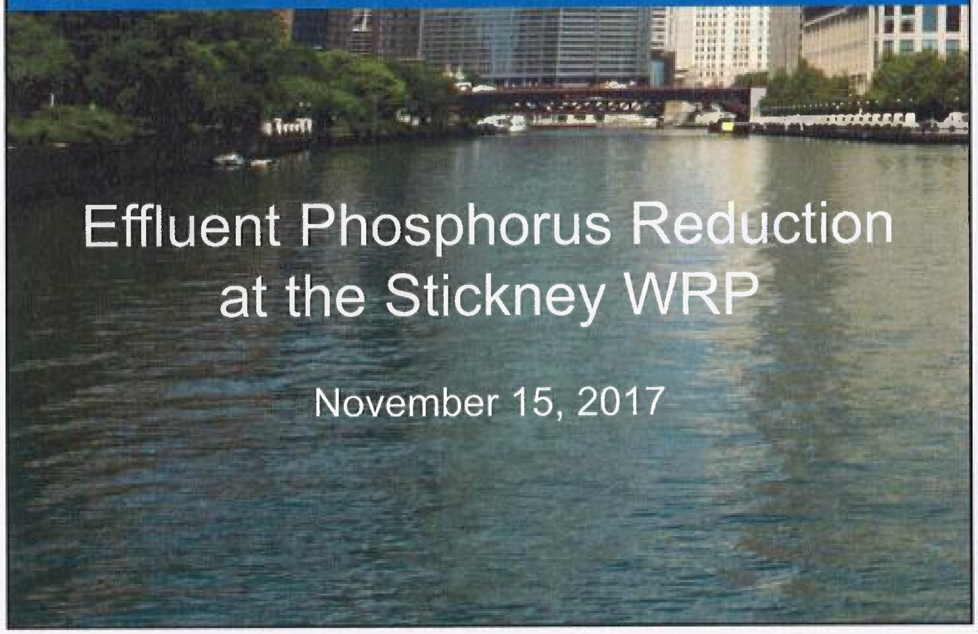
Metropolitan Water Reclamation District of Greater Chicago



Background

- Citizens suit - phosphorus limit of 1.0 mg/L at the three big plants 0.5 mg/L annual
- Considerations related to this limitation:
  - District will implement EBPR
  - Compliance schedules agreed to allow the District to implement necessary operational changes and schedule capital projects
- District created multi-departmental phosphorus task forces

Options for Phosphorus Reduction in Effluent

- Chemical precipitation
- Traditional conversion to EBPR
- EBPR utilizing existing infrastructure and phosphorus recovery

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Chemical Precipitation

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Disadvantages of Chemical Precipitation

- Similar capital costs as phosphorus recovery, but much higher annual chemical costs
- High volume of chemical deliveries required
  - 18 million gallons per year
  - 12 trucks per day
- Sequesters phosphorus in solids in a form that is not readily available for plant uptake

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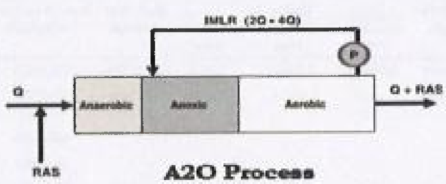
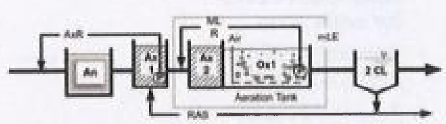
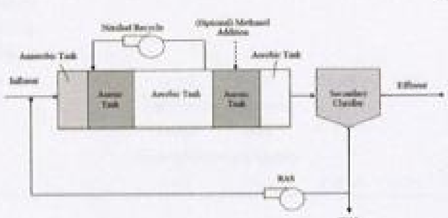
Traditional EBPR Options



A2O Process



Modified UCT Process



Modified Bardenpho Process

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Infrastructure for Traditional EBPR

- Baffles
  - Separation of zones
  - Allows for sludge blanket accumulation
- Mixers
  - To keep solids in suspension
  - To occasionally refresh the sludge blanket
- Recycle Pumps
  - To recycle between specific zones within each aeration tank

Infrastructure for Traditional EBPR (continued)

- Extra aeration capacity
  - Process dependent HRTs for each zone
  - Anaerobic HRTs of 0.5 – 3 hrs
  - Anoxic HRTs of 1.5 – 4 hrs
  - Aerobic HRTs of 4 – 12 hrs

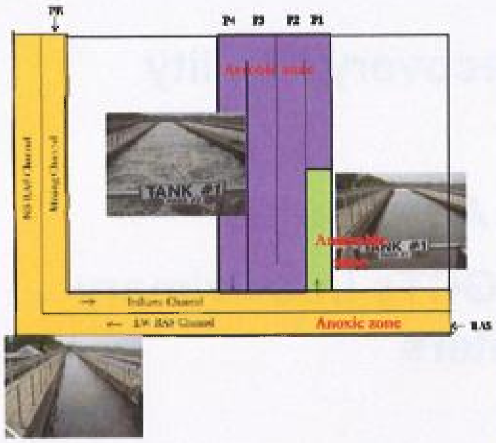
Design parameter or process	SRT, d[b]	MLSS, g/L	HRT, h[c] Anaerobic zone	HRT, h[c] Anoxic zone	HRT, h[c] Aerobic zone	RAS, % of influent	Internal recycle, % of influent
A^2/O	5 to 25	3 to 4	0.5 to 1.5	1.5 to 2.5	4 to 8	25 to 100	200 to 400
UCT	8 to 25	3 to 4	1 to 3	2 to 4	4 to 12	80 to 100	100 to 200 (anoxic) 100 to 200 (aerobic)
VIP	5 to 10	2 to 4	1 to 2	2 to 4	4 to 6	80 to 100	100 to 200 (anoxic) 100 to 300 (aerobic)
Bardenpho (five-stage)	10 to 20	3 to 4	0.5 to 1.5	1 to 3 (first stage) 2 to 4 (second stage)	4 to 12 (first stage) 0.5 to 1 (second stage)	50 to 100	200 to 400
SBR	20 to 40	3 to 4	1.5 to 3	1 to 3	2 to 4		

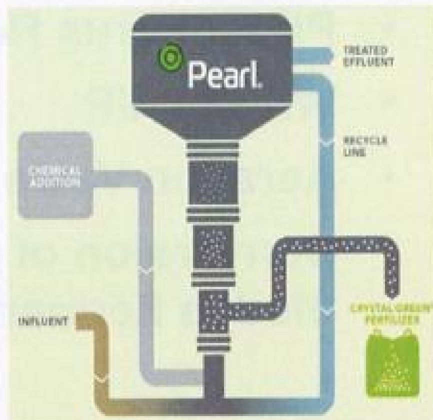
[a]Adapted from WEF, 1998b.

[b]Total SRT, including anaerobic and anoxic zones.

[c]The HRT refers to the retention time of the zones in terms of the average flow. Thus, an HRT of 1 hour refers to the volume that will be filled in 1 hour at average flow.

EBPR with Recovery





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Stickney WRP Operational Optimization for EBPR

- Operational Changes
  - Creation of Anoxic and Anaerobic Zones in Aeration Batteries
  - Limiting P-loading variability by equalizing recycle stream flow
  - Optimizing air input to all zones
  - Increased MLSS concentrations
  - Operating preliminary tanks to increase carbon loadings to EBPR process
  - Operating final tanks to minimize NO3 load from RAS

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Stickney WRP Capital Improvements

- Phosphorus Recovery Facility
- WASSTRIP
- Aeration Valve Automation
- Conversion of GCTs into Primary Sludge Fermenters

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Additional and Offset Costs

- Citric Acid costs associated with periodic cleaning of Ostara reactors
- Sulphuric Acid costs associated with struvite control in equipment and piping downstream of the centrifuges
- Reduced solids handling costs, including polymer, with improved dewaterability
- Reduced maintenance costs associated with chain-knocking of piping for struvite mitigation

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20-Year Life Cycle Costs

Process	Capital Cost (Mil)	Annual Operating Cost (Mil)	Total Cost (20 yr)
Chemical Precip	$28.0 (+642)	$29.10	$610
Traditional EBPR	$750+	-	$750+
EBPR w/ Recovery	$50.0	$0.65	$63.0

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Stickney Compliance Plan (EBPR w/ Recovery)

- Convert plant to EBPR utilizing existing infrastructure
- Recover phosphorus from the sidestream (post-digestion centrifuge centrate)

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RFP Process

- A panel of eight comprised the Selection Advisory Committee (2-Engineering, 2-M&R, 3-M&O and 1-Procurement)
- RFP was advertised June 27, 2012
- Review of RFP included:
  - Technical review of the initial proposal
  - Cost proposal review
  - Interview of proposers
  - Best and Final Offer review

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Proposers

- Three proposers submitted initial proposals and were interviewed.
  - Black & Veatch/Ostara
  - IHC/MutiForm Harvest/Pharmer Engineering
  - Midwestern Electric
- Shortlisted to two proposers for the submittal of a Best and Final Offer
  - Black & Veatch/Ostara
  - IHC/MutiForm Harvest/Pharmer Engineering
- Black & Veatch/Ostara selected

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B&V/Ostara Team Strengths

- Reliability
  - Consistent recovery has been shown.
- Expertise
  - B&V brought well-known individuals in the phosphorus removal field.
- Experience
  - Ostara has greater number of installations.
- Market
  - Numerous contracts with buyers already established.
- Beneficial Reuse
  - Dollar per ton for product higher with Ostara.

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Benefits of WASSTRIP

- Potential to produce 3X as much product
- Improvements to the solids dewatering process
- Reduction of struvite build-up in the digesters and post-digestion equipment
- Reduction of effluent phosphorus to 0.3 mg/L based by process modeling

Program for Phosphorus Recovery

- Largest of this type of facility to be built
- First time construction and use of reactors of this size
- Agreements based on partnerships for the design and construction of the facility
- Shared risk
- Agreed upon scope of work related to the construction of the facility

History of Implementation

- Construction of the facility began in October 2014
- First reactor receives centrate flow in May 2016 and testing of the system started
- Major outages in January 2017 through February 2017 and June 2017 through August 2017 due to struvite issues with the reactor feed pumps.
    - Issued change order for the design and construction of a sulfuric acid dosing system
    - Implemented interim measures for temporary citric acid washing until permanent automated systems have been constructed
- Completion of reactor testing and acceptance of system for operations in March 2017

Current Operational Status

- Producing 5-8 tons per day of product
- In 2017 the Stickney WRP effluent met the 1.0 mg/L monthly limit for phosphorus, with the exception of February when Ostara was not in operation
- In 2017, the Stickney effluent has geomean 0.47 mg/L for the year
  - Pre-Design modeling indicated an average effluent concentration of 0.6 mg/L phosphorus with recovery only from post-digestion centrate
  - The modeling indicated an average of 0.3mg/L once WASSTRIP is implemented.

Projected Annual Operational Costs

- Projected costs and offsets based on full production with WASSTIP online
- Chemical costs of approximately $3.7 M
  - Magnesium Chloride - $1.5 M
  - Sodium Hydroxide – $2.0 M
  - Sulfuric Acid – $0.2 M
- Offsets for fertilizer production of approximately $2.9 M

Outstanding Change Orders

- Negotiated Changes
  - Negotiated to approximately 55% of originally requested amounts
  - Unforeseen conditions includes encountering underground interferences, differences between expected conditions and those shown on as-built drawings used in design, etc.
  - Changes from basis of design includes potable water relocation, steam design changes, duct bank reinforcement, etc.
- WASSTRIP licensing and commissioning
- Additional one year operations by OSTARA
  - Will allow training of additional District operations and maintenance staff
  - Continued optimization as WASSTRIP comes on-line