobic digestion with the addition of Alum vs. CleanB®.

Table 2. Total Phosphorus & Total Nitrogen Comparison: AD vs. CleanB®

Treatment Type	TOTAL PHOSPHORUS		TOTAL NITROGEN		TP Returned to WWTP	TN Returned to WWTP
	SLUDGE	FILTRATE	SLUDGE	FILTRATE		
	[lbs/min]	[lbs/min]	[lbs/min]	[lbs/min]	[%]	[%]
AD	0.47	0.06	0.94	0.52	12.90%	54.90%
AD	0.44	0.05	0.92	0.47	12.20%	51.10%
AD	0.42	0.06	0.92	0.54	13.60%	58.60%
AD	0.42	0.07	0.87	0.59	15.70%	68.50%
AD	0.44	0.06	0.93	0.57	14.50%	60.90%
AD	0.4	0.06	0.91	0.6	15.30%	66.30%
Averages:					14.0%	60.1%
CleanB®	0.47	0.04	1.6	0.07	7.90%	4.60%
CleanB®	0.48	0.05	1.55	0.09	9.90%	5.50%
CleanB®	0.49	0.04	1.65	0.09	7.40%	5.40%
CleanB®	0.44	0.04	1.48	0.09	9.90%	6.00%
CleanB®	0.47	0.03	1.54	0.08	6.80%	4.90%
CleanB®	0.44	0.04	1.47	0.07	9.10%	5.00%
Averages:					8.5%	5.2%