Innovative Lagoon Wastewater Treatment: Delivering the Complete Solution through Modeling

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Presented by: Jim Martin
Benefits of Lagoon Treatment:

Simple process designed for BOD and TSS removal.

- Ability to handle peak flows.
- Great with high or low concentrations.
- No daily, weekly, monthly, yearly sludge handling.
- Minimal operator interface:
  - Pass through design process
  - No tough decisions
  - Simple and easy to operate.
Traditional Lagoon Treatment Shortcomings

- Lagoon systems require more land than other treatment methods.
- The inability to meet more stringent TSS limits due to the presence of algae in the effluent, particularly during warm weather.
- In cold climates, low temps will limit process efficiency during the winter.
  - Overall treatment performance is seasonal.
  - Difficult to nitrify or remove ammonia in cold climates.
- Nutrient Removal options are limited.
The Advancement of Lagoon Treatment has been limited due to:

• Until recently, there has been a void of reliable treatment technologies that can be integrated to enhance overall performance.

• There is very little/no theoretical (text book) methods for predicting or calculating performance of these advanced technologies.
Lagoon Treatment-Advancing Performance

Lagoon process control and performance is enhanced by 5 primary methods or strategies:

• Improve the ratio of Theoretical vs. Actual HRT in the lagoon
  • Adding baffles to create discrete treatment cells (BOD, TSS, Solids storage)
• Optimize oxygen transfer and mixing
  • Optimizing aeration equipment (BOD, TSS, Ammonia removal, sludge digestion, energy conservation)
• Improve Sludge digestion/decay
  • Settling zone for solids management and sludge digestion
LemTec™ Biological Treatment Process – Advancing Performance

Lagoon process control and performance can be enhanced by introducing a variety of simple yet effective advanced technologies within the lagoon process (continued):

• Augment environmental design conditions-temperature
  • Covering a portion/all of lagoon (BOD, TSS, Ammonia removal, sludge digestion, energy conservation)
• Post treatment tertiary treatment processes
  • Tertiary treatment (Phosphorus, TN, lower BOD, lower TSS & ammonia removal)
LemTec™ Biological Treatment Process

Complete Mix Cell  Hydraulic Baffle  Partial Mix Cells  Phosphorus Removal  Settling Cell  Lemna Polishing Reactor

Modular Insulated Cover
Traditional Lagoon Design - Limitations

• An advanced method to simulate the effects alternative technologies have on lagoon processes has not been historically available.

• The outdated design standards do not allow for incorporation of non steady state design conditions.
Traditional Lagoon Treatment - Lagoon Design Limitations

- Only takes into account a few key parameters:
  - BOD
  - Detention Time
  - Temperature

- Does not provide any process control for other key treatment objectives:
  - TSS
  - Ammonia
  - Phosphorus
  - Total Nitrogen

**Equation 1: EPA First Order Reaction Rate for Aerated Pond BOD Removal**

\[
BOD_{\text{Effluent}} = \frac{BOD_{\text{Influent}}}{\left(1 + \frac{kt}{n}\right)^n}
\]

- \( k = 0.276 \times 1.036^{T-20} \text{ (d}^{-1}) \)
- \( t = \text{Total Aerated Detention Time (d)} \)
- \( n = \text{Number of equally sized aeration cells} \)
- \( T = \text{Temperature (°C)} \)
Intro to Process Modeling

- Wastewater treatment process simulator that ties together biological, chemical, and physical process
- Accepted world-wide to design, upgrade, and optimize wastewater treatment plants of all types
- Allows for the creation of dynamic design input including flow, loading, effluent requirements, and physical characteristics
- Allows for a cause an affect analysis as we add other process technologies to the lagoons
- A unique process module was created to mimic our common treatment scenarios and configurations
Wastewater Process Modeling

- The model enables LET to consider the effects of non-steady state factors such as peak flows, constituent loading, and ambient air and water temperatures on all treatment objectives.

- The model may be adapted to site specific geometries and influent conditions.

- Modeling allows for each component to be individually analyzed to determine various efficiencies.

- Improves upon traditional steady state wastewater treatment process design methodology; The model may be manipulated to reflect the size, configuration, loading, aeration and effluent requirements for current or future facilities.

- Is especially useful in predicting and troubleshooting cold weather nitrification.
Model Example:

**Influent Data**
- \( Q_{des} = 0.140 \text{ MGD} \)
- \( BOD_{inf} = 0.240 \frac{mg}{L} \)
- \( TSS_{inf} = 240 \frac{mg}{L} \)
- \( NH3_{inf} = 33 \frac{mg}{L} \)

**CM Pond Data**
- \( V = 0.841 \text{ MG} \)
- HRT = 6 days
- Air = 994 SCFM

**PM Pond Data**
- \( V = 0.599 \text{ MG} \)
- HRT = 4.3 days
- Air = 70 SCFM

**Settling Pond Data**
- \( V = 0.762 \text{ MG} \)
- HRT = 5.4 days
- Air = 0 SCFM

**LPR Data**
- Cube Dimensions = 6′ x 6′ x 6′
- # of Cubes = 7 Cubes
- \( \frac{48 ft^2}{5 ft^3} = 9.6 ft^2 \)
- Air = 72 SCFM
- \( V = 25,000 \text{ gallons} \)
- HRT = 4.3 hours

**Permit Data**
- \( BOD_{eff} = 12 \frac{mg}{L} \)
- \( TSS_{eff} = 20 \frac{mg}{L} \)
- \( NH3_{eff, summer} = 4.1 \frac{mg}{L} \)
- \( NH3_{eff, winter} = 12.0 \frac{mg}{L} \)

**Variable Historical Data Input**
- Flow
- BOD
- TSS
- TN
- Temperature
- pH
- Alkalinity
Insulated Modular Cover

- Preserves temperature
- Eliminates algae growth
- Provides easy equipment access
- Rainwater can pass through casings
LET Covered Lagoon – Design Impacts

- Increased bulk volume temperature allows for more efficient treatment based on biological kinetics:
  - BOD Removal
  - Ammonia Removal
  - Sludge Digestion

- Overall reduced footprint of operations

- Reduced equipment sizing

- Allows for retrofits of existing lagoons
LET Covered Lagoon Temperature Model

To predict bulk wastewater temperature within lagoons, LET uses the following information:

- System design flow rate
- Influent design temperature
- Lagoon dimensions and surface area
- Local average temperature from the coldest month
- Modular cover insulation factor (R-value)
LET Covered Lagoon Temperature Model

Heat Balance Equation: \[ q_{out} \left( \frac{BTU}{hr} \right) = q_{in} \left( \frac{BTU}{hr} \right) \mp q_{amb} \left( \frac{BTU}{hr} \right) \]

- Flow
- Temperature
- Collection System
- Seasonal air temperature
- Insulation rating
- Pond dimensions
LET Covered Lagoon Temperature Model – Sloan, IA

- Evaluation of how well LETs model can predict lagoon operating temperature in Sloan, IA
- Temperature data taken from a nearby NOAA weather station with 5 years of historical temperature data
- Influent and effluent temperature data collected weekly from facility
LET Covered Lagoon Temperature Model – Sloan, IA

R-Value:

8

(Actual Conditions)
LET Covered Lagoon – Design Impacts

- Reduced required footprint for design
- Reduced cost of aeration due to reduced mixing energy
- Fewer desludging events required throughout lifetime of the system
Calibration of Model: Pilot Plant

- Pilot LPR Configuration
  - Three media modules housed in three tanks
  - Aeration and media volume fill ratios similar to full scale applications

- Objectives
  - Discern whether conventional design removal rates or process design software removal rates most accurately reflect LPR performance
Pilot LPR is being used to confirm parameters in the model:

- Growth rate
- Half saturation constant
- Temperature correction (theta)
Batch test results

Pilot Batch Tank Chart

- Ammonia
- Temperature
- 4°C Line (Minimum suggested activation temperature)
LemTec™ Biological Treatment Process – Complete Mix

Equation 2: Complete Mix Equation for Aerated Pond BOD Removal

\[
BOD_{\text{effluent}} = \frac{K_s (1 + k_d \times DT)}{DT(\mu_m - k_d) - 1}
\]

Where:
- \(K_s\) = Half – Saturation Constant (\(\text{mg} / L\))
- \(\mu_m\) = Maximum heterotrophic growth rate (\(d^{-1}\))
- \(k_d\) = Bacterial decay rate (\(d^{-1}\))
- \(DT\) = Detention time (\(d\))

- Utilize biosolids suspension to increase BOD removal performance within the cell
- Elevated influent BOD concentrations increase biosolids concentration within the reactor
- Elevated influent BOD concentration don’t impact effluent BOD quality
- Required energy to maintain mixing conditions
- Can nitrify ammonia under certain conditions
Aeration Equipment

• Aeration diffusers ranging from 9 SCFM to 32 SCFM
• Diffusers suspended from lagoon cover to prevent fouling and increase advective performance
• Easily serviceable from the lagoon cover with no additional equipment required for removal
• High reliability with an expected lifetime of 10 years
Polishing Reactor-Ammonia Removal

- Easily retrofitted to lagoons for increased performance
- Effectively removes ammonia and polishes BOD
- Submerged, attached growth process is reliable and consistent
- Out-of-pond applications typically utilize concrete tanks
Lemna Polishing Reactor

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LPR-operating
Glasgow, MT Case Study

PROJECT BACKGROUND
• Rural community in Valley County, Montana
• Existing Lagoon System
• Population of 3,364
• Faced with the decision to upgrade or replace its existing system
• More stringent effluent requirements
• Cold weather ammonia treatment required
Glasgow, MT Design

Flow: 0.650 MGD
Glasgow, MT Modular Cover
Glasgow, MT Aeration
Glasgow, MT LPR
Montana BTP

Concentration (mg/L)

Model BOD
DMR BOD

Performance Plot – BOD
Glasgow, MT Results

- System is achieving year-round effluent limits as low as 10 mg/l BOD, 10 mg/l TSS and 1 mg/l NH3-N
- Fraction of the cost of a mechanical system
- Low capital and operating costs, expandability and low maintenance
- Operational simplicity
- The City is now able to confidently meet their permit requirements while protecting their natural resources now and in the future
Performance Plot – Ammonia

Wisconsin BTP

Model Ammonia
DMR Ammonia

Concentration (mg/L)

Altamont, IL Case Study

PROJECT BACKGROUND

- Rural community in Effingham County
- Existing Lagoon System
- Population of 2,319
- Faced with the decision to upgrade or replace its existing system
- More stringent effluent requirements
- Land is expensive
- Large variations in seasonal flow
- Cold weather ammonia treatment required
Altamont, IL

Complete mix/Partial mix cell (prior to covering)

Partial mix/settling cells

LPR
Altamont, IL Design Parameters

- Total Flow: 0.992 MGD
  - Influent BOD: 158 mg/l
  - Influent TSS: 150 mg/l
  - Influent NH3: 15 mg/l
- Effluent Limits
  - BOD: 10 mg/l
  - TSS: 12 mg/l
  - NH3: 1.5 mg/l

Ambient Mean Temperature in Coldest Month: 28

Lagoon Design: CM/PM/SC

LPR: 24 cubes, 54 lbs NH3/Day
Altamont, IL Site Photos

Cover

Aeration

Lemna Polishing Reactor (LPR)
Altamont, IL Effluent Results

Flow

![Graph showing flow data from January 2015 to January 2018, with MO AVG and DAILY MX markers.](image)
Altamont, IL Effluent Results

BOD

ALTAMONT SOUTH STP, CITY OF (IL0027448) 001 – BOD, carbonaceous [5 day, 20 C] – Effluent Gross – Concentration

Late/Missing Reports Timeline

Concentration (mg/L)

MO AVG LIMIT  MO AVG  WKLY AVG LIMIT  WKLY AVG

Jan '15  Jul '15  Jan '16  Jul '16  Jan '17  Jul '17  Jan '18
Altamont, IL Effluent Results

TSS

![Graph showing TSS concentration over time with various data points and limits.](image-url)
Altamont, IL Effluent Results

NH3
Altamont, IL Results

- System capable of achieving year-round effluent limits as low as 10 mg/l BOD, 10 mg/l TSS and 1 mg/l NH3-N
- Fraction of the cost of a mechanical system
- Low capital and operating costs, expandability and low maintenance
- Operational simplicity
- The City is now able to confidently meet their permit requirements while protecting their natural resources now and in the future
Sloan, IA
Project Background

- Rural community in Woodbury County.
- Existing Lagoon System.
- Population of 973.
- More stringent effluent requirements.
- Wanted to use existing infrastructure.
- Large variations in seasonal flow.
- Required phased approach to allow ongoing treatment.
- Influent BOD: 67 mg/l
- Influent TSS: 126 mg/l
- Influent NH3: 10 mg/l

- Effluent Limits
  - BOD: 25 mg/l
  - TSS: 40 mg/l
  - NH3: 3.1 mg/l (Summer) / 4.8 mg/l (Winter)
LET Design
Installation
Installation
Controls
Results
Results - BOD treatment
Results - TSS removal

The graph shows the TSS concentration (mg/L) over time from April 2014 to January 2016. Two main lines are plotted: Influent TSS and Effluent TSS. The Effluent Limit is also marked, with a dashed line. The graph indicates significant TSS removal over the period, with fluctuations in concentration and temperature.
Results - Ammonia removal
Smithton, IL Case Study

PROJECT BACKGROUND

- Rural community in St. Clair County
- Existing Lagoon System
- Population of 2,248
- Faced with the decision to upgrade or replace its existing system
- More stringent effluent requirements
- Land is expensive
- Large variations in seasonal flow
- Cold weather ammonia treatment required
Smithton, IL
Smithton, IL Design Parameters

- Total Flow: 0.950 MGD
  - Influent BOD: 200 mg/l
  - Influent TSS: 204 mg/l
  - Influent NH3: 25 mg/l
  - Influent P: 6 mg/l

- Effluent Limits
  - BOD: 10 mg/l
  - TSS: 12 mg/l
  - NH3: 1.5 mg/l
  - P: 1 mg/l

Ambient Mean Temperature in Coldest Month: 31

Lagoon Design: CM/PM/PM/SC

LPR: 28 cubes, 98 lbs NH3/Day

Phosphorus Reduction: 48 lbs P/Day
Smithton, IL Effluent Results

Flow

[Graph showing data points and timeline for flow quantities]
Smithton, IL Effluent Results

BOD

[Graph showing BOD concentration over time with various data points and comparison to limits]
Smithton, IL Effluent Results

TSS

SMITHTON STP, VILLAGE OF (IL0020834) 001 – Solids, total suspended – Effluent Gross – Concentration

Late/Missing Reports Timeline

Concentration (mg/L)

Jan '15    Jul '15    Jan '16    Jul '16    Jan '17    Jul '17

MO AVG LIMIT  MO AVG  DAILY MX LIMIT  DAILY MX
Smithton, IL Effluent Results

NH3
Smithton, IL Effluent Results

Phosphate Concentration (mg/L) over Time

- MO AVG: Average Concentration
- MO AVG LIMIT: Maximum Allowable Concentration Limit

Timeline:
- Jan '15
- Jul '15
- Jan '16
- Jul '16
- Jan '17
- Jul '17

Concentration levels vary slightly above and below the average and limit throughout the time period.
Current Ammonia Loading at Forestville, WI WWTF

Ammonia Loading at Forestville, WI WWTF

- Ammonia Load
- Design Ammonia Load
- Strawberry Point Ammonia Loading
Current Ammonia Treatment at Forestville, WI WWTF
Current TSS & Ammonia Loading Rate at Forestville, WI WWTF
Forest Junction, WI Case Study

PROJECT BACKGROUND

- Rural community in Calumet County
- Existing Lagoon System
- Population of 616
- Faced with the decision to upgrade or replace its existing system
- More stringent effluent requirements
- Land is expensive
- Large variations in seasonal flow
- Cold weather ammonia treatment required
Forest Junction, WI

- Partial Mix Cells
- Complete Mix Cell
- LPR
- Settling Cell & Phosphorus Removal
Forest Junction, WI

- Total Flow: 0.056 MGD
  - Influent BOD: 240 mg/L
  - Influent TSS: 300 mg/L
  - Influent NH₃: 30 mg/L
  - Influent P: 6 mg/L

- Effluent Limits
  - BOD: 20 mg/L
  - TSS: 20 mg/L
  - NH₃ Summer: 1.3 mg/L; Winter: 4.5 mg/L
  - P: 1 mg/L

Ambient Mean Temperature in Coldest Month: 15⁰ F

Lagoon Design: CM/PM/PM/SC

LPR: 4 cubes, 33 lbs NH₃/Day
Forest Junction, WI Effluent Results

![BOD Graph](image)
Forest Junction, WI Results

![Graph showing TSS levels over time with distinct peaks on specific dates.](image-url)
Forest Junction Effluent Results

NH3
Forest Junction Effluent Results

![Graph showing effluent phosphorus levels from 8/18/2016 to 7/19/2018, with peaks in 9/22/2017 and 6/14/2017.](image-url)
Forest Junction, WI Conclusion

- System capable of achieving year-round effluent limits as low as 10 mg/l BOD, 10 mg/l TSS, 1 mg/l NH3-N and 1 mg/l P
- Fraction of the cost of a mechanical system
- Low capital and operating costs, expandability and low maintenance
- Operational simplicity
- The City is now able to confidently meet their permit requirements while protecting their natural resources now and in the future
Three Forks, MT Case Study
Three Forks, MT Project Background

- Rural community in Gallatin County, Montana
- Existing Lagoon System
- Population of 1,944
- Faced with the decision to upgrade or replace its existing system
- More stringent effluent requirements
- Large variations in seasonal flow
- Cold weather ammonia treatment required
Three Forks, MT Layout

Flow: 0.616 MGD
Three Forks, MT Modular Cover
Three Forks, MT Aeration
Three Forks, MT Aeration
Three Forks, MT LPR
Three Forks, MT Effluent NH3
Three Forks, MT Results

- System achieving year-round effluent limits as low as 10 mg/l BOD, 10 mg/l TSS and 1-2 mg/l NH3-N and 1 mg/l P.
- Fraction of the cost of a mechanical system.
- Low capital and operating costs, expandability and low maintenance.
- Operational simplicity.
- The City is now able to confidently meet their permit requirements while protecting their natural resources now and in the future.
The next level of Lagoon Process Design: Conclusion

- Advanced treatment technologies, coupled with sound, reliable process modeling and confirmed with operating site data provides:
  - The most reliable treatment processes, while addressing new treatment standards for Ammonia, Nitrogen and Phosphorus.
  - Lowered Capital and Operating Costs
  - Capability to design for Continuous Improvement.
Thank you-Questions?

Lemna Environmental Technologies, Inc.
Jim Martin
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