Municipal Wastewater Treatment Technologies: Present and Future

Thomas E. Kunetz, P.E., BCEE, WEF Fellow
Assistant Director of Monitoring and Research
Metropolitan Water Reclamation District of Greater Chicago

Recovering Resources, Transforming Water

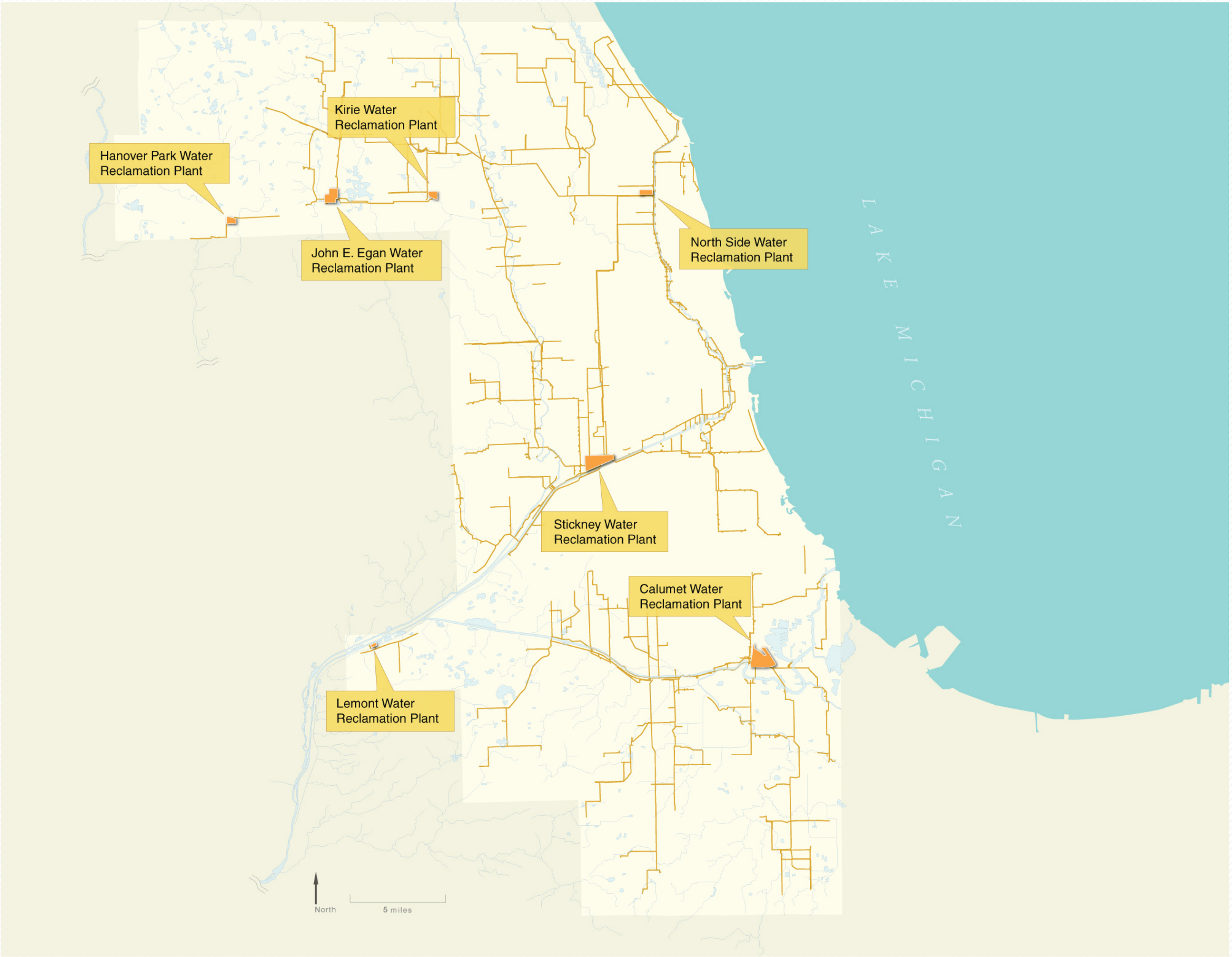
Metropolitan Water Reclamation District of Greater Chicago

- Independent government and taxing body
- Treatment of wastewater from 125 municipalities plus city of Chicago
- Collection is done by local municipalities
- Stormwater management for Cook County
- TARP system for pollution and flood control

Metropolitan Water Reclamation District of Greater Chicago

Real population served	5.25 million
Equivalent Commercial and Industrial population served	4.5 million
Combined Sewer Overflow Equivalent Population	0.6 million

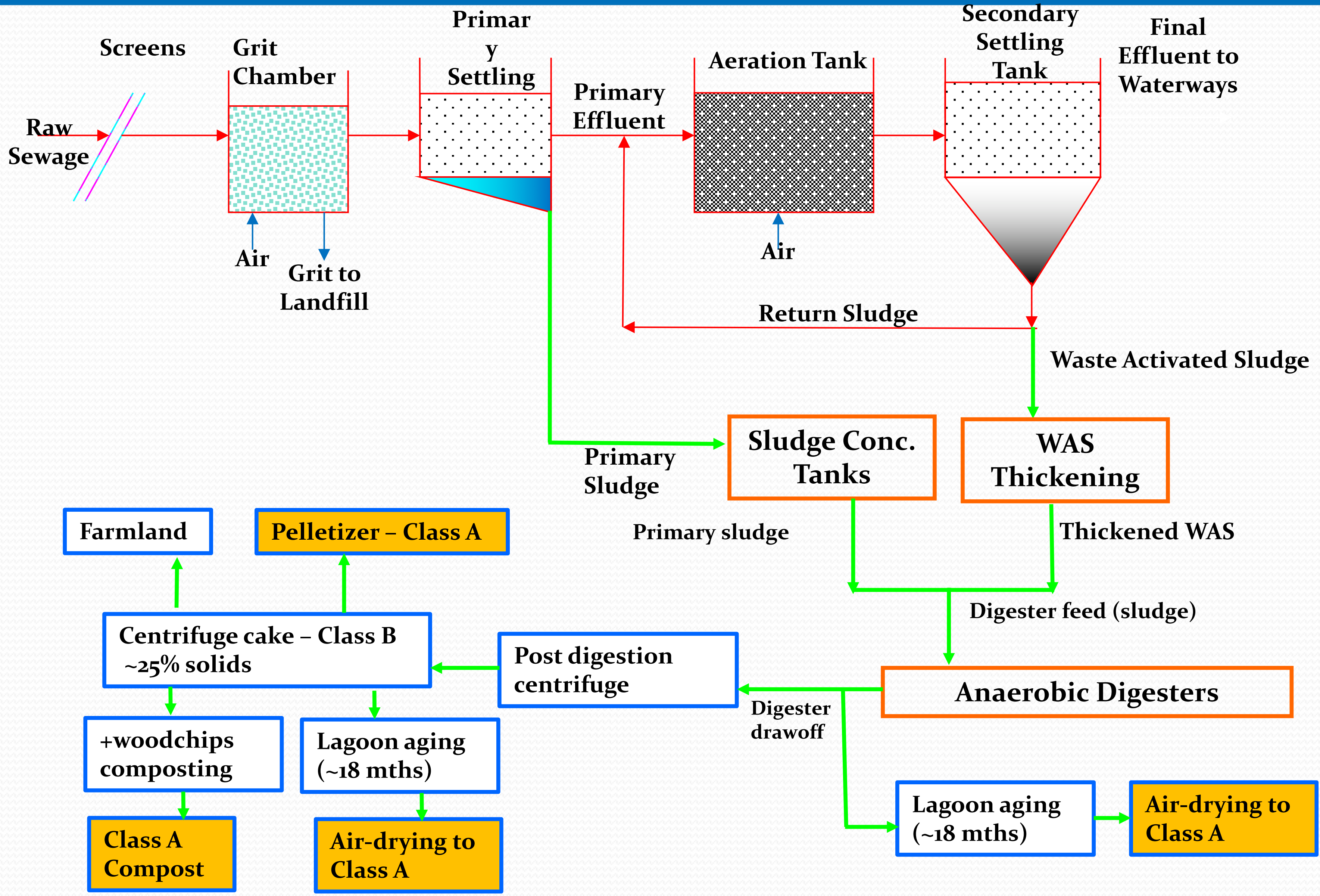
MWRD Intercepting Sewers and Water Reclamation Plants

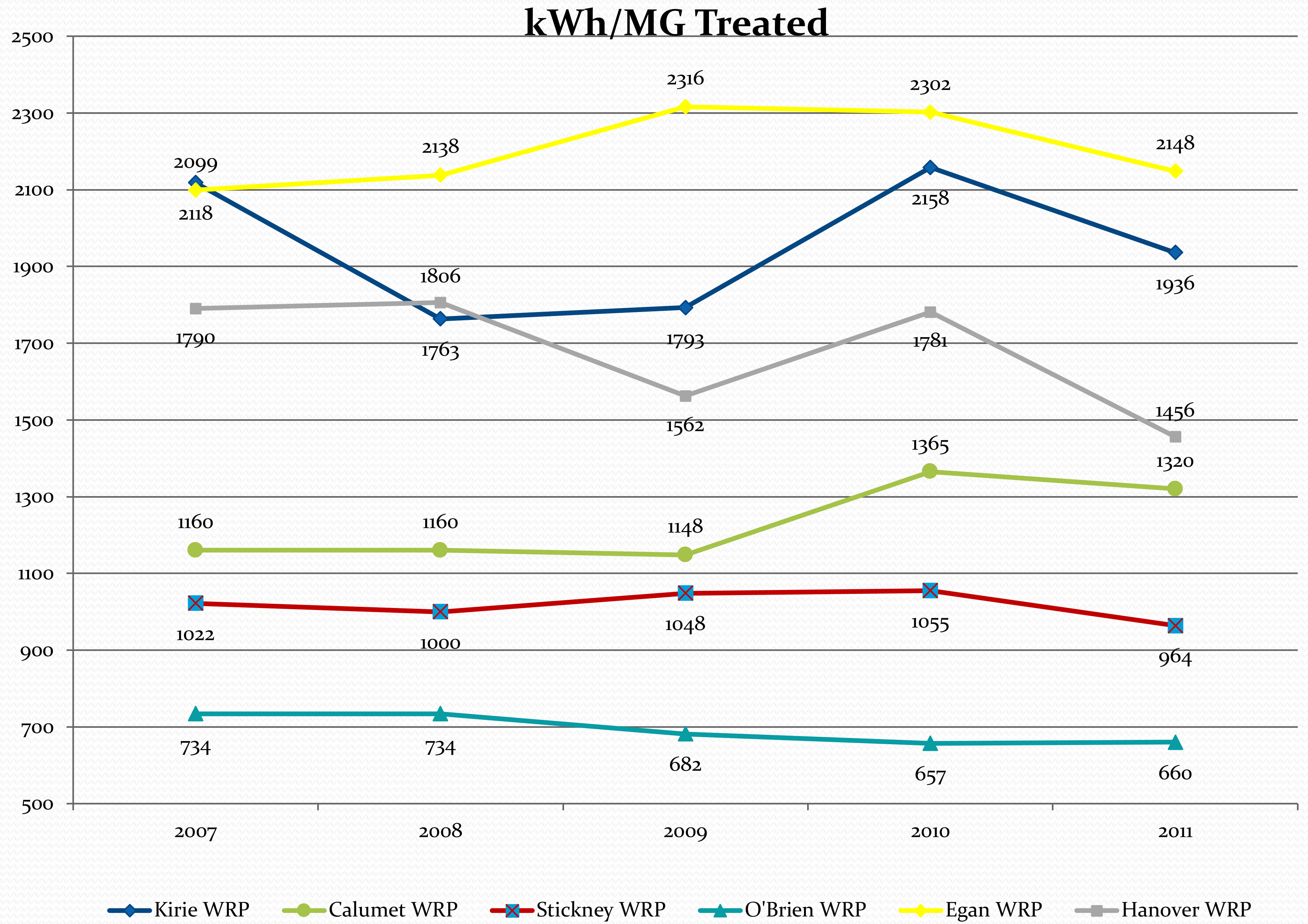


MWRD Water Reclamation Plants

Water Reclamation Plant	Design Capacity (MGD)	Design Capacity (M^3/day)
Stickney	1,200	4,542,000
Calumet	354	1,340,000
O'Brien	333	1,260,000
Kirie	52	196,000
Egan	30	113,000
Hanover Park	12	45,000
Lemont	2.3	8,700

Schematic of MWRD Stickney WRP Treatment Process




kWh/MG Treated
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
2007
2008
2009
2010
2011
2099
2138
2316
2302
2148
2118
1806
1763
1793
2158
1936
1790
1562
1781
1456
1160
1160
1148
1365
1320
1022
1000
1048
1055
964
734
734
682
657
660
Kirie WRP
Calumet WRP
Stickney WRP
O'Brien WRP
Egan WRP
Hanover WRP

Current Regulatory, Operational and Public Relations Challenges

Regulatory Requirements

- Disinfection
  - WRP effluents - Fecal coliforms – monthly geometric mean 200 CFU/mL
  - Combined sewer overflows
- Biosolids pathogen reduction – Class A standards for beneficial reuse
  - Fecal coliform <1,000 MPN/g,
  - Helminth ova <1/4g,
  - Enteric virus <1 PFU/4g
- Nutrient removal & recovery– Effluent P discharge limits
  - Current – 1 mg/L total P
  - Future – 0.5 mg/L total P

Current Regulatory, Operational and Public Challenges

Public Concerns

- Emerging Contaminants (EC) – pharmaceutical and personal care products (PPCPs), endocrine disrupting compounds (EDCs) etc.
- Odor emissions – within and outside of treatment plants

Operations

- Energy Neutrality

  -- Decrease energy consumption

  – Increase biogas utilization

  -- Increase biogas production

  -- Biosolids to fuel

Conventional and Current Technologies
Phosphorus Recovery

Sludge Liquor	Pre or Post Digested Sludge
Pearl®	AirPrex®
Crystalactor®	NuReSys®
Multiform Harvest (MFH)	CalPrex™
Phospaq™	Quick Wash™
Phosnix®	ANPHOS®
Quick Wash™	Phosnix®
Struvia™	
NuReSys®	

Phosphorus Recovery

- Produce Struvite (Magnesium ammonium phosphate)
- Process removes 80-85% of the Phosphorus that enters the treatment plant
- Can generate up to 9,000 metric tons per year of product

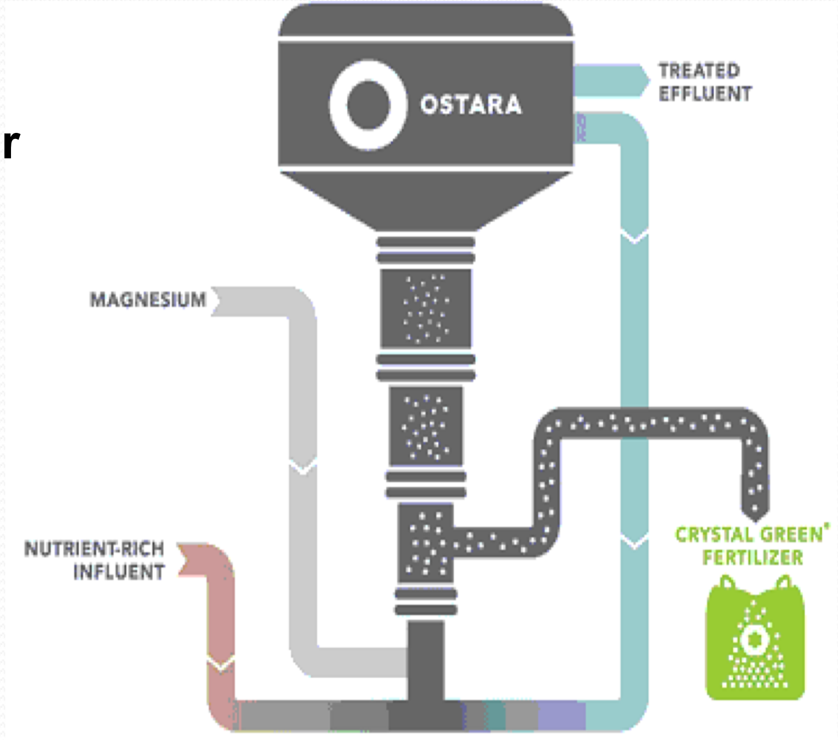
OSTARA
Creating Value from Waste

Conventional and Current Technologies
Phosphorus Recovery

Pearl®

- **Input Stream: Sludge Liquor**
- **Type of Reactor: Fluidized Bed Reactor**
- **Reagents: $MgCl_2$, NaOH**
- **Influent Quality: >75 mg/L ortho-P**
  <1,000 mg/L SS
- **Product: Struvite Pellets**
- **Recovered**
- **Removal Efficiency : 80-90 % P**

- **Ostara installation at Stickney WRP**

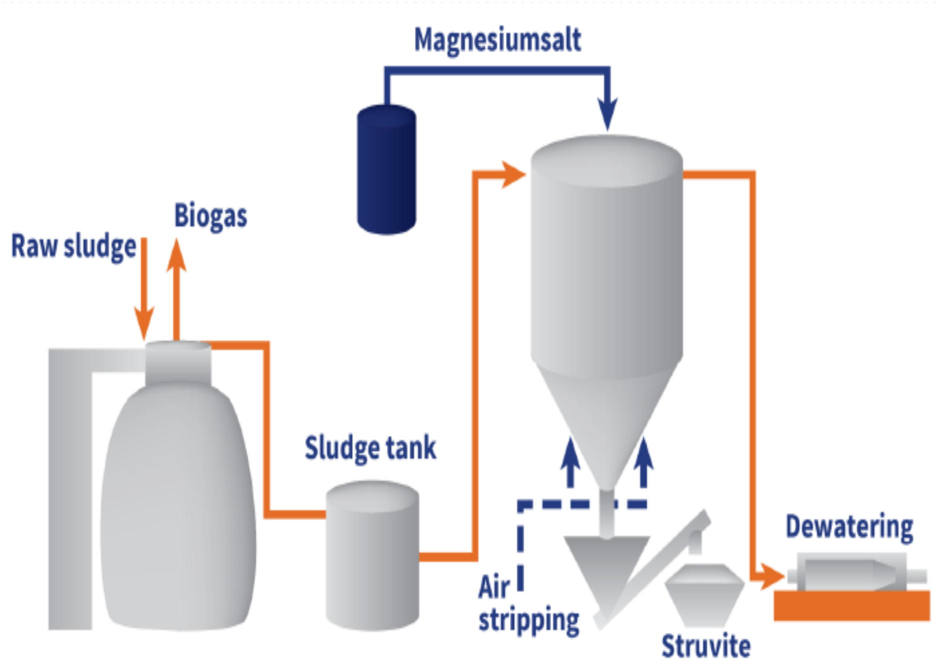


Pearl® Reactor

Phosphorus Recovery

Airprex

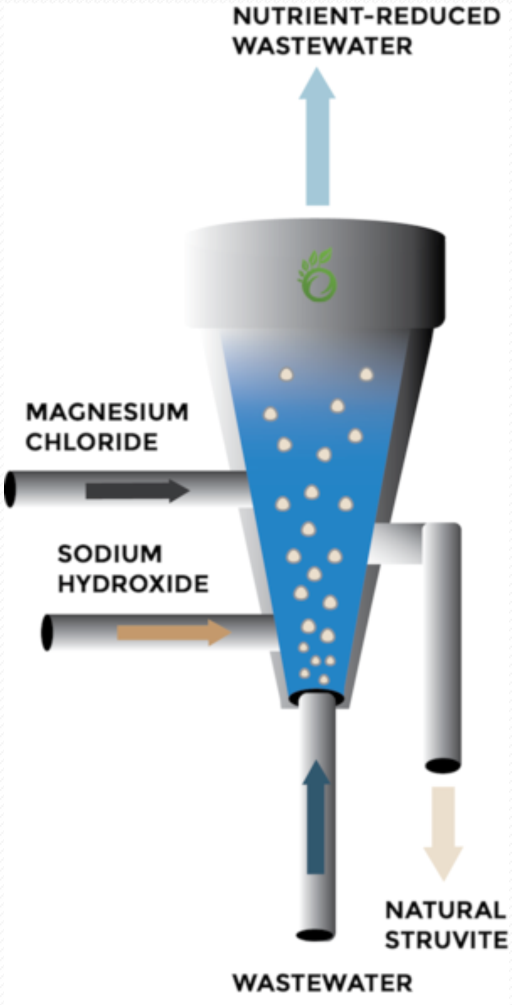
- Input Stream: Digested Sludge
- Type of Reactor: Airlift Reactor
- Reagents: $MgCl_2$, Air
- Influent Quality: >50 mg/L ortho-P
- Product Recovered: Struvite
- Removal Efficiency : >90 % P



Conventional and Current Technologies
Phosphorus Recovery

Multiform™ Harvest

- Input Stream: Digested Sludge
- Type of Reactor: Upflow Reactor
- Reagents: $MgCl_2$, NaOH
- Product Recovered: Struvite
- Removal Efficiency : 80-90 % P; 10- 40% NH_3-N

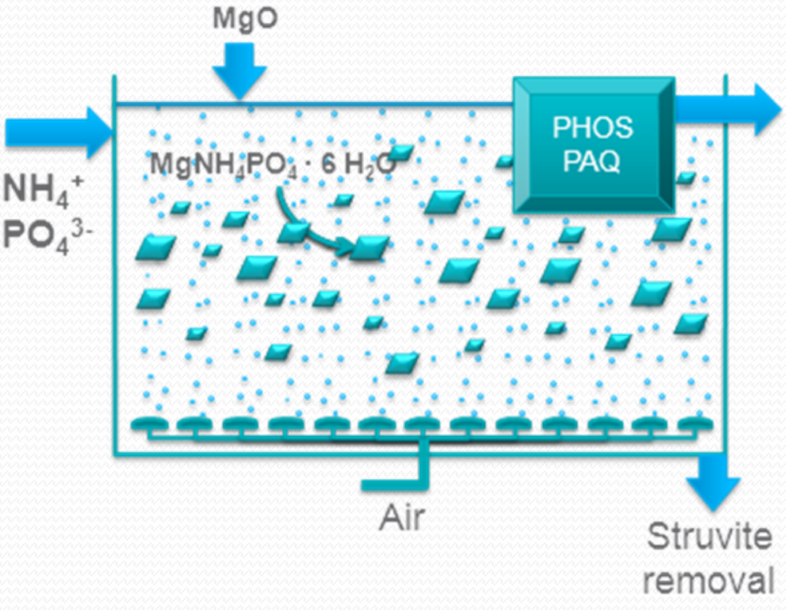


Multiform Harvest Reactor

Conventional and Current Technologies
Phosphorus Recovery

Phospaq™

- Input Stream: Sludge Liquor
- Type of Reactor: Continuous Stired Tank
- Reagents: MgO or $MgCl_2$, Air
- Product Recovered: Struvite
- Removal Efficiency : 80-90 % P; 10- 40% NH_3-N



Phospaq Process

Conventional and Current Technologies
Disinfection

Mature Technologies

- Chlorination
- Chloramination
- Ozonation
- Ultraviolet Irradiation

Practicable Tech.

- Chlorine Dioxide
- Peracetic Acid

Combination Tech.

- Ultraviolet/Ozonation
- Ultraviolet/Peracetic
- Ultraviolet/Chlorination
- Ultraviolet/Peroxide
- Ozonation/Peroxide

Emerging/Innovative Technologies

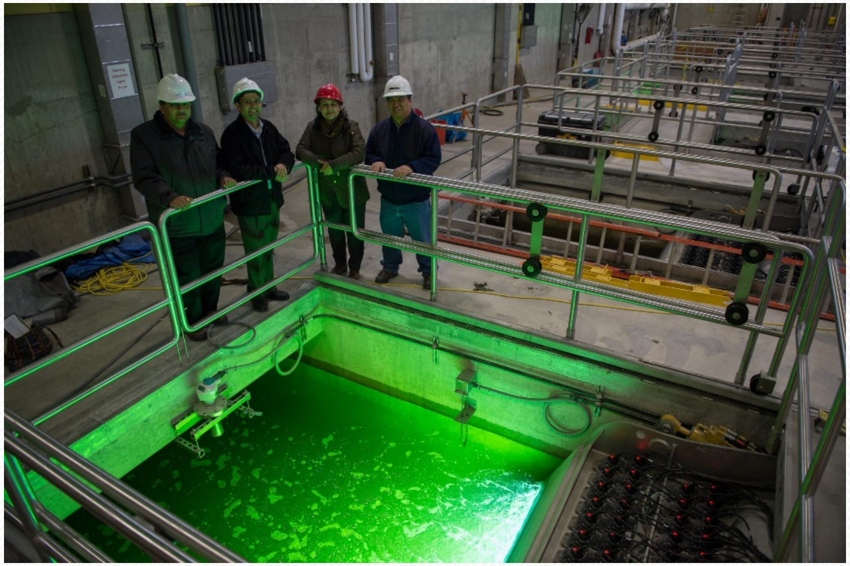
- Bromine chemicals
- Ferrate
- Gamma/Electron Beam
- Membrane
- Microwave Irradiation
- Pasteurization
- Pulse Ultraviolet
- Quatanary Ammonium
- Tin Oxide Anodes
- TiO2/Photocatalysis
- Ultrasonic Caviation
- Zero Valent Iron

Conventional and Current Technologies
Disinfection

Calumet WRP – Chlorination/Dechlorination

- DAF: 354 mgd
- Installed 2016
- Disinfection season: March – Nov.
- Chemical cost: ~$12/ mil gal.

Conventional and Current Technologies
Disinfection



O’Brien WRP – UV Disinfection

- DAF: 333 mgd
- Installed 2016
- Disinfection season: March – Nov.
- Electricity: ~40 kwh/mil gal, ~ $3/mil gal.
- 900 bulbs replacement: every 3 yrs, ~$500,000/yr

Conventional and Current Technologies
Emerging Contaminants (EC)

- EC destruction processes
  - Ozone
  - Advanced oxidation processes (AOPs)
- EC removal (separation) processes
  - Membranes (e.g. RO, NF)
  - Activated carbon
- Advanced treatment can provide complete to near complete removal of most ECs, but at a high cost

Conventional and Current Technologies
Emerging Contaminants (EC)

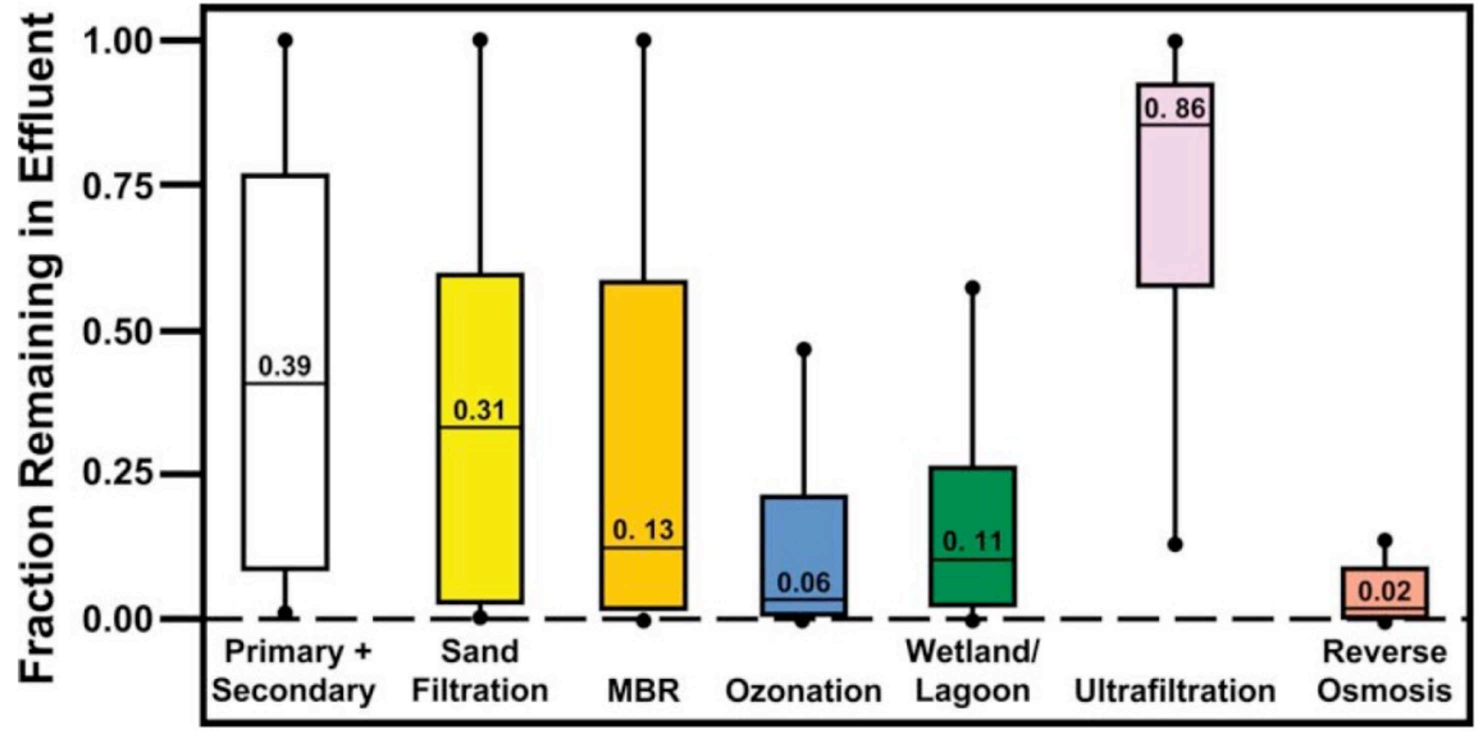
Cost ranking of options for reducing ECs in effluent

High cost ↕ Low cost

1. Advanced treatment
   - Membranes, activated carbon
   - Ozone, advanced oxidation processes
2. Tertiary treatment
   - BNR
   - Sand filtration
3. Optimize conventional WWT
   - Increase SRT
4. Source control
   - (Effectiveness is uncertain)

Conventional and Current Technologies
Emerging Contaminants (EC)

Comparison of PPCP Removal efficiencies by different WWTP technologies



Oulton et al. 2010. Pharmaceuticals and personal care products in effluent matrices: a survey of transformation and removal during wastewater treatment and implications for wastewater management. *Journal of Environmental Monitoring*. 12. 1956-1978.

Conventional and Current Technologies

Emerging Contaminants (EC)

O'Brien WRP – UV disinfection: Pharmaceuticals Pre and Post-Disinfection 2016-2017

Compound	Samples Detected§	Average Concentration (ng/L) Pre-disinfection	Post-disinfection	Percent Change
estrone (E1)	1	9 ± 2	9 ± 2	-6
estradiol (E2)	1	2 ± 3	nd	-
bupropion	15	120 ± 50	100 ± 40	-1
carbamezipine	15	230 ± 150	170 ± 70	-29
citalopram	15	130 ± 40	120 ± 40	-7
duloxetine	10	12 ± 15	4 ± 3	-65
fluoxetine	15	13 ± 17	20 ± 35	53
norfluoxetine	7	3 ± 4	4 ± 6	66
norsertraline	15	210 ± 140	180 ± 150	-6
paroxetine	4	8 ± 1	2 ± 2	-68
sertraline	16	60 ± 90	24 ± 16	-62
venlafaxine	16	240± 440	160 ± 60	-37

Data from Heiko Schoenfuss: NSF Study

Conventional and Current Technologies
Emerging Contaminants (EC)

Calumet WRP – Hypochlorite disinfection: Pharmaceuticals Pre and Post-Disinfection

Compound*	Samples Detected[§]	Average Concentration (µg/L) Pre-disinfection	Post-disinfection	Percent Change
estrone (E1)	1	9 ± 1	8 ± 1	-12
estradiol (E2)	0	nd	nd	
bupropion	16	90 ± 100	60 ± 40	-30
carbamazepine	16	160 ± 50	150 ± 50	-1
citalopram	16	82 ± 70	29 ± 20	-64
duloxetine	16	3 ± 3	2 ± 2	-53
fluoxetine	16	320 ± 550	130 ± 140	-59
norfluoxetine	10	63 ± 68	18 ± 31	-71
norsertraline	16	270 ± 240	220 ± 180	-12
paroxetine	4	3 ± 1	2 ± 1	-17
sertraline	16	39 ± 65	13 ± 6	-66
venlafaxine	16	100 ± 40	67 ± 28	-33

Data from Heiko Schoenfuss: NSF Study

Conventional and Current Technologies
Class A Biosolids

Biosolids Class A pathogen reduction

- USEPA – Processes to further reduce pathogens (PFRP)
- Includes composting, heat drying, irradiation, pasteurization

MWRD – Lagoon-aging and air-drying (USEPA approved site-specific PFRP)

Conventional and Current Technologies
Class A Biosolids

Heat Drying

Biosolids Pelletizing Facility at Stickney WRP

Conventional and Current Technologies
Class A Biosolids

Biosolids Composting at MWRD
1 part biosolids:3 parts wood chips
~23 day active composting followed by ~ 16 weeks curing

Opportunities for E-beam Treatment

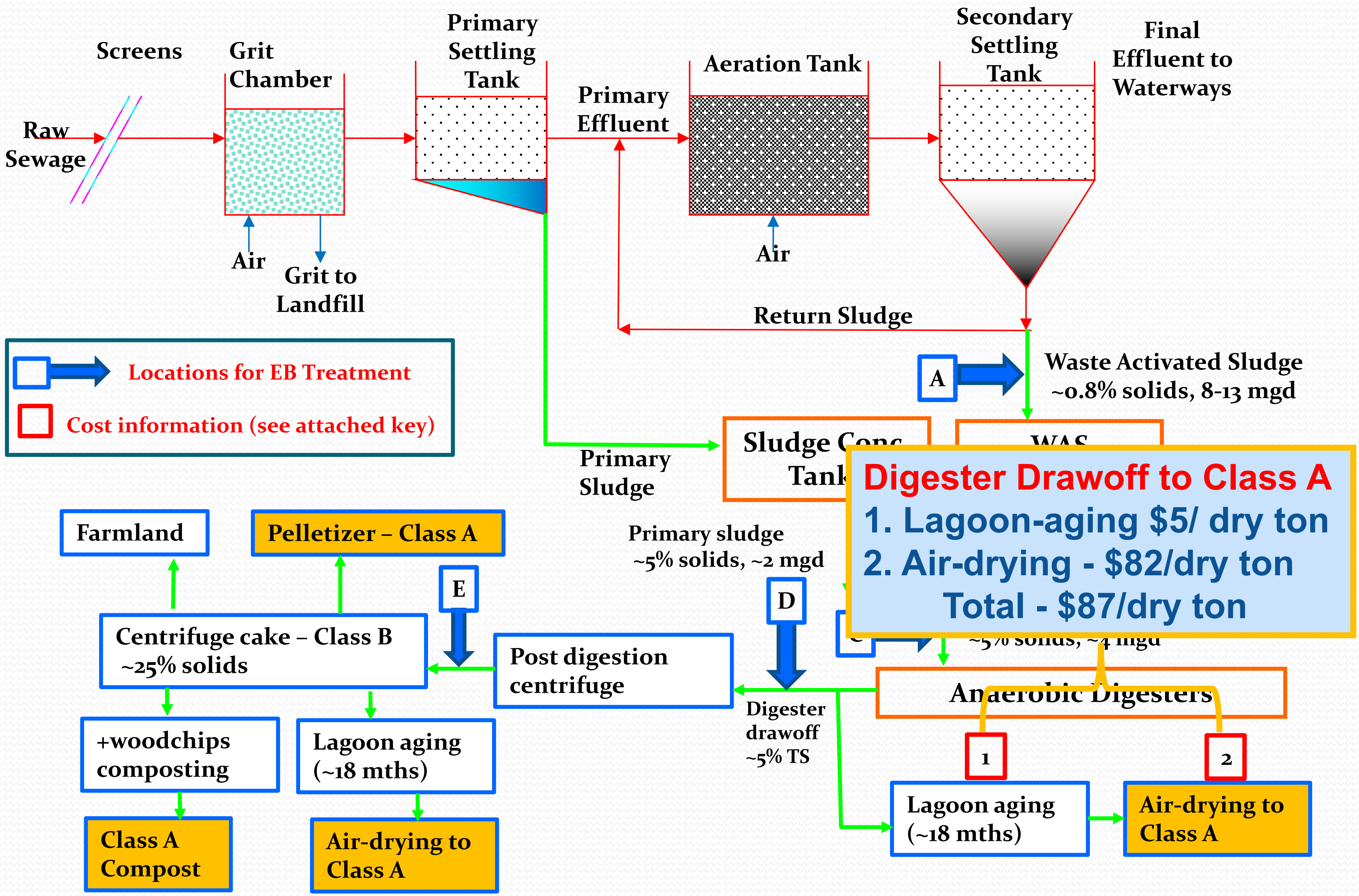
- Sludge and biosolids - Cell lysing
  - Energy recovery
  - Carbon for biological P removal
  - P release for recovery via Ostara
  - Pathogen reduction – Class A biosolids
- Disinfection and
  - WRP Effluent
  - Combined sewer overflows
  - Reduce EC
- Odor Control
  - Odor emissions from WRP

Opportunities for E-beam Treatment
Sludge and Biosolids

Location	Description	Potential Benefits
A	Waste activated sludge (WAS)	• Improve dewatering of WAS • Solubilize P for recovery in centrate
B	Thickened WAS	• Solubilize P for recovery in centrate via Ostara
C	Digester feed	• Pathogen reduction – USEPA Part 503 Class A standard • Increase recovery of digester gas • Solubilize P for recovery
D	Digester drawoff	• Pathogen reduction – USEPA Part 503 Class A standard
E	Centrifuge cake	• Pathogen reduction – USEPA Part 503 Class A standard

Opportunities for E-beam Treatment

Sludge and Biosolids



Opportunities for E-beam Treatment
Sludge and Biosolids

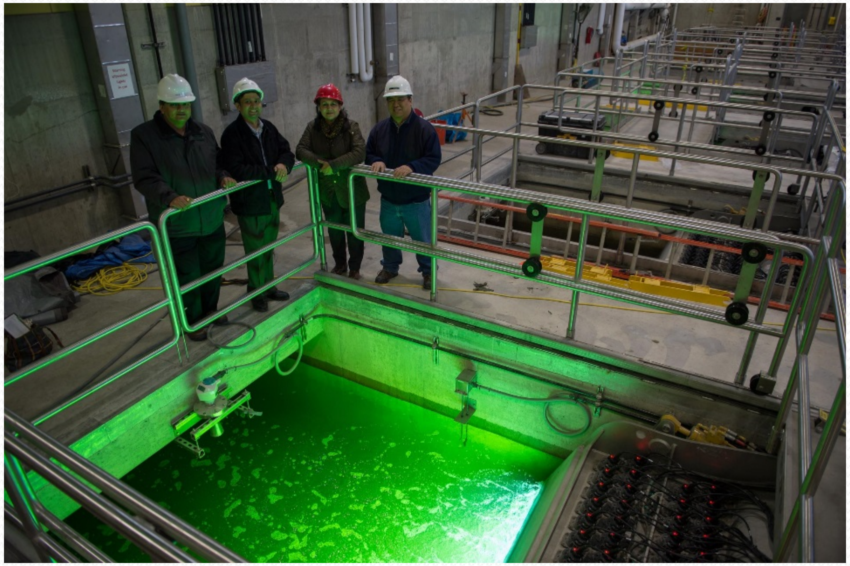
Centrifuges

Anaerobic digesters

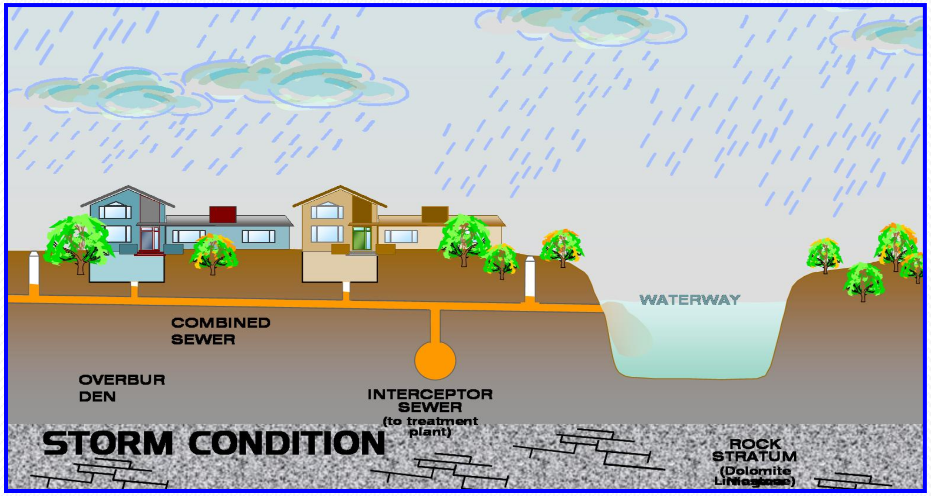
Opportunities for E-beam Treatment
Disinfection of Effluents & CSOs

Lemont Wet Weather Facility

O'Brien WRP UV Disinfection Facility



Opportunities for E-beam Treatment
Disinfection of Effluents & CSOs



Combined Sewer Overflows (CSO) during wet-weather conditions

Disinfection requirement

Opportunities for E-beam Treatment
Odor Control

Biofilter at Stickney WRP

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO