Evaluation of Disinfection Technologies for the Calumet and North Side Water Reclamation Plants

Technical Memorandum 3

Date: February 17, 2012

To: Disinfection Task Force Advisory Committee

From: Disinfection Task Force

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 disinfection technologies provided in Technical Memorandum 1. This memorandum includes a description of the matrix, rating scale, ratings given for each technology, and an explanation of the ratings given. A separate evaluation matrix was completed for the Calumet and North Side Water Reclamation Plants (WRPs). The results of the matrix evaluations will be used to select the best technology for each plant.

2.0. Evaluation Matrix

The short list of disinfection technologies developed in Technical Memorandum 1, which are listed in Table 1, were evaluated on a per-plant basis using a matrix consisting of weighted criteria, as shown in Table 2. For each technology, a rating was given to the criteria using a rating scale from negative three (-3) to positive three (+3), with -3 being the worst, or having greater negative impacts, and +3 being the best, or having greater positive impacts. Zero is neutral, neither negative nor positive. The following sections detail the results of the evaluation matrix for the Calumet and North Side WRPs.

TABLE 1: SHORT LIST OF DISINFECTION TECHNOLOGIES*

Chlorination/Dechlorination
- Sodium hypochlorite with sodium bisulfite

Ultraviolet Irradiation
- Low pressure high output lamps
- Medium pressure lamps

Ozonation
- Oxygen

Peracetic Acid

Ultraviolet Irradiation for DWF with Chlorination/Dechlorination for WWF
- Low pressure high output lamps
- Medium pressure lamps
- Sodium hypochlorite with sodium bisulfite

Ultraviolet Irradiation for DWF with Peracetic Acid for WWF
- Low pressure high output lamps
- Medium pressure lamps

Ozonation for DWF with Chlorination/Dechlorination for WWF
- Oxygen
- Sodium hypochlorite with sodium bisulfite

Ozonation for DWF with Peracetic Acid for WWF
- Oxygen

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* DWF: dry weather flow
WWF: wet weather flow

TABLE 2: EVALUATION MATRIX CRITERIA AND WEIGHTING

CRITERIA	GROUP WEIGHT	ITEM WEIGHT
Economic Criteria	**33.3%**	
Total NPV[1]		100%
Environmental Criteria	**33.3%**	
GHG Indirect Emissions		33.3%
Water Quality Effects		33.3%
Environmental Effects		33.3%
Social Criteria	**33.3%**	
Health, Safety & Security		20%
Traffic		20%
Reliability		20%
Footprint		20%
Odors		20%

[1] NPV = net present value

3.0. Evaluation Results

The completed matrices with ratings for the Calumet and North Side WRPs are shown in Tables 3 and 4, respectively. The two plants have some differences, such as current infrastructure and space availability, so a separate matrix was completed for each plant. The following subsections provide an explanation of the ratings given.

3.1 Total Net Present Value

The capital and operating and maintenance (O&M) costs were estimated for the short-listed technologies. These cost estimates were converted to a net present value (NPV). The estimated NPVs for each technology at the Calumet and North Side WRPs are provided in Tables 5 and 6, respectively, with more details provided in Appendix A. The technologies with the lowest NPVs are different at the two plants. This difference is due to (1) the presence of an existing chlorine contact tank at the Calumet WRP and (2) a limited amount of hydraulic head available at the Calumet WRP resulting in the need for a low lift pump station for application of some technologies. The North Side WRP currently has enough hydraulic head available for application of all the evaluated technologies. The rating given to each technology for this criterion were based on the technology's NPV. The rating scale was correlated with NPV ranges of equal size, which spanned the highest and lowest NPVs. For the Calumet WRP, chlorination/dechlorination with purchased sodium hypochlorite ($NaOCl$) and sodium bisulfite ($NaHSO_3$) was given the highest rating of +3 due to this technology having the lowest NPV, while peracetic acid (PAA) was given the lowest rating of -3 as it had the highest NPV. The remaining technologies were given ratings ranging between these two extremes. The NPV ratings for all the technologies evaluated for the Calumet WRP are provided in Table 3.

TABLE 3: MATRIX RATING RESULTS FOR THE CALUMET WATER RECLAMATION PLANT[1]

			Chlorination/Dechlorination		**UV**		**Ozone**	**PAA**
	Group Weight	**Item Weight**	NaOCl, Bisulfite	On-site NaOCl, Bisulfite	LPHO	MP	-	-
Economic Criteria	**33.3%**							
Total NPV		100%	3	2	1	-2	-2	-3
Environmental Criteria	**33.3%**							
GHG indirect Emissions		33.3%	-1	-1	-1	-2	-3	-1
Water Quality Effects		33.3%	1	1	3	3	2	2
Environmental Effects		33.3%	2	3	2	2	3	2
Social Criteria	**33.3%**							
Health, Safety & Security		20%	1	1	2	2	1	1
Traffic		20%	-1	2	3	3	3	2
Reliability		20%	2	1	1	1	1	2
Footprint		20%	2	1	-3	-3	1	3
Odors		20%	1	1	1	1	1	-1
OVERALL TOTAL[2]			**1.56**	**1.40**	**1.04**	**-0.07**	**0.02**	**-0.20**

TABLE 3 (Continued): MATRIX RATING RESULTS FOR THE CALUMET WATER RECLAMATION PLANT[1]

	Group Weight	Item Weight	DWF: UV WWF: Chlor/ Dechlor		DWF: UV WWF: PAA		DWF: Ozone WWF: Chlor/ Dechlor	DWF: Ozone WWF: PAA
			LPHO	MP	LPHO	MP	-	-
Economic Criteria	**33.3%**							
Total NPV		100%	2	-1	-1	-3	1	-2
Environmental Criteria	**33.3%**							
GHG indirect Emissions		33.3%	-1	-2	-1	-2	-3	-2
Water Quality Effects		33.3%	2	2	2	2	2	2
Environmental Effects		33.3%	2	2	2	2	2	2
Social Criteria	**33.3%**							
Health, Safety & Security		20%	1	1	1	1	1	1
Traffic		20%	1	1	2	2	1	2
Reliability		20%	1	1	1	1	1	1
Footprint		20%	-3	-3	-3	-3	1	1
Odors		20%	1	1	1	1	1	1
OVERALL TOTAL[2]			**1.07**	**-0.04**	**0.13**	**-0.64**	**0.78**	**-0.04**

[1] NaOCl: sodium hypochlorite
UV: ultraviolet irradiation
LPHO: low pressure high output UV lamps
MP: medium pressure UV lamps
PAA: peracetic acid
NPV: net present value
DWF: dry weather flow
WWF: wet weather flow
Chlor/Dechlor: chlorination/dechlorination
[2] Overall Total = $\sum$(Criteria Rating x Item Weight x Group Weight)

TABLE 4: MATRIX RATING RESULTS FOR THE NORTH SIDE WATER RECLAMATION PLANT[1]

	Group Weight	Item Weight	Chlorination/Dechlorination		UV		Ozone	PAA
			NaOCl, Bisulfite	On-site NaOCl, Bisulfite	LPHO	MP	-	-
Economic Criteria	**33.3%**							
Total NPV		100%	2	1	3	2	-3	-3
Environmental Criteria	**33.3%**							
GHG indirect Emissions		33.3%	-1	-1	-1	-2	-3	1
Water Quality Effects		33.3%	1	1	3	3	2	2
Environmental Effects		33.3%	2	3	2	2	3	2
Social Criteria	**33.3%**							
Health, Safety & Security		20%	1	1	2	2	1	1
Traffic		20%	-1	2	3	3	3	2
Reliability		20%	2	1	1	1	1	2
Footprint		20%	-1	-1	2	2	-1	-1
Odors		20%	1	1	1	1	1	-1
OVERALL TOTAL[2]			**1.02**	**0.93**	**2.04**	**1.60**	**-0.44**	**-0.47**

TABLE 4 (Continued): MATRIX RATING RESULTS FOR THE NORTH SIDE WATER RECLAMATION PLANT[1]

	Group Weight	Item Weight	DWF: UV WWF: Chlor/ Dechlor		DWF: UV WWF: PAA		DWF: Ozone WWF: Chlor/ Dechlor	DWF: Ozone WWF: PAA
			LPHO	MP	LPHO	MP	-	-
Economic Criteria	**33.3%**							
Total NPV		100%	2	2	-1	-1	-1	-3
Environmental Criteria	**33.3%**							
GHG indirect Emissions		33.3%	-1	-2	-1	-2	-3	-2
Water Quality Effects		33.3%	2	2	2	2	2	2
Environmental Effects		33.3%	2	2	2	2	2	2
Social Criteria	**33.3%**							
Health, Safety & Security		20%	1	1	1	1	1	1
Traffic		20%	1	1	2	2	1	2
Reliability		20%	1	1	1	1	1	1
Footprint		20%	-1	-1	-1	-1	-1	-1
Odors		20%	1	1	1	1	1	1
OVERALL TOTAL[2]			**1.20**	**1.09**	**0.27**	**0.16**	**-0.02**	**-0.51**

[1] NaOCl: sodium hypochlorite
UV: ultraviolet irradiation
LPHO: low pressure high output UV lamps
MP: medium pressure UV lamps
PAA: peracetic acid
NPV: net present value
DWF: dry weather flow
WWF: wet weather flow
Chlor/Dechlor: chlorination/dechlorination

[2] Overall Total = Σ(Criteria Rating x Item Weight x Group Weight)

TABLE 5: NET PRESENT VALUE ESTIMATES IN DOLLARS FOR THE CALUMET WATER RECLAMATION PLANT[1,2]

	Chlorination/Dechlorination[3]		Ultraviolet Irradiation[4]		Ozone[5]	PAA[6]
	NaOCl, $NaHSO_3$	On-site NaOCl, $NaHSO_3$	LPHO Lamps	MP Lamps		
Capital Cost	31,880,000	51,990,000	106,200,000	107,890,000	38,997,000	19,540,000
O&M Cost	127,367,000	108,774,000	105,800,000	167,517,000	221,240,000	279,266,000
Total NPV	159,256,000	160,764,000	212,000,000	275,407,000	260,237,000	298,806,000
Annual O&M	3,554,000	3,035,000	2,953,000	4,675,000	6,173,000	7,793,000

	DWF: UV WWF: Chlor/Dechlor[7]		DWF: UV WWF: PAA[7]		DWF: Ozone WWF: Chlor/Dechlor[7]	DWF: Ozone WWF: PAA[7]
	LPHO Lamps	MP Lamps	LPHO Lamps	MP Lamps		
Capital Cost	73,685,000	74,635,625	68,286,250	69,236,875	35,883,313	30,484,563
O&M Cost	115,239,500	149,955,313	181,691,375	216,407,188	180,174,500	246,626,375
Total NPV	188,924,500	224,590,938	249,977,625	285,644,063	216,057,813	277,110,938
Annual O&M	3,215,388	4,184,021	5,069,514	6,038,147	5,027,190	6,881,316

[1] Life=60 years; Interest=4.875; Inflation=3; Present Worth Factor=35.84; Average Energy Cost=$0.0780/kWh; Disinfection=275 days; Nov. 2010 ENR Index=8951; Nov. 2011 ENR Index=9173

[2] Maximum flow = 480 million gallons per day (MGD); average flow = 270 MGD

[3] NaOCl=sodium hypochlorite; $NaHSO_3$=sodium bisulfite; 6 mg/L chlorine dose; 15 minute contact time; $NaHSO_3$ for 2 mg/L chlorine residual; No filtration; No pumping station

[4] UV=ultraviolet irradiation; MP=medium pressure; LPHO=low pressure high output; Includes pumping station; No filtration; Calculated 40 mJ/cm^2 dose; 65% minimum UV transmittance

[5] Oxygen from Praxair pipeline; 8 mg/L dose; 10 minute contact time; No filtration; No pumping station; 10% side stream pumping for ozone injection; 8 mg/L dose may be too conservative, but was used due to conflicting doses found in literature and the lack of site specific data

[6] PAA=peracetic acid; 2 mg/L dose; 15 minute contact time; No filtration; No pumping station

[7] DWF=dry weather flow (270 MGD); WWF=wet weather flow (210 MGD); Capital cost for 270 MGD and 210 MGD prorated based on 480 MGD capital cost; O&M cost for 210 MGD is prorated based on 270 MGD O&M cost

TABLE 6: NET PRESENT VALUE ESTIMATES IN DOLLARS FOR THE NORTH SIDE WATER RECLAMATION PLANT[1,2]

	Chlorination/Dechlorination[3]		Ultraviolet Irradiation[4]		Ozone[5]	PAA[6]
	$NaOCl$, $NaHSO_3$	Onsite $NaOCl$, $NaHSO_3$	LPHO Lamps	MP Lamps		
Capital Cost	85,100,000	104,530,000	77,300,000	77,200,000	109,881,000	75,710,000
O&M Cost	113,613,000	98,345,000	73,974,000	112,932,000	215,613,000	249,160,000
Total NPV	198,713,000	202,875,000	151,274,000	190,132,000	325,494,000	324,870,000
Annual O&M	3,171,000	2,745,000	2,065,000	3,152,000	6,016,000	6,953,000

	DWF: UV WWF: Chlor/Dechlor[7]		DWF: UV WWF: PAA[7]		DWF: Ozone WWF: Chlor/Dechlor[7]	DWF: Ozone WWF: PAA[7]
	LPHO Lamps	MP Lamps	LPHO Lamps	MP Lamps		
Capital Cost	81,567,925	81,522,642	76,430,000	76,384,717	96,321,585	91,183,660
O&M Cost	95,663,264	113,304,623	169,830,491	187,471,849	159,801,679	233,968,906
Total NPV	177,231,189	194,827,264	246,260,491	263,856,566	256,123,264	325,152,566
Annual O&M	2,669,176	3,161,402	4,738,574	5,230,800	4,458,753	6,528,151

[1] Life=60 years; Interest=4.875; Inflation=3; Present Worth Factor=35.84; Average Energy Cost=$0.0780/kWh; Disinfection=275 days; Nov. 2010 ENR Index=8951; Nov. 2011 ENR Index=9173

[2] Maximum flow = 530 million gallons per day (MGD); average flow = 240 MGD

[3] $NaOCl$=sodium hypochlorite; $NaHSO_3$=sodium bisulfite; 6 mg/L chlorine dose; 15 minute contact time; $NaHSO_3$ for 2 mg/L chlorine residual; No filtration; No pumping station

[4] UV=ultraviolet irradiation; MP=medium pressure; LPHO=low pressure high output; No filtration; No pumping station; Calculated 40 mJ/cm^2 dose; 65% minimum UV transmittance

[5] Oxygen generated onsite; 8 mg/L dose; 10 minute contact time; No filtration; No pumping station; 10% side stream pumping for ozone injection; 8 mg/L dose may be too conservative, but was used due to conflicting doses found in literature and the lack of site specific data

[6] PAA=peracetic acid; 2 mg/L dose; 15 minute contact time; No filtration; No pumping station

[7] DWF=dry weather flow (240 MGD); WWF=wet weather flow (290 MGD); Capital cost for 240 MGD and 290 MGD prorated based on 530 MGD capital cost; O&M cost for 290 MGD is prorated based on 240 MGD O&M cost

For the North Side WRP, ultraviolet irradiation (UV) with low pressure high output (LPHO) lamps, specifically Trojan's Signa lamps, were given the highest rating of +3 due to this technology having the lowest NPV. Ozone was given the worst rating of -3 as it has the highest NPV. The remaining technologies were given ratings ranging between these two extremes. The NPV ratings for all the technologies evaluated for the North Side WRP are provided in Table 4.

3.2 Greenhouse Gas Emissions

The short-listed disinfection technologies do not directly emit greenhouse gases (GHGs), but they do have indirect emissions associated with their use. The indirect emissions that were considered in rating each technology for greenhouse gas emissions included emissions from electricity use, emissions from the transportation of chemicals, and emissions from chemical production off-site. The estimated emissions and assumptions used are provided in Appendix B. In general, the emissions due to chemical transportation were minimal compared to those emissions due to electricity use and off-site chemical production. Any indirect GHG emissions was considered a negative impact, so all ratings in this criterion ranged from -1 to -3. These negative ratings were correlated with equal ranges of estimated emissions. The ozone and ozone/chlorination/dechlorination alternatives were given the lowest rating of -3 due to these technologies using the greatest amount of electricity Refer to Tables 3 and 4 for the ratings of all the technologies. The ratings apply to both the Calumet and North Side WRPs.

3.3. Water Quality Effects

Disinfection of wastewater treatment plant effluent, regardless of which technology is used, can have several positive and/or negative impacts on the water quality of the effluent as well as the receiving stream. Introduction of a disinfectant may (1) lead to the formation of disinfection by-products (DBPs) through reactions with organic and inorganic compounds, (2) reduce anthropogenic and other undesirable compounds such as pharmaceuticals and endocrine disrupters, (3) impact effluent and downstream dissolved oxygen (DO) concentrations by either adding oxygen or increasing organic carbon which depletes DO, (4) cause toxicity in treated effluent if the disinfectant is not neutralized, and (5) increase total dissolved solids. Other than continually meeting the National Pollutant Discharge Elimination System permit limits for parameters including but not limited to suspended solids, carbonaceous biochemical oxygen demand, ammonia, DO, and fecal coliform, the only disinfection related parameter that may be regulated by the permit is the remaining oxidant concentration in the effluent. DBPs are not regulated in non-reuse, treated wastewater effluents.

The water quality effects criterion took into account all the possible effects each disinfection technology may have on the water quality of the effluent as well as the receiving stream. A sub-matrix for this criterion was created as shown in Table 7 to account for all the potential impacts of each technology. The chlorination/dechlorination process (using either purchased or on-site generated chemicals) was given a rating of +1 due to the likely formation of DBPs, decrease in DO and increase in assimilable organic carbon (AOC) which increases oxygen demand. UV was given a rating of +3 due to its minimal formation of DBPs. Although ozone will increase the DO in the effluent and remove some emerging contaminants, it can also be a source of DBPs and so was given a rating of +2. The in-parallel, combined technologies were rated with the effects of the dry weather process weighted more heavily since the dry weather flow will be continuous, with the wet weather occurring intermittently. These ratings apply to both WRPs.

TABLE 7: DISINFECTION TECHNOLOGIES' EFFECTS ON EFFLUENT AND RECEIVING STREAM WATER QUALITY[1,2]

Effect	Chlor, Dechlor	UV	Ozone	PAA	DWF: UV WWF: Chlor,Dechlor	DWF: UV WWF: PAA	DWF: Ozone WWF: Chlor,Dechlor	DWF: Ozone WW: PAA
Reduce Bacteria	3	3	3	3	3.0	3.0	3.0	3.0
Reduce Viruses	1	3	3	1	2.5	2.5	2.5	2.5
DO/AOC[3,4]	-1	1	-1	-2	0.5	0.25	-1	-1.25
DBPs[5]	-3	-1	-1	-2	-1.5	-1.25	-1.5	-1.25
TDS[6]	-3	1	-1	1	0.0	1.0	-1.5	-0.5
ECs[7]	3	1	1	1	1.5	1.0	1.5	1
Overall Rating	1	3	2	2	2	2	2	2

[1] Chlor.,Dechlor.=chlorination, dechlorination; UV=ultraviolet irradiation; PAA=peracetic acid; DWF=dry weather flow; WWF=wet weather flow.
[2] Ratings for the combined technologies calculated by taking a weighted average of the individual technologies (75% for DWF, 25% for WWF).
[3] AOC=assimilable organic carbon; increases in AOC increase microbiological activity and oxygen demand (lower DO) in the receiving stream.
[4] DO=dissolved oxygen; concentrations in effluent and receiving streams can be affected by some disinfection technologies.
[5] DBPs=disinfection byproducts; some disinfectants can result in harmful byproducts, some of which are known carcinogens.
[6] TDS=total dissolved solids; increased by some disinfection technologies; can comprise health of aquatic organisms.
[7] ECs=emerging contaminants; some disinfectants can also remove emerging contaminants such as endocrine disrupting compounds, pharmaceuticals, and personal care products, resulting in additional improvement in water quality.

3.4 Environmental Effects

There are very few non-water related environmental effects associated with the short list of disinfection technologies, other than indirect GHG formation, which is covered separately. The major environmental effects include possible spills that may occur during transport and storage of NaOCl, $NaHSO_3$, and PAA and possible release of mercury from UV lamps. As such, the technologies using only purchased NaOCl, $NaHSO_3$, PAA, or UV lamps were given a lower rating of +2. Those technologies that do not require these chemicals or UV lamps were given a rating of +3. Because both effects, spills and the release of mercury, can be prevented with proper transportation, handling, and/or disposal, the given ratings were considered appropriate. These ratings apply to both the Calumet and North Side WRPs.

3.5 Health, Safety, and Security

The health, safety, and security criterion examined the impact that each technology may have on the health and safety of plant staff, neighbors, and the public at-large, as well as any possible security issues that may arise from the use of a technology. Chlorination/dechlorination with purchased NaOCl and PAA were given a rating of +1 due to their low risk of chemical release, through transportation, handling, and storage and increased risk to security due to the large amount of truck traffic for chemical transportation. Chlorination/dechlorination with onsite generation of hypochlorite was rated similarly, except instead of the security risk regarding truck traffic, onsite generation has additional risk to plant staff due to chlorine gas which is generated and then used during the NaOCl production process and hydrogen gas which is a byproduct of the production process.

The UV alternatives had the highest rating of +2, as the plant staff has a low risk of electric shock and low risk of exposure to mercury. There are no security issues or risk to plant neighbors. Ozone was given a rating of +1 due to the low risk of ozone exposure to plant staff and the low risk of explosion of the oxygen and ozone-generating equipment. The combined, in-parallel technologies using either purchased NaOCl or PAA have some security risk associated with the transportation of the chemicals, and also have a low risk of exposure of plant staff to ozone or mercury. These processes were given a rating of +1. These ratings apply to both the Calumet and North Side WRPs.

3.6 Traffic

The short-listed disinfection technologies using purchased chemicals will require a number of truck deliveries per week. While the truck traffic will not interfere with operations, it can be a nuisance to plant staff who will need to be present during delivery. As such, the ratings for this criteria ranged between -1 and +3. The technologies were evaluated based on the number of trucks required each week and equal ranges of weekly truck deliveries were correlated with the range of ratings. Chlorination/dechlorination with purchased chemicals was given a rating of -1 due to the multiple truck deliveries required each day, which will increase traffic but will not be an unreasonable number during a weekday work shift. Chlorination/dechlorination with onsite generation of NaOCl, on the other hand, was given a rating of +2 as only a few deliveries per week would be required for $NaHSO_3$ and salt. UV (MP and LPHO) and ozone were given a rating of +3 as no truck traffic is required on a weekly basis. PAA was given a rating of +2 due to the lower amount of chemical required resulting in only a few truck deliveries per week. Finally, the combined, in-parallel technologies using PAA for wet weather flow were given a rating of +2 while those using chlorination/dechlorination for wet weather flows were given a rating of +1. These ratings apply to both the Calumet and North Side WRPs.

3.7. Reliability

The short-listed disinfection technologies were evaluated for their reliability. Chlorination/dechlorination, with purchased NaOCl, and PAA both have a low risk of mechanical failure. As a result these technologies were given a rating of +2. Chlorination/dechlorination with onsite generation of hypochlorite has added risk of mechanical failure of the generation equipment and was given a rating of +1. There is a risk of electrical failure when using UV (LPHO and MP lamps) and as a result these alternatives were given a rating of +1. The remaining technologies, ozone and the combined, in-parallel technologies, have multiple risks of mechanical failure. As a result, these were given a rating of +1. These ratings apply to both the Calumet and North Side WRPs.

3.8. Footprint

For the Calumet WRP, available space is limited for some of the short-listed disinfection technologies, especially if a low lift pumping station is required in addition to the disinfection process infrastructure. Unlike the North Side WRP, the Calumet WRP has the benefit of having an existing chlorine contact tank. As a result, the processes requiring a contact tank, chlorination/dechlorination, PAA and ozone, were given a higher rating. PAA was given a rating of +3 due to the fewer chemical storage tanks required and resulting smaller space requirements. Chlorination/dechlorination requires a greater number of storage tanks than PAA, resulting in a larger footprint, and was therefore given a rating of +2. Ozone will require space for the ozone generator and side-stream pumping for ozone injection, so it was given a rating of +1. Those alternatives using UV were given the lowest rating of -3 due to the space needed for the UV equipment as well as additional footprint for a low lift pump station.

For the North Side WRP, space is available so that any one of the short-listed disinfection technologies will "fit" into the site plan. However, some of the technologies will take up more space, which limits flexibility in any future process needs. The technologies requiring the most space are chlorination/dechlorination, ozone, and PAA, as a contact tank providing 10 to 15 minutes of residence time at maximum flow conditions is required. These technologies were given a rating of -1. The combined, in-parallel technologies require a smaller contact tank since chemical disinfection will only be applied to wet-weather flows, but there will still be a significant amount of UV equipment or ozone equipment with contact tank required. Therefore, these technologies were also given a rating of -1. UV, using both MP and LPHO lamps, will require the least amount of footprint and was therefore given a rating of +2.

3.9. Odors

The only disinfection technology that has an odor outside of the chemical handling area is PAA. A vinegar-like odor is usually detected in effluents where PAA is used as a disinfectant. As a result, PAA was given a rating of -1. The combined, in-parallel processes utilizing PAA for disinfecting wet weather flows were given a rating of +1. It is expected that the combined wet weather flow dosed with PAA and the dry weather flow treated with UV or ozone will not have a significant odor outside the chemical handling areas. Odors associated with the UV, ozone, and chlorination/dechlorination disinfection technologies are limited to the chemical handling areas and will not have a detectable odor in the effluent or surrounding communities. As a result, these technologies were given a rating of +1. These ratings apply to both the Calumet and North Side WRPs.

4.0. Summary

The short list of disinfection technologies was evaluated using a matrix with weighted criteria. A separate matrix was completed for the Calumet and North Side WRPs due to their differences such as their existing infrastructure and available space. The disinfection alternatives are listed in ranking order in Table 8 for both WRPs. Based on these results, the recommended and top ranked alternative for the Calumet WRP is chlorination/dechlorination with purchased chemicals and the recommended and top ranked alternative for the North Side WRP is UV with LPHO lamps, specifically the TrojanUV Signa system, which uses a higher wattage LPHO lamp.

TABLE 8: SHORT LIST OF TECHNOLOGIES IN RANKING ORDER BASED ON SCORING RESULTS FROM THE EVALUATION MATRIX[1]

North Side WRP		Calumet WRP	
Technology	Overall Total	Technology	Overall Total
UV – LPHO Lamps	2.04	Chlorination/Dechlorination	1.56
UV – MP Lamps	1.60	Chlorination/Dechlorination (on-site NaOCl generation)	1.40
UV – LPHO Lamps (DWF) Chlor/Dechlor (WWF)	1.20	UV – LPHO (DWF) Chlor/Dechlor (WWF)	1.07
UV – MP Lamps (DWF) Chlor/Dechlor (WWF)	1.09	UV – LPHO	1.04
Chlorination/Dechlorination	1.02	Ozone (DWF) Chlor/Dechlor (WWF)	0.78
Chlorination/Dechlorination (onsite generation)	0.93	UV – LPHO (DWF) PAA – (WWF)	0.13
UV – LPHO Lamps (DWF) PAA – (WWF)	0.27	Ozone	0.02
UV – MP Lamps (DWF) PAA (WWF)	0.16	UV – MP (DWF) Chlor/Dechlor (WWF)	-0.04
Ozone (DWF) Chlor/Dechlor (WWF)	-0.02	Ozone (DWF) PAA (WWF)	-0.04
Ozone	-0.44	UV – MP	-0.07
PAA	-0.47	PAA	-0.20
Ozone (DWF) PAA (WWF)	-0.51	UV – MP (DWF) PAA (WWF)	-0.64

[1] NaOCl: sodium hypochlorite
UV: ultraviolet irradiation
LPHO: low pressure high output UV lamps
MP: medium pressure UV lamps
PAA: peracetic acid
DWF: dry weather flow
WWF: wet weather flow
Chlor/Dechlor: chlorination/dechlorination

5.0. References

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Appendices

Appendix A: Cost Estimate Summaries

A summary of the estimated costs are provided in Tables A.1 to A.6 for chlorination/dechlorination, chlorination/dechlorination with on-site generation of sodium hypochlorite, ultraviolet irradiation with low pressure high output lamps, ultraviolet irradiation with medium pressure lamps, ozone, and peracetic acid. A summary of the costs for the in-parallel combined technologies are not provided, as they were calculated by prorating the cost estimates in the tables below. The capital cost for the dry and wet weather flow were prorated based on the capital cost for the maximum flow. The operating cost for the wet weather flow was prorated based on the operating cost of average flow. The dry weather flow is equal to the average flow.

TABLE A.1: COST SUMMARY FOR CHLORINATION/DECHLORINATION AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Chlorination/Dechlorination	**Calumet WRP[1] 480 MGD/270 MGD**	**North Side WRP[2] 530 MGD/240 MGD**
Capital Cost Estimates		
A. General Sitework	$10,730,000	$21,730,000
B. Chemical Storage Tanks and Disinfection Building	$18,100,000	$20,540,000
C. Chlorine Contact Tanks	$3,050,000	$42,830,000
Total Capital Cost	$31,880,000	$85,100,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$79,000	$79,000
B. Chemical Storage Tanks and Disinfection Building	$3,475,000	$3,091,000
Total Annual M&O Cost	$3,554,000	$3,171,000
Total Present Worth M&O Cost (60 Years)	$127,376,000	$113,613,000
Total Present Worth	$159,256,000	$198,713,000

[1] Maximum Flow: 480 MGD; Average Flow: 270 MGD.
[2] Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE A.2: COST SUMMARY FOR CHLORINATION/DECHLORINATION WITH ONSITE GENERATION OF SODIUM HYPOCHLORITE AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Chlorination/Dechlorination (On-site Generated NaOCl)	**Calumet WRP[1] 480 MGD/270 MGD**	**North Side WRP[2] 530 MGD/240 MGD**
Capital Cost Estimates		
A. General Sitework	$12,030,000	$21,730,000
B. Chemical Storage Tanks and Disinfection Building	$36,910,000	$39,970,000
C. Chlorine Contact Tanks	$3,050,000	$42,830,000
Total Capital Cost	$51,990,000	$104,530,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$643,000	$581,000
B. Chemical Storage Tanks and Disinfection Building	$2,392,000	$2,163,000
Total Annual M&O Cost	$3,035,000	$2,745,000
Total Present Worth M&O Cost (60 Years)	$108,774,000	$98,345,000
Total Present Worth	$160,764,000	$202,875,000

[1] Maximum Flow: 480 MGD; Average Flow: 270 MGD.
[2] Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE A.3: COST SUMMARY FOR ULTRAVIOLET IRRADIATION USING LOW PRESSURE HIGH OUTPUT LAMPS AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Ultraviolet Irradiation (Low Pressure High Output)	**Calumet WRP[1] 480 MGD/270 MGD**	**North Side WRP[2] 530 MGD/240 MGD**
Capital Cost Estimates		
Total Capital Cost	$106,200,000	$77,300,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$82,000	$79,000
B. Low Lift Pumping Station	$875,000	NA
C. Disinfection System	$1,994,000	$1,980,000
Total Annual M&O Cost	$2,953,000	$2,065,000
Total Present Worth M&O Cost (60 Years)	$105,800,000	$73,974,000
Total Present Worth	$212,000,000	$151,274,000

[1] Maximum Flow: 480 MGD; Average Flow: 270 MGD.

2 Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE A.4: COST SUMMARY FOR ULTRAVIOLET IRRADIATION USING MEDIUM PRESSURE LAMPS AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Ultraviolet Irradiation (Medium Pressure)	**Calumet WRP[1] 480 MGD/270 MGD**	**North Side WRP[2] 530 MGD/240 MGD**
Capital Cost Estimates		
Total Capital Cost	$107,890,000	$77,200,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$82,000	$79,000
B. Low Lift Pumping Station	$1,319,000	NA
C. Disinfection System	$3,273,000	$3,072,000
Total Annual M&O Cost	$4,675,000	$3,152,000
Total Present Worth M&O Cost (60 Years)	$167,517,000	$112,932,000
Total Present Worth	$275,407,000	$190,132,000

1 Maximum Flow: 480 MGD; Average Flow: 270 MGD.
2 Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE A.5: COST SUMMARY FOR OZONE AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Ozone	**Calumet WRP[1] 480 MGD/270 MGD**	**North Side WRP[2] 530 MGD/240 MGD**
Capital Cost Estimates		
A. General Sitework	$14,422,000	$9,253,000
B. Disinfection System	$24,575,000	$100,628,000
Total Capital Cost	$38,997,000	$109,881,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$23,000	$19,000
B. Disinfection System	$6,150,000	$5,997,000
Total Annual M&O Cost	$6,173,000	$6,016,000
Total Present Worth M&O Cost (60 Years)	$221,240,000	$215,613,000
Total Present Worth	$260,237,000	$325,494,000

1 Maximum Flow: 480 MGD; Average Flow: 270 MGD.
2 Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE A.6: COST SUMMARY FOR PERACETIC ACID AT THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Peracetic Acid	Calumet WRP[1] 480 MGD/270 MGD	North Side WRP[2] 530 MGD/240 MGD
Capital Cost Estimates		
A. General Sitework	$10,730,000	$21,730,000
B. Chemical Storage Tanks and Disinfection Building	$5,760,000	$11,150,000
C. PAA Contact Tanks	$3,050,000	$42,830,000
Total Capital Cost	$19,540,000	$75,710,000
Operation & Maintenance Cost Estimates		
A. General Sitework	$79,000	$79,000
B. Chemical Storage Tanks and Disinfection Building	$7,714,000	$6,872,000
Total Annual M&O Cost	$7,793,000	$6,953,000
Total Present Worth M&O Cost (60 Years)	$279,266,000	$249,160,000
Total Present Worth	$298,806,000	$324,870,000

[1] Maximum Flow: 480 MGD; Average Flow: 270 MGD.
[2] Maximum Flow: 530 MGD; Average Flow: 240 MGD.

Appendix B: Greenhouse Gas Indirect Emissions

The greenhouse gas (GHG) indirect emissions were estimated by summing the emissions due to electricity usage, transportation of chemicals, and off-site production of chemicals. Table B.1 lists the sum of GHG indirect emissions for each plant. The assumptions used to estimate the emissions are provided in Table B.2.

TABLE B.1: ESTIMATED SUM OF INDIRECT GREENHOUSE GAS EMISSIONS FROM EACH TECHNOLOGY FOR THE CALUMET AND NORTH SIDE WATER RECLAMATION PLANTS

Technology	Metric Tons of CO_2 Equivalent	
	Calumet WRP[1] 480 MGD/270 MGD	North Side WRP[2] 530 MGD/240 MGD
Chlorination/Dechlorination	6,883	6,341
Chlorination/Dechlorination (on-site generation)	7,754	8,115
Ultraviolet Irradiation (LPHO)	3,926	4,005
Ultraviolet Irradiation (MP)	21,673	22,473
Ozone	31,960	33,971
Peracetic Acid	80	65
Ultraviolet LPHO/Chlorination,Dechlorination	7,900	10,300
Ultraviolet MP/Chlorination,Dechlorination	19,694	21,903
Ultraviolet LPHO/Peracetic Acid	2,658	2,605
Ultraviolet MP/Peracetic Acid	14,452	14,208
Ozone/Chlorination,Dechlorination	26,531	29,127
Ozone/Peracetic Acid	21,289	21,432

[1] Maximum Flow: 480 MGD; Average Flow: 270 MGD.
[2] Maximum Flow: 530 MGD; Average Flow: 240 MGD.

TABLE B.2: ASSUMPTIONS USED TO ESTIMATE TOTAL GREENHOUSE GAS INDIRECT EMISSIONS

Emission Category	Assumptions
From Electricity Use	1. Electricity used by each technology obtained from manufacturer of equipment 2. Emissions from electricity use obtained from Illinois Commerce Commission (www.icc.illinois.gov) - CO_2: 1680.2 lbs/1000 kWh - N_2O: 1.70 lbs/1000 kWh 3. Global warming potential of 310 for N_2O relative to CO_2 based on IPCC Second Assessment Report 1996 (100 yr time horizon)
From Transportation	1. Miles traveled 2. Mile-ton method used as proposed by the World Resources Institute's Greenhouse Gas Protocol: 0.00033 metric tons of total GHG emissions in CO_2 equivalents per mile-ton 3. One-way miles to travel for sodium hypochlorite Calumet: 21 North Side: 40 4. One-way miles to travel for sodium bisulfite Calumet: 5 North Side: 35 5. One-way miles to travel for peracetic acid Calumet: 51 North Side: 51
From Off-Site Production	1. Sodium hypochlorite production: 1.75 kWh/lb produced 2. Emissions from electricity use same as above. 3. No emissions from sodium bisulfite or peracetic acid production