Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

REPORT NO. 14-45

CALUMET PHOSPHORUS TASK FORCE

TECHNICAL MEMORANDUM NO. 3

EVALUATION OF CARBON ADDITION TECHNOLOGIES FOR THE CALUMET WATER RECLAMATION PLANT – EVALUATION MATRIX RATINGS AND RESULTS

October 2014

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FORWARD

The Metropolitan Water Reclamation District of Greater Chicago (MWRD) recognizes the value of phosphorus as a non-renewable resource. In an effort to optimize the sustainable removal of phosphorus from its wastewater influents and the subsequent recovery of phosphorus in various forms suitable for use as an agronomic fertilizer, the MWRD initiated a Phosphorus Removal and Recovery Task Force in 2012. The Task Force initiated a study phase at several of the MWRD's Water Reclamation Plants (WRPs) to evaluate the feasibility of implementing enhanced biological phosphorus removal and to develop operational guidelines for optimizing its effectiveness. The Task Force has created WRP specific study workgroups that are focused on each of the WRPs that have been identified to participate in this initiative. As the workgroups complete various phases of their studies and evaluations they are documenting their findings and recommendations in technical memoranda. These memoranda are written by the WRP specific workgroups and vetted by the Task Force before being published. Their purpose is to capture the state of knowledge and study findings and to make recommendations for implementation of enhanced biological phosphorus removal as they are understood at the time the memoranda are published.

DISCLAIMER

The contents of this technical memorandum constitute the state of knowledge and recommendations developed by the MWRD's Phosphorus Task Force at the time of publication, and are subject to change as additional studies are completed and experience is attained, and as the full context of the MWRD's operating environment is considered.

Evaluation of Carbon Addition Technologies for the Calumet Water Reclamation Plant

Technical Memorandum 3

Date:	March 14, 2014
To:	Phosphorus Task Force & Advisory Committee
From:	Phosphorus Study/Planning Team
Subject:	Evaluation Matrix Ratings and Results

1.0 Purpose

This technical memorandum summarizes the results of the matrix evaluation completed using the short list of carbon addition technologies provided in Technical Memorandum 2 (TM2). This memorandum includes a description of the matrix, rating scale, ratings given for each technology, and an explanation of the ratings given.

2.0 Short List

A short list of carbon addition technologies was developed in TM2; this technical memorandum includes a detailed description of each technology as well as the amount of carbon generated from application in consideration of Calumet plant operations. Since the writing of that report, the evaluation team had further thoughts on the technologies which warrant a brief discussion.

Primary Sludge Fermentation

Because the low flows of primary sludge ultimately yield low VFA loads discussed in TM2, adding significant infrastructure and equipment does not seem to be a worthwhile venture. However, the existing gravity concentration tanks are fed only primary sludge. These can be operated as static primary sludge fermenters, and the supernatant can be redirected directly to the aeration tanks for optimal usage of the VFAs generated. As stated in TM2, the supernatant is returned to the head of the plant under current operations.

Return Activated Sludge Fermentation

Lab scale tests were done to confirm the VFA production potential from CWRP return activated sludge (RAS). At the same time, the potential of the mixed liquor (ML) to produce VFAs was also tested as some plants have seen success with inline fermentation in aeration tanks. For each sampling event, four samples from Battery A, the CWRP battery currently configured for EBPR, were collected and brought back to the M&R laboratories. Two of the samples were RAS and two ML. One of each sample was kept in a cooler to simulate winter conditions (11 deg C) and the other left at room temperature (21 deg C) for summer conditions. The results from the preliminary testing are in Table 1. As noted in TM2, RAS has a typical production of VFAs based on a VFA/VSS ratio around 0.09 ('Fermenters for Biological Phosphorus Removal Carbon Augmentation', Issued by WERF August 9, 2011). Using the measured solCOD/VSS ratio as surrogate, it is markedly less than this literature value; additionally VFA concentrations were less than reporting limits (5 mg/L) for almost all scenarios and times except for one summer condition. Although solCOD/VSS is not the same measure as VFA/VSS, the lack of VFA formation indicates that the VFA/VSS ratio from fermentation at CWRP would likely be less than the already low solCOD/VSS ratio. The times where VFAs were generated, the mixed liquor and RAS fermentation had low average VFA concentrations of 27 mg/L and 40 mg/L, respectively, after fermentation for 3 days. In addition, fermentation of CWRP RAS releases nearly the same concentration of Ortho-P as VFAs. Because of the marginal increase in VFAs and the additional Ortho-P load unintentionally released back to the system, the evaluation team deemed it unnecessary to pursue this option.

TABLE 1: RAS AND MIXED LIQUOR FERMENTATION RESULTS

	Summer Conditions	Winter Conditions
Number of Trials	2	2
RAS [solCOD] @ ~52 hrs (mg/L)	65.5	30
RAS [orthoP] @ 52 hrs (mg/L)	36.2	27.5
ML [solCOD] @ ~52 hrs (mg/L)	49	27.5
ML [orthoP] @ 52 hrs (mg/L)	17.1	12.8
RAS solCOD/VSS	0.03	0.02
ML solCOD/VSS	0.06	0.05

Focused-Pulse Technology

Since the development of TM2, the Focused-Pulse technology has been discovered to be too underdeveloped for full-scale implementation at a large facility. In conversations with a company representative, the technology will be in full scale operation by 2014, but operating at a much smaller scale facility. Because of this, per the manufacturer's recommendation, it is unnecessary to further develop this option until the technology is matured.

Chemical Addition

The chemicals considered in TM2 were acetic acid, propionic acid, Sucrose 20 Brix, MicroC2000, and QLF. With further investigation, there is not widespread use of Sucrose 20 Brix for phosphorus removal; this chemical was no longer considered for evaluation. The remaining chemicals are shown in Table 2 and noted with respect to total volume needed, annual cost, and the safety of the chemical.

TABLE 2: CHEMICAL DETERMINATION

Substrate	COD (mg/L)	rbCOD: COD	Flow Needed for solCOD Deficit Range	Cost ($/gal)	Cost (Million $/yr)	Other Notes
Acetic Acid, 99%	1,095,000	1	5,480 – 10,960 gal/day	2.79[1]	$5.6 – $11.2	• Corrosive • Combustible – explosion proof feed system needed • High freeze temperature
Propionic Acid, 99%	1,494,900	1	4,020 – 8,030 gal/day	6.35[1]	$9.3 – 18.6	• Corrosive • Combustible – explosion proof feed system needed
MicroC2000	1,040,000	0.86	6,710 – 13,420 gal/day	1.5[2]	$3.7 – $7.4	• Non-toxic • Non-flammable
QLF	902,000	0.91	7,310 – 14,620 gal/day	1.5[2]	$4.0 – $8.0	• Non-toxic • Non-flammable

[1]: Estimates provided by a representative from Silver Fern Chemical.

[2]: Estimates provided by representatives from MicroC and QLF, respectively.

Due to the freezing points, all chemicals would need to be housed in a building. However, the cost for the explosion proof feed systems necessary for acetic and propionic acids would greatly increase the capital cost. In addition, given the corrosive nature of acetic and propionic acids, they present a safety hazard to workers. Lastly, while the daily volume of propionic acid needed is smaller than the other chemicals considered, the annual cost of the chemical is much higher than all other choices, making it not at all cost effective. Considering the above, Micro C2000 and QLF were the only chemicals considered in this evalution.

Both MicroC and QLF are comparable in terms of the quantity utilized and estimated annual costs (QLF prices were decreased to $1.50/gallon as an initial estimate from conversations with the QLF representative). For the purposes of a conceptual level cost estimate and planning, MicroC2000 was utilized as the chemical for the feed system; however, either MicroC or QLF can be used within the system designed below.

Imported Wastes

There are a few promising industrial waste sources in the CWRP service area; these were examined with respect to flows and BOD concentrations from records kept by the Industrial Waste Division. The BOD concentrations, however, are those measured and reported as what enters the sewer system. As such, for any industrial waste source with a pretreatment program, the actual BOD content could be higher. Table 3 lists the flows of some of the most viable sources, with respect to their effluent BOD concentrations.

TABLE 3: IMPORTED WASTE DATA

FACILITY NAME	FLOW (GPD)	BOD (LB/DAY)
Kappa Products Corp	10,355	1,313
Agri-Fine Corporation	37,685	3,373
Liquid Environmental Solutions	35,260	1,946
American Sweetener Corporation	30,129	1,173
Rupari Food Service, Inc.	47,309	1,615
CPC Laboratories, Inc.	111,992	2,489
Dedicated Trailer Cleaning Services, Inc.	71,200	1,582
Marigold, Inc.	15,862	335
Solvay USA, Inc.	190,731	3,770
Blue Island Phenol, LLC	164,198	3,146
Calumet Tank & Equipment Co	16,539	298
Bullen Midwest, Inc.	17,107	267
Griffith Laboratories U.S.A., Inc.	38,082	590
Labriola Baking Company	22,388	339
B&B Pullman Properties, LP	42,700	590
Arkema Emulsion Systems	25,532	325
Ed Miniat, Inc.	124,273	1,544
Legendary Baking	14,661	180
Quala Services, LLC	91,541	1,065
Gelita USA, Inc.	347,928	3,903
Ventura Foods, LLC	44,238	479

Keebler Company	8,881	82
Darling Restaurant Services	2,807	26
T&J Meat Packing	8,795	76
Coca-Cola Refreshments, Inc.	187,986	1,610
Ashland Specialty Chemical Co	68,064	578

Ideally, in order to calculate the increase in the carbon provided from the fermentation and use of these wastes for EBPR, laboratory scale tests would be conducted. In addition, the District could potentially have discussions with some of these facilities in order to decrease any pretreatment in order to increase BOD contributions. It is anticipated that negotiating to reduce pretreatment requirements on industrial sources would have a likely negative effect on the revenue from User Charges. Although importing high strength waste may appear to reduce annual operating costs for the EBPR process, there is the potential for a revenue loss that could neutralize the annual operating costs.

In the absence of these, several assumptions were made to develop this scenario:

- The high strength waste would be in liquid form.
- The volume of high strength waste is limited by the number of trucks able to deliver at the treatment plant. Assuming 5,000 gallon tankers and a maximum of 50 trucks per day, 250,000 gal/day would be the maximum flow of high-strength waste.
- From TM2, the carbon contents of imported wastes cover a relatively large range. For the purposes of this memo, a conservative BOD concentration of 50,000 mg/L is used.
- It is assumed that 40% of the total BOD would manifest itself to soluble, usable carbon (range of 20 – 90% rbCOD:COD from 'Comparisons of Organic Sources for Denitrification: Biodegradability, Denitrification Rates, Kinetic Constants and Practical Implication for Their Application in WWTPs', Onnis-Hayden, A., Gu, A.)

$$0.25\,MGD \cdot 50{,}000\frac{mg\ BOD}{L} \cdot 40\% \cdot 8.34 = 41{,}700\ \frac{lb\ solCOD}{day}$$

This additional flow could be added to the primary sludge fermentation system.

Summary

The technologies that remain have been grouped into alternatives which are listed in Table 4. These technologies are all evaluated with respect to meeting the 100,000 lb solCOD/day carbon deficit developed in TM2; this is at the conservative end of the carbon deficit estimate.

TABLE 4: SHORT LIST OF CARBON SUPPLEMENTATION TECHNOLOGIES

	TECHNOLOGY USED	CARBON SOURCE	DESCRIPTION
Alternative A	Chemical Feed System	• 100,000 lb solCOD/day MicroC (13,420 gal/day)	• Based on MicroC as the feed chemical. • Separate chemical feed facility consisting of storage tanks, metering pumps, and piping.
Alternative B	Chemical Feed System + Primary Sludge Fermentation	• 90,000 lb solCOD/day MicroC (12,075 gal/day) • 10,000 lb solCOD/day from primary sludge	• Same chemical feed system as Alternative A. • Use of the GCTs for primary sludge fermentation – pumps and piping to reroute GCT overflow to primary effluent.
Alternative C	Chemical Feed System + Primary Sludge Fermentation + Imported Waste Fermentation	• 48,300 lb solCOD/day MicroC (6,480 gal/day) • 10,000 lb solCOD/day from primary sludge • 41,700 lb solCOD/day from high strength waste	• Same chemical feed system as Alternative A. • Use of the GCTs for primary sludge and imported high strength waste fermentation – pumps and piping to reroute GCT overflow to primary effluent. • Additional feed station for tankers to feed GCTs.

3.0 Evaluation Matrix

The short-listed technologies were evaluated using a matrix consisting of weighted criteria, as shown in Table 5. For each technology, a rating was given to the criteria using a rating scale from negative three (-3) to 0, with -3 being the worst, or the having greater negative impacts, and 0 being the best, or having lesser negative impacts. The following sections detail the logic behind each of the weightings as well as the results of the evaluation matrix.

TABLE 5: EVALUATION MATRIX CRITERIA AND WEIGHTING

CRITERIA	GROUP WEIGHT	ITEM WEIGHT
Economic Criteria	34%	
NPV[1]		50%
M&O Hours		20%
Energy Usage		15%
Effect on Digester Gas Production		10%
Environmental Criteria	33%	
Reliability/Stability		20%
Resources Used		40%
Material Transport		40%
Social Criteria	33%	
Odors		50%
Health & Safety		50%

[1] NPV = net present value, includes Capital Cost & Annual Chemical Cost.

4.0 Evaluation Results

The completed matrix with ratings is shown in Table 6.

TABLE 6: MATRIX RATING RESULTS

	ITEM WEIGHT	ALT A	ALT B	ALT C
Economic Criteria	**34%**			
NPV	50%	-2	-2	0
M&O Hours	20%	0	-1	-3
Energy Usage	15%	0	-1	-1
Effect on Digester Gas Production	10%	0	-1	-1
Environmental Criteria	**33%**			
Reliability/Stability	20%	0	-1	-1
Resources Used	40%	-3	-2	0

Material Transport	40%	-1	0	-2
Social Criteria	**33%**			
Odors	50%	0	-2	-3
Health & Safety	50%	0	-1	-3
OVERALL TOTAL		**-0.86**	**-1.31**	**-1.60**

The following subsections provide an explanation of the ratings given.

4.1 Economic Criteria

The economic criteria include NPV, M&O hours, energy usage, and the effects on digester gas production.

4.1.1 Net Present Value

The capital and chemical costs were estimated for the short-listed technologies. All annual costs assume a 20-year life analysis. These cost estimates were converted to a net present value (NPV). The estimated NPV for each alternative is provided in Table 7.

TABLE 7: NPVS FOR EACH ALTERNATIVE[1,2]

	ALT A	ALT B	ALT C
Capital Cost	$10,689,000	$21,858,000	$26,791,000
Chemical Cost – Present Value	$129,330,000	$116,360,000	$62,444,000
NPV	$140,019,000	$138,218,000	$89,235,000
Annual Chemical Cost	$7,347,000,000	$6,611,000	$3,548,000

[1]: Life = 20 years; Interest = 3.75; Inflation = 2.47

[2]: Costs from energy calculated separately and impacts on digester gas calculated separately.

Alternative A

A chemical feed system of this magnitude requires a separate facility. The main facility components are a building containing storage tanks, metering pumps, and piping. Based on the volume of required storage at the maximum end of the carbon deficit, 15 days of storage was considered reasonable. Although MicroC has a shelf life of approximately 12 months, increased storage will be more costly to construct and maintain. Table 8 summarizes the design criteria and major equipment selection used to develop the NPV.

TABLE 8: DESIGN CRITERIA FOR NPV FOR ALTERNATIVE A

PARAMETER	VALUE	COMMENTS
DESIGN		
Flow	13,420 gal/day	Based on maximum deficit values
Storage	201,300 gallons	Delivery 2x/month
EQUIPMENT		
Storage Tanks	• 10 FRP Tanks • 20,000 gallon active volume capacity	• MicroC is compatible with all materials except carbon steel and aluminum. FRP was chosen as it is compatible with a large range of chemicals should feed chemical need to switch in the future. • Active capacity based on a 20% safety factor (25,000 gallon actual volume).
Feed Pumps	10 metering pumps	• Utilize 1 pump/tank. • Sized at 1 gpm/pump.
Analyzers	2 COD analyzers 2 TP analyzers	Analyzer recommended at primary tank effluent to connect to metering pumps for proper dosage.

The chemical storage and feed facilities are to be sited as close to the primary effluent conduit as possible; siting closer to the end of the conduit is preferable.

The bulk of the NPV for the chemical feed option is from the annual chemical costs. As such, any amount of the chemical that can be saved would result in significant savings.

Alternative B

Primary sludge fermentate has the potential to meet approximately 10,000 lb solCOD/day of the total demand; this leaves a 90,000 lb solCOD/day deficit to be met by chemical usage. The daily flow of MicroC is then reduced from the Alternative A value of 13,420 gal/day to 12,075 gal/day. This difference is reflected in the annual operation cost. However, there are additional capital costs from the equipment necessary to both pump the GCT overflow to an optimal location and to elutriate the sludge; elutriation would allow for an increased SRT and increased VFA production. These design criteria are outlined in Table 9.

TABLE 9: DESIGN CRITERIA FOR NPV FOR ALTERNATIVE B

PARAMETER	VALUE	COMMENTS
DESIGN		
MicroC Flow	12,075 gal/day	Based on maximum deficit values.
Alternative A Equipment		
ADDITONAL EQUIPMENT		
Pump House Building	Directly to north of GCT building	• The GCT building has very limited space – there is no room for additional pumps. • Sludge recycle needs to have piping from GCTs to pump house and then returned.
Transfer Pumps	2 duty, 1 spare	• Designed to match the elutriation pumps. • Centrifugal pumps, 800 gpm capacity
Elutriation Pumps	3 duty, 1 spare	• 1 pump/4 tanks • Based on drawing sludge from bottom 1/3 of each GCT. • Centrifugal pumps, 800 gpm capacity • Sludge is recycled over 2 hours, 3 times/day for each tank.
Odor Control	1 system for building	• Discussed in later section.

Alternative C

Using the theoretical numbers, an additional 41,700 lb solCOD/day of the total demand could be met through fermenting imported wastes; coupled with primary sludge fermentation, this totals 51,700 lb solCOD/day. This leaves a 48,300 lb solCOD/day deficit to be met by chemical usage. The daily flow of MicroC is then reduced from the Alternative A value of 14,620 gal/day to 6,480 gal/day.

In addition to the system developed under Alternative B for the fermentation of primary sludge, Alternative C would require a fill station and transfer pumps for the imported wastes.

TABLE 10: DESIGN CRITERIA FOR NPV FOR ALTERNATIVE C

PARAMETER	VALUE	COMMENTS
DESIGN		
MicroC Flow	6,480 gal/day	Based on maximum deficit values and 40% of BOD as usable carbon.
Alternative A Equipment		
Alternative B Equipment		
ADDITONAL EQUIPMENT		
Fill Station	Adjacent to GCTs	
Transfer Pumps	2 duty, 1 spare	• Feeding imported wastes to GCTs.
Odor Control		• Discussed in later section.

4.1.2 Maintenance & Operation Hours

The Maintenance and Operation hours are based on those from the estimate for the disinfection facilities at CWRP. Further verification from M&O staff regarding the values included here is still necessary, but will likely not significantly alter the matrix results.

Alternative A

The maintenance and operation hours for the Alternative A scenario are taken from the Chemical Storage Tanks and Disinfection System hours developed the estimate.

TABLE 11: ALTERNATIVE A M&O HOURS

	NO. OF OPERATORS (PER DAY)	TIME (HRS/UNIT-TIME/OPERATOR)	TOTAL TIME (HRS/YEAR)
Electrician for routine maintenance	1	1	260
Labor – Maintenance	2	2	1,040
Labor – Operator	2	8	4,160

Due to the amount of chemical being used, the filling of the tanks will be a significant new effort as part of daily maintenance and operations. CWRP will need to have deliveries on-site. Estimates of the time and effort required to refill the tanks are provided in Table 12. These are based on complete fill and drain scenarios.

TABLE 12: TANK FILILNG SUMMARY

DAYS OF STORAGE	VOLUME REQUIRED	# OF TRUCKS	ESTIMATED TIME TO FILL (HRS)
1	13,420	3	2
7	93,940	19	14
10	134,200	27	20
15	201,300	40	29.5

Because of the number of trucks and the time required to fill the tanks, it is recommended that the tanks be refilled more often than every 14 days. This could be daily, twice weekly, or whatever interval is most convenient for the operating staff.

Alternative B

Alternative B would include the labor hours for the Alternative A scenario; they also include those for the operation of the elutriation pumps and low-lift pumping to the aeration batteries. Based on the Disinfection Estimates for the low-lift pumping station included there, this would essentially double the M&O hours per year.

TABLE 13: ALTERNATIVE B – M&O HOURS

	NO. OF OPERATORS (PER DAY)	TIME (HRS/UNIT-TIME/OPERATOR)	TOTAL TIME (HRS/YEAR)
Electrician for routine maintenance	1	2	520
Labor – Maintenance	2	4	2,080
Labor – Operator	4	8	8,320

Alternative C

Although there is not a lot of equipment being added under this option, there is an increase to operation due to the direction of food waste tankers. Given the number of trucks entering the facility, this would likely amount to a full-time job, resulting in slight increases to the maintenance hours and another full-time operator.

TABLE 14: ALTERNATIVE C – M&O HOURS

	NO. OF OPERATORS (PER DAY)	TIME (HRS/UNIT-TIME/OPERATOR)	TOTAL TIME (HRS/YEAR)
Electrician for routine maintenance	1	3	780
Labor – Maintenance	2	6	3,120
Labor – Operator	5	8	10,400

4.1.3 Energy Usage

Energy usage calculations included annual energy usage for each of the major pieces of equipment.

Alternative A

The only equipment that would consume electric energy is chemical feed pumps. Table 15 summarizes the annual power usage and estimated annual electricity cost. The annual power consumption is approximately 2,600 kWh per year and annual electricity cost is approximately $200 per year.

TABLE 15: ALTERNATIVE A – ANNUAL POWER CONSUMPTION AND ELECTRICITY COST

DESIGN CRITERIA	VALUE
Total chemical feed flow	13,420 gpd
# of chemical feed pumps on duty	10
Feed flow rate per pump	1 gpm
Total discharge head	116 ft
Working hydraulic HP, each	0.03 hp
Wire power in hp, each[1]	0.04 hp
Wire power in kwh, each	0.03 kwh
Average operating hours per day	24 hrs
Average operating hours per year	8760 hrs

Total power consumption per year	**2,557 kWh/yr**
Annual electricity cost[2]	**$ 192/yr**

[1]: Based on 90% motor efficiency, 65% pump efficiency

[2]: Based on unit cost of $0.075/kwh.

Alternative B

The pieces of equipment that would consume electric energy are chemical feed pumps, sludge transfer pumps, and elutriation pumps. Table 16 summarizes the annual power consumption and estimated annual electricity cost. The annual power consumption is approximately 403,000 kWh per year and annual electricity cost is approximately $30,000 per year.

TABLE 16: ALTERNATIVE B – ANNUAL POWER CONSUMPTION AND ELECTRICITY COST

DESIGN CRITERIA	VALUE
Chemical feed pumps	
Total chemical feed flow	12,075 gpd
# of chemical feed pumps on duty	10
Feed flow rate per pump	1 gpm
Total discharge head	116 ft
working hydraulic HP, each	0.02 hp
Wire power in hp, each[1]	0.04 hp
Wire power in kwh, each	0.03 kwh
Average operating hours per day	24 hrs
Average operating hours per year	8760 hrs
Total power consumption per year	2,304 kWh/yr
Annual electricity cost[2]	$ 173/yr
Sludge transfer pumps	
# of transfer feed pumps on duty	2
Feed flow rate per pump	800 gpm
Total discharge head	40 ft
working hydraulic HP, each	8 hp

Wire power in hp, each[1]	14 hp
Wire power in kwh, each	10 kWh
Average operating hours per day	17 hrs
Average operating hours per year	6,269 hrs
Total power consumption per year	129,288 kWh/yr
Annual electricity cost[2]	$ 9,697/yr
Elutriation pumps	
# of elutriation pumps on duty	3
Feed flow rate per pump	800 gpm
Total discharge head	40 ft
working hydraulic HP, each	8 hp
Wire power in hp, each[1]	14 hp
Wire power in kwh, each	10 kWh
Average operating hours per day	24 hrs
Average operating hours per year	8,760
Total power consumption per year	270,974 kWh/yr
Annual electricity cost[2]	$ 20,323/yr
Total annual power consumption for Alt B	**402,566 kWh**
Total annual electricity cost for Alt B	**$ 30,192/yr**

[1]: Based on 90% motor efficiency, 65% pump efficiency

[2]: Based on unit cost of $0.075/kwh.

Alternative C

The pieces of equipment that would consume electric energy for this alternative are similar to Alternative B, including chemical feed pumps, sludge transfer pump and elutriation pumps. Table 17 summarizes the annual power consumption and estimated annual electricity cost. The annual power consumption is approximately 422,000 kWh per year and annual electricity cost is approximately $32,000 per year. This increase from Alternative B is due to the increased hours of operation of the pumps; with a greater flow to the GCTs, the elutriation and transfer pumps would be in operation longer.

The high strength food wastes (after any industrial pretreatments) are currently fed into the sewer system, which increases the treatment required in CWRP's mainstream treatment system.

Fermenting high strength waste would reduce the amount of high strength waste entering the sewer system; in turn, this would reduce the energy required for treatment at CWRP.

TABLE 17: ALTERNATIVE C – ANNUAL POWER CONSUMPTION AND ELECTRICITY COST

DESIGN CRITERIA	VALUE
Chemical feed pumps	
Total chemical feed flow	6,480 gpd
# of chemical feed pumps on duty	10
Feed flow rate per pump	1 gpm
Total discharge head	116 ft
working hydraulic HP, each	0.02 hp
Wire power in hp, each[1]	0.03 hp
Wire power in kwh, each	0.02 kwh
Average operating hours per day	24 hrs
Average operating hours per year	8760 hrs
Total power consumption per year	2050 kwh/yr
Annual electricity cost[2]	$ 154/yr
Sludge transfer pumps	
# of transfer feed pumps on duty	2
Feed flow rate per pump	800 gpm
Total discharge head	40 ft
working hydraulic HP, each	8 hp
Wire power in hp, each[1]	14 hp
Wire power in kwh, each	10 kwh
Average operating hours per day	20 hrs
Average operating hours per year	7219 hrs
Total power consumption per year	148,878 kwh/yr
Annual electricity cost[2]	$ 11,166/yr
Elutriation pumps	

# of elutriation pumps on duty	3
Feed flow rate per pump	800 gpm
Total discharge head	40 ft
working hydraulic HP, each	8 hp
Wire power in hp, each[1]	14
Wire power in kwh, each	10 kwh
Average operating hours per day	24 hrs
Average operating hours per year	8760 hrs
Total power consumption per year	270,974 kwh/yr
Annual electricity cost[2]	$ 20,323/yr
Total annual power consumption for Alt C	**421,901 kwh/yr**
Total annual electricity cost for Alt C	**$ 31,643/yr**

[1]: Based on 90% motor efficiency, 65% pump efficiency

[2]: Based on unit cost of $0.075/kwh.

4.1.4 Effect on Digester Gas Production

Alternative A

Alternative A is neutral for its effect on gas production as it is assumed that all of the additional chemical will be utilized.

Alternative B

Under this option, the fermentation process will convert primary solids to VFAs and transfer these out of the solids handling system. This will reduce the organic loading to the digesters as that carbon is no longer available for further conversion to biogas. Depending upon the type of sludge and the level of fermentation, it is generally believed that fermentation of primary and secondary sludge could reduce digester gas production by five to ten percent or more (based on information learned from a WEFTEC conference presentation, 2013). Therefore, application of the fermentation process must be done to balance the plant's biogas utilization and external chemical addition goals.

Table 18 summarizes the potential impact on digester gas production from primary sludge fermentation. In order to generate the estimated 9,950 lbs of readily biodegradable carbon for EBPR process through primary sludge fermentation, there is potential to reduce digester gas production by 84,000 ft^3/day, or approximately 9 percent of digester gas that could be generated from the primary sludge. The lost amount of digester gas has a potential heat value of 50 Dtherm per day or equivalent electricity potential of 5,000 kwh per day.

TABLE 18: IMPACT ON DIGESTER GAS PRODUCTION – ALTERNATIVE B

THEORETICAL DIGESTER GAS PRODUCTION FROM PRIMARY SLUDGE WITHOUT FERMENTATION	
TSS in primary sludge	1.24%
VSS/TS ratio	64%
Primary sludge flow	1.67 MGD
VSS in primary sludge	110,531 lbs/day
VSS reduction rate in digester[1]	50%
VSS reduced in digester	55,266 lbs/day
ft^3 digester gas produced per lbs of VSS reduced[1]	16
Total estimated gas produced	884,248 ft^3/day

[1] Values from Metcalf&Eddy Wastewater Engineering Treatment, Disposal Reuse 3rd edition, 1991

POTENTIAL DIGESTER GAS REDUCTION FROM PRIMARY SLUDGE FERMENTATION	
Carbon stripped out from fermentation process	0.09 g solCOD/g VSS
VSS in Primary sludge	110,531 lbs/day
Carbon stripped out from the primary sludge	9,948 lbs/day
ft^3 of CH_4 produced per lbs of COD removed (assumed)	5.62
ft^3 of digester gas produced per lbs of COD removed@ 2/3 CH_4	8
Potential digester gas from Carbon stripped out from the primary sludge	83,860 ft^3/day
Potential digester gas reduction due to fermentation	9%
Potential heat value of digester gas	600 Btu/ft^3
Potential heat value of lost digester gas	50 Dtherm/day
Potential electricity value of lost digester gas @ 34% engine efficiency	100 kwh/Dtherm
Potential electricity value of lost digester gas	5,032 kwh/day

Alternative C

The impact to digester gas production under Alternative C is the same as Alternative B. The high strength food wastes considered are currently fed into the sewer system and all carbon is removed through the CWRP mainstream treatment system. If fed to the GCT, the carbon amount not stripped out in the fermentation process will be further digested in the anaerobic digester to generate gas. There will be increase in the digester gas production based on current operation. However, if there are future plans to add high strength food waste directly to the digester for co-digestion, fermentation would take carbon from this and thus reduce gas production, making the end result neutral.

The high strength food waste, already originating in the service area and after any industrial pretreatment is currently fed into the intercepting sewer system, which is then treated in CWRP's secondary treatment system. Diverting this high strength waste to a fermentation side process would reduce loading on the secondary treatment system; in turn reducing the energy requirement for treatment. This energy saving however would not be realized if high strength waste was imported from outside of the current service area.

4.2 Environmental Criteria

The environmental criteria considered here included reliability and stability of the system, resources used, and material transport. The reliability of the system was given the greatest weight, because a failed carbon system would result in increases in phosphorus to the effluent stream.

4.2.1 Reliability/Stability

Certainly, the most reliable source of carbon would be the chemical addition, hence it would receive the least negative score. Less reliable is primary sludge fermentation as the carbon load available from the sludge would fluctuate on a daily basis. Similarly, the reliability of high strength waste in Alternative C could also become an issue, dependent upon the industry found, the availability of a constant stream, movement of industries out of the area, etc. Because of reliability issues, the design of each of the options evolved to include a full-scale chemical addition system. The final scoring in the reliability/stability section has a smaller weight given to it and small differences between the options because each has the chemical capability to reliably treat the system and provide the necessary carbon if the fermentation and industrial waste additions fall short.

4.2.2 Resources Used

Each of the options was rated in relation to the others. The Alternative A option was given the most negative score as the most outside resources were used while Alternatives B and C were given more positive scores, respectively, as they required less outside chemical. Alternative C redirects wastes in a positive way. In addition, although not captured in the NPV, Alternative C also beneficially uses BOD rather than sending it through the CWRP treatment process, resulting in less air usage and energy savings.

4.2.3 Material Transport

Similar to resources used, the options were rated in relation to each other for material transport, too. The impact of the Alternative C was most negative because two sources of carbon require transportation to CWRP. Alternative A option was slightly negative while Alternative B ranked as neutral because it required the least amount of material transport.

4.3 Social Criteria

Odors were considered because of the effects on the areas neighboring CWRP; health and safety were considered with respects to the plant operating staff and public.

4.3.1 Odors

Alternative A

No significant odor issues are expected for this alternative.

Alternative B

The existing gravity concentration tanks (GCTs) are currently used for holding and concentrating primary sludge. There is noticeable odor observed in the existing GCT building. Currently, there is an exhaust fan with ozone injection on the discharge of the fan provided as an odor control system. This is operated during summer months. Alternative B will modify the GCTs and use it for primary sludge fermentation by adding pumps and increasing sludge retention time, which could increase the odor generation. A more robust odor control system may be needed for this alternative. Table 19 summarizes the odor control system design and gives a cost estimate. An engineered biofilter system is used due to the significant amount of air that needs to be treated. The biofilter odor control system would require approximately 7,000 sf of land to construct and a capital cost of approximately $5,000,000. Annual O&M cost is approximately $200,000 per year.

TABLE 19: ODOR CONTROL SYSTEM DESIGN AND COST ESTIMATE FOR GCT BUILDING

DESIGN CRITERIA	VALUE
GCT Building Dimensions	476' x 150' x 11'
Volume of the building	785,400 ft^3
Air exchange for the building	6 AE/hr
Capacity of ventilation system	78,540 scfm
Land area required for biofilter*	7,000 sf
Capital cost per 10,000 scfm**	$600,000
Capital cost for odor control system	**$5,000,000**
O&M cost per year per 10,000 scfm system**	$25,000
O&M cost for odor control system	**$200,000/year**

* Assume using Engineered biofilter, 30 seconds detention time and 6-ft media depth

** **Engineered Biofilter design and cost information resource:**

10,000 scfm, H2S 20 ppm in & <1 ppm out; $97.3K capital, $7.9K/yr O&M, year 1990 cost)

(source; http://www.colorado.edu/engineering/civil/CVEN4434/resources/costs.html)

180,000 scfm(two filter units,90,000 scfm each) $10,300 K capital, $380K/yr O&M)

82,000 scfm (two filter units, 41,000 scfm each), $11,000K capital, $350-450K/yr O&M, year 1999)
(Source: Camden County Municipal Utilities Authority & Rockland County Solid Waste Management Authority)

Alternative C

Fermenting high strength food waste could also generate a significant amount of odor and worsen the existing odor problem. Like Alternative B, an odor control system needs to be added. The odor control system for Alternative B would be sufficient for Alternative C, as well, requiring approximately 7,000 sf of land and a capital cost of approximately $5,000,000. Annual O&M cost is approximately $200,000 per year.

4.3.2 Health & Safety

The health, safety, and security criterion examined the impact that each alternative may have on the health and safety of plant staff, neighbors, and the public at-large. Alternative B was the highest ranking due to the lowered amount of chemical and feed being transported (compared to Alternative A) and the use of systems that are already in place (plant operators have familiarity with). Alternative C was given a lower rating because both chemicals and high strength waste would be traveling to the plant; in addition, with a new feed system for the waste, there are greater chances for safety issues. Alternative A was considered neutral.

5.0 Conclusion

Based on the factors selected and the weights given to each, the Alternative A seems to be the best of the three options considered. While Alternatives B and C lower the annual chemical costs, the additional burden placed on the energy, digester gas production, M&O hours, odors, material transport, health and safety do not seem worthwhile given the projected increase in carbon. If any of the assumptions were changed, particularly for Alternative C, and a higher amount of carbon would be expected, the numbers could shift.

It is also important to note that this memo also assumes that all CWRP needs for successful EBPR is the addition of carbon. There may still be additional infrastructure changes necessary after carbon is added. At CWRP, there are significant limitations in the aeration batteries as they are a 1-pass system (except for Battery C); if EBPR necessitates more anaerobic time, nitrification could be compromised. Similarly, the addition of baffles, mixers, and other equipment would need evaluation as these facilities could potentially reduce the demand for supplemental carbon and/or improve EBPR efficiency with respect to lowering the overall HRT in the EBPR system.