SIMULATION BENCHMARK #1

WHAT IS IT?

- DEFINITION OF A SIMULATION PROTOCOL FOR EVALUATING ACTIVATED SLUDGE CONTROL STRATEGIES
  - plant layout (configuration)
  - simulation models (biological and settling)
  - model parameter values
  - influent loads and disturbances
  - test procedures
  - evaluation criteria

WHY?

- STANDARDISE THE EVALUATION PROCEDURE
  - experimental evaluation prohibitively expensive
  - innumerable perturbations in possible configurations and simulation results (i.e. model parameters, influent waste ...)
  - unbiased comparison of reported simulation results impossible

BENCHMARK HISTORY

- ORIGINALLY CONCEIVED OF BY 1ST IAWQ TASK GROUP ON RESPIROMETRY
  - aim: standardise method for the evaluation of activated sludge respirometry-based control strategies through simulation

- FORMULATION OF THE BENCHMARK ADOPTED BY ‘COST’
  - aim: a 'general' standardised method for the evaluation of activated sludge control strategies
  - EU publication

- EXTENSION BY 2ND TASK GROUP ON RESPIROMETRY
  - aim: to remain as consistent as possible with the generalised benchmark
    - IWA Scientific and Technical Report

- EXTENSION BY NEW TASK GROUP ON BENCHMARKING
  - aim: to extend BSM system to whole plant modelling
    - BSM1_LT, BSM2, BSM3...

NEW STR - 2008
IWA Task Group on "Benchmarking of Control Strategies for Wastewater Treatment Plants"

Watermatex2007 Workshop, 6 May 2007, Washington DC, USA

IWA Task Group on "Respirometry in Control of the Activated Sludge Process"

European Co-operation in the Field of Scientific and Technical Research (COST)

'COST-624' DEFINITION

DEFINED BIOLOGICAL AND SETTLING MODELS

- INTERNATIONALLY ACCEPTED ACTIVATED SLUDGE MODELS

BIOLOGICAL:
- IAWQ's ACTIVATED SLUDGE MODEL #1 (ASM#1)

SETTLING:
- TAKACS DOUBLE EXPONENTIAL SETTLING VELOCITY MODEL

NO BIOLOGICAL REACTIONS IN THE SETTLER OR RECYCLES

'DYNAMIC DISTURBANCES

DEFINED INFLUENT WASTEWATER

- 3 different 14-DAY influent files
- representations of 3 potential weather disturbances

CHARACTERISTICS:
- DIURNAL VARIATIONS IN FLOW AND CONSTITUENT CONCENTRATIONS

'RESPIROMETRY EXTENSION

SAME 5 TANKS-IN-SERIES DESIGN

PROCESS EXPANSION
- completely aerobic C-only
- completely aerobic nitrifying

STEP-FEED CAPABILITY

EFFLUENT QUALITY VARIANCE ADDED TO PERFORMANCE INDEX

'PERFORMANCE ASSESSMENT

- PLANT PERFORMANCE ASSESSMENT
  - effluent quality
  - effluent violations
  - sludge production & disposal
  - pumping & aeration energy

- CONTROLLER ASSESSMENT
  - error calculations (setpoint tracking)
  - variance in manipulated variables
**SIMULATION DEFINITION**

**DEFINED STEP-WISE TESTING PROCEDURE:**

1. **SIMULATION SET-UP IN SIMULATOR OF CHOICE** (benchmark definition is platform independent)
2. **STEADY STATE SIMULATIONS** (without any active controllers)
3. **DYNAMIC SIMULATIONS** (using dynamic influent files)
4. **DEFINED CONTROL STRATEGY IMPLEMENTATION** (NO3 and DO)
5. **EVALUATION OF USER-DEFINED STRATEGY**

**NOTE:** simulation output is compared to verified data at each step (excluding the last) to ensure simulator tuned correctly.

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**BENCHMARK SET-UP**

**STEP 1:**
- **CHOOSE APPROPRIATE PLANT LAYOUT**
  - BASED ON CHARACTERISTICS OF CONTROL STRATEGY TO BE EVALUATED
  - CARBON REMOVAL OR NITRIFYING LAYOUT
  - DENITRIFYING LAYOUT

**STEP 2:**
- **CONFIGURE LAYOUT**
  - ACCORDING TO DESCRIBED FEATURES
  - **ASSIGN THE APPROPRIATE MODEL TO EACH UNIT PROCESS**
  - **INPUT THE DEFINED PARAMETER VALUES**

**STEP 3:**
- **OUTPUT COMPARISON**
  - (simulator tuning)
  - **VERIFIED OUTPUT**
    - (data verified using 6 different simulators and one user defined FORTRAN coded implementation)

**STEP 4:**
- **STEADY STATE**
  - (100 DAYS or STEADY STATE)

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**STEP 5:**
- **OUTPUT COMPARISON**
  - (simulator tuning)
  - **VERIFIED OUTPUT**
    - (data verified using 6 different simulators and one user defined FORTRAN coded implementation)
BENCHMARK SIMULATIONS

STEP 6:
- DYNAMIC INFLUENT
  (28 days, data analysis on last 7 days of output)

DYNAMIC INFLUENT FILES
(dry weather, rain weather & storm weather files)

STEP 7a:
- OUTPUT COMPARISON
  (qualitative)

QUALITATIVE COMPARISON OF DIFFERENT STRATEGIES

STEP 7b:
- OUTPUT COMPARISON
  (performance index)

USE OF THE PERFORMANCE INDEX ALLOWS FOR A MORE QUANTITATIVE COMPARISON

STRATEGY EXAMPLE

- STENSTROM AND ANDREWS (1979)
  
  AIM: TO DECREASE THE INFLUENCE OF A DYNAMIC INFLUENT ON EFFLUENT QUALITY
  APPROACH: CONTROL REACTOR SOUR
  METHOD: Q_{in} MANIPULATION

- TASK GROUP STRATEGY
  
  AIM: TO DECREASE THE VARIABILITY IN EFFLUENT QUALITY
  APPROACH: CONTROL OUR IN 5TH TANK
  METHOD: STEP-FEED MANIPULATION
PROBLEM DEFINITION

- TWO STRATEGIES
- SIMILAR, BUT DIFFERENT PROCESS AIMS
- DIFFERENT LAYOUTS
- DIFFERENT CONTROL OBJECTIVES
- DIFFERENT MANIPULATED VARIABLES

How is an unbiased comparison made?

BENCHMARK RESULTS

- SIMILARLY APPLIED ANALYSES ALLOW A MULTI-CRITERIA COMPARISON TO BE MADE
- FURTHER ANALYSES CAN BE BASED ON LOCATION SPECIFIC CRITERIA AND TERM WEIGHTING (i.e. SLUDGE PRODUCTION MORE IMPORTANT THAN PUMPING COSTS...)

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FEATURES RECAP

- DEFINED CONFIGURATIONS
  - C-only, Nitrifying, Denitrifying (IWA)
  - Denitrifying (COST)
- FIXED PROCESS MODELS & PARAMETERS
  - ASM#1, Takacs
- DEFINED DYNAMIC DISTURBANCES
- DEFINED SIMULATION PROCEDURES
- DEFINED PERFORMANCE ASSESSMENT

CONCLUSION

- BENCHMARKING IS:
  - A valuable tool for the comparison of multi-faceted simulation problems
  - The first step in evaluating the potential impact of particular control strategies
  - A multi-criteria decision making problem