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WASTEWATER LOAD MODELLING

What you don't know can hurt you!

New England Water Environment Association

January 24, 2018

Agenda

- What is a WLM?
- Why develop a WLM?
- How do I develop a WLM?
- Considerations when developing a WLM
- Do WLMs work? (Case Studies)

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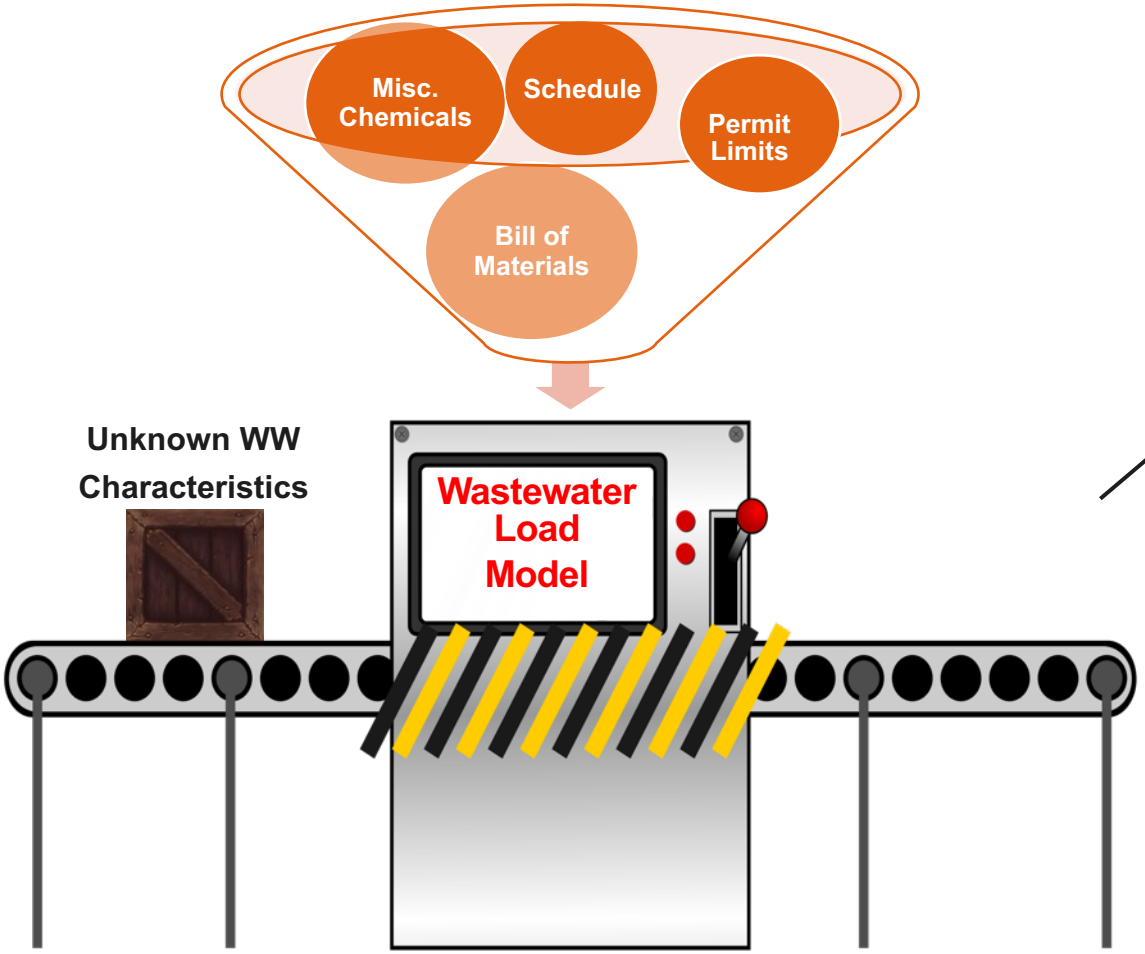
What is a wastewater load model?

What is a WLM?



1. Provides flow and loading information
   - Organic
   - Nutrients
2. Provides daily synopsis of production impact on wastewater

What is a WLM?

- A tool used to predict influent loading to wastewater treatment plant (WWTP)
  - Organic (chemical oxygen demand (COD))
  - Nutrient (nitrogen (N) and phosphorus (P))
  - Hydraulic (flow)
- Equates raw materials to constituents of concern (COC)
  - Based on stoichiometry
- Developed so user can understand the impact of its raw materials on wastewater
- Developed in MS Excel to be easily customized and modified
- “Living” Model of production

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Why develop a wastewater load model?

Why develop a WLM?

- Users often don't understand the potential impact of production on wastewater
  - "I need to dump this tank to prepare it for the next batch."
  - This can lead to potential regulatory ramifications.
- Communication between production and onsite WWTP staff is not optimal
  - "The influent COD spiked this morning. I wonder why."
  - Staff can effectively operate the WWTP
- Allows reevaluation of quantities of chemicals prepared versus needed for production
  - Deep dives into the process may uncover inefficient use of raw materials

Why develop a WLM?

- Regulatory authorities require wastewater characterization as part of permit applications
- WLMs can help:
  - prevent/decrease WWTP upsets
  - justify permit modifications
  - with wastewater treatment plant design

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How do I develop a wastewater load model?

How do I develop a WLM?

Five Ws of… ~~Reporting~~ WLM Development

- Who is going to be the end user of the WLM?
- What chemicals are used (strength and volume)?
- Where in the process are chemicals used?
- When in the process are chemicals discharged?
- Why is a WLM being developed (e.g. permitting, design)?
- How are chemicals discharged (slug vs. gradual)?

Usability and functionality of a WLM is also critical

How do I develop a WLM?

- The development of a defensible WLM typically relies on the following:
  - Bill of Materials (BOM): Materials/chemicals used in process
  - Production Schedule
  - Interviews with the “boots on the ground”
  - Stakeholder input
  - Confirmatory Sampling

Bill of Materials

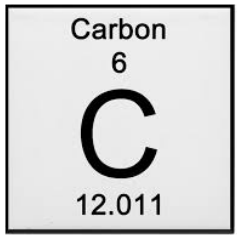
- The crux of the whole model (“recipe”)
- Identifies chemicals used (ingredients)
  - Strength of chemicals
  - Volume of each chemical
- High level picture of when and how in the process they are used (instructions)

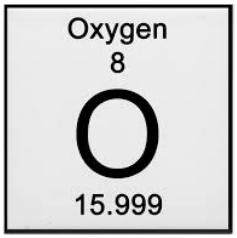
If outsourcing WLM development, an NDA is critical

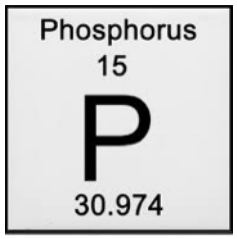
Bill of Materials

Chemicals in BOM are converted to COC

- Uses basic chemistry
  - COD assumes complete oxidation of chemical
  - N and P based on stochiometric formula
- High level understanding of:
  - Alkalinity
  - Acidity
  - Total Dissolved Solids







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Bill of Materials

- Goal is to estimate weight of COC per unit weight/volume of chemical
  - This value is theoretical!
  - Published data may be available
- Units are critical (M vs. mM vs. %)
- Don't forget about the heel!
  - BOM ≠ what is used in production
  - Heel dumping leads to slug doses

Bill of Materials

Okay…so what does that all mean?

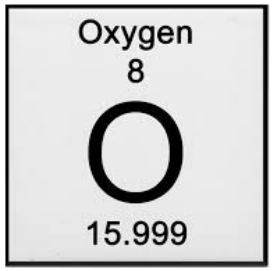
Bill of Materials

Assume the following is in a BOM:

- 100 gallons of 10% Ethanol
  - Ethanol = C_2H_6O
  - MW = 46.1 g/mol; density = 6.58 lb/gal
  - What is the impact on COD?

Chemistry Alert!

Bill of Materials



1. Write oxidation reaction for ethanol

$$C_2H_6O + \mathbf{3O_2} = 2CO_2 + 3H_2O$$

2. Determine theoretical COD for ethanol

$$ThCOD_{Ethanol} = \frac{3\times(16\times2)}{46.1} = \frac{2.08gO_2}{g\ Ethanol}$$

3. Calculate COD Loading

$$lb\ of\ COD = \left(\frac{10}{100}\right)\times2.08\times\left(100gal\times6.58\frac{lb}{gal}\right) = \mathbf{137\ lbs\ COD}$$

A WLM does all this in the background.

Production Schedule

- Understanding which products are made and when
- Indicates how BOM is implemented
  - On which day a chemical is used, and how it is discharged (dumped vs. gradual)
  - Daily wastewater loading schedule
- Cleaning is important!
  - Cleaning chemicals typically alter pH
  - Hydraulic loading spikes
  - Need to know frequency and magnitude of cleaning

Operator Interviews

- Allows user to understand what actually happens
  - They know the process better than anyone
- Learn about practices not formally documented, but necessary
- Understand level of communication between production and utilities

Stakeholder Input

- The eventual end-user
  - Usability and functionality need to be agreed upon
  - Determine if end-user intends on maintaining WLM
- Dictates the goal(s) of the WLM
  - Why the WLM is being developed
- Specifies the outputs
  - How should results be presented?
  - Factor of safety

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Confirmatory Sampling

- Opportunity to validate/calibrate WLM
  - Provides defensibility to WLM
- Minimizes/confirms assumptions
- Samples should be collected:
  - At each process step
  - At influent to WWTP (onsite)
  - For each COC
- Verify hydraulic loading with flow meters
  - May need to develop Water Balance

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Considerations when developing a Wastewater Load Model

WLM Considerations

- End-users version of MS Excel
  - Backwards compatibility (e.g. concat vs. concatenate)
  - Avoid macros, if possible.
- Who will perform edits/maintenance on WLM?
  - User Excel proficiency varies
  - Logic/formulas should be easily understood
- User Interface
  - What will be the user inputs (e.g. permit limits, units)?
  - Can certain WLM components be toggled OFF?

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WLM Considerations

- Visual feedback
  - Overall layout and look of WLM
  - Conditional formatting to highlight threshold exceedances
- Workbook Security
  - Version control
- Think long-term
  - Link cells (carefully) to promote universal changes
  - Build a common database that feeds info to everything else
- Instructions
  - Users need guidance on how to navigate WLM
  - If user training takes >1hr, WLM is too complicated (usage only)

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Do WLMs work?

Chemical Manufacturer

Background

- Manufacturers various products for use in laboratory and pharmaceutical sectors
- Recently installed new equalization tank to feed under-designed onsite wastewater treatment plant
- Production increased faster than anticipated causing issues balancing organic and hydraulic loading
  - Frequent effluent limit encroachments and exceedances
- Poor communication between production and WWTP Operator
  - Operated reactively instead of proactively
  - Frequently contracted waste hauler to remove wastewater

Chemical Manufacturer

Client Request

- Client requested WLM that would provide/allow:
  - A simple, easy way to track COD
  - A daily schedule layout
  - User to select process and product being operated that day
  - User to enter current IWWTP information (e.g. feed rate, EQT level, influent COD concentration)
  - Projections for COD loading and EQT water level

Chemical Manufacturer

Product

- Arcadis developed:
  - A chemical library, equating all raw materials to COD
  - A matrix of all processes (3) and products (~30) that the Tool used as an index
  - Daily calendar with dropdowns for process and product
  - Conditional formatting (green, yellow, red) to alert user of potential issues
  - User interface to select formatting thresholds

Chemical Manufacturer

Results

- Improved communication between production and WWTP staff
  - 2-week schedule inputted into WLM to determine potential issues
  - If found, production would adjust schedule
- WLM daily projections allowed operator to adjust feed rates to avoid organic/hydraulic bottlenecks
- Significantly reduced need for waste haulers
- WLM was simple and required minimal training
  - Instructions fit on a single page

Pharmaceutical Manufacturer

Background

- Client site major location for manufacturing of its flagship product
- Demand required increase in production
  - Existing effluent limits were prohibitory
  - Existing onsite WWTP was inadequate
- Impact of practices in production were not understood (e.g. heel dumps)
- Client requested predictive WLM to aid it in making future capital improvements
- Client entered an agreement with local regulator in effort to increase permit limits
  - Part of agreement was to develop WLM

Pharmaceutical Manufacturer

Client Request

- Client requested:
  - A fluid, comprehensive WLM for:

COD	TN	TDS	Alkalinity
BOD	TP	Acidity	Flow

  - A multi-month lookahead schedule
  - A user interface to modify WLM assumptions
  - Ability to scale up/down production in the WLM

Pharmaceutical Manufacturer

Product

- Arcadis developed:
  - Library of nearly 60 chemicals, equating all raw materials to the COC
  - Detailed matrix of vessel cleaning and raw material usage
  - 200-day lookahead
  - “Live” graphical representations of results
  - Expanded user interface to allow use to change:
    - Units of measure
    - Production length
    - Safety factors
    - Particular chemical usage

Pharmaceutical Manufacturer

Results

- WLM successfully used to justify modification to client's permit
  - Higher flow and loading
- WLM used as basis for new onsite WWTP design
  - Regulatory approval of design largely predicated on WLM
  - WLM easily modified for client's other site to verify design of its WWTP
- Site-wide notification conducted alerting staff of impact of chemical dumping
  - Decreased significantly

Wrap-up

- WLMs convert BOM and production schedules into wastewater loading schedules
- WLMs can be a reliable tool in predicting/projecting wastewater characteristics
- With proper validation, can be used to:
  - justify requests for permit modifications
  - supplement a basis of design
- WLMs help increase education and communication among staff with respect to wastewater
- WLMs are flexible, intuitive, and can be built with a level of complexity suitable to an end-users comfort level

Thank you!

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