A Feasibility Study for the Automated Monitoring and Control of Mine Water Discharges

2017 WV Mine Drainage Taskforce

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Presentation Outline

1. BACKGROUND
2. BENCH-SCALE SYSTEM
3. MAMDANI CONTROLLER
4. PROOF-OF-CONCEPT RESULTS
5. ONGOING WORK & CONCLUSIONS
Automated Outlet Treatment

MOTIVATION
Challenges in CAPP

- Remote Locations
- No Utilities
- Area/Access Limited by Topography
- Several parameter limits: pH, TSS, Fe, Al, Mn, etc.
- Lab Results Take Time
Traditional Practices in CAPP

Rob

Not an environmental chemist, but knows practical water treatment.

Can get to the remote locations, but takes time.

May make it to problematic sites once or twice per day.

Not available 24/7/365.

Will eventually retire or find another job.
**Problem Statements:**
- Given the unique environmental challenges in CAPP, traditional methods of water monitoring and treatment are costly and inefficient.
- The current and future regulatory trajectory may deem many of these practices cost prohibitive.

**Research Objectives:**
- Evaluate the technical and economic feasibility of automated monitoring and advanced control algorithms for chemical treatment of mine water discharges
Process Disturbances:
- Incoming pH
- Flow Rate
- Atmospheric Conditions

Problem: pH Treatment is Nonlinear!

Titration of HCl with Na2CO3

Steady State pH vs. Base Treatment Flowrate (ml/min)
Automated Outlet Treatment

BENCH-SCALE SYSTEM CONSTRUCTION
Components

Reactor

Conductivity Sensor

pH Sensor
Components

Transmitters/Power Supply

DAQ Unit
Components

Supply Pump

Treatment Pump
Components

Baffle

Installed Baffle
Bench Scale Model

- pH & EC Sensors (hidden)
- Reactor 1
- Reactor 2
- Reactor 4
- Reactor 3
- Distribution Manifold
- Flow Sensor
- Transmitters
- DAQ & I/O Units
- Personal Computer
- System Outlet
- AMD Supply Tank 1
- AMD Supply Tank 2
- Alkaline Tank
- Feed & Treatment Pumps
Automated Outlet Treatment

MAMDANI FUZZY CONTROLLER
Several advanced pH control techniques exist; however, they are currently unproven in a mine environmental setting.
Modeling Approach

Precision and Significance in the Real World

A 1500 kg mass is approaching your head at 45.3 m/sec.

Precision

LOOK OUT!!

Significance
Fuzzy Logic - Basics
Fuzzy Logic – Membership Functions

- Use of non-precise classes to segment process behavior

**Error**

1. Constant
2. Setpoint
3. Error
4. pH2

**Input Value**

**Crisp Output**

- MF1
- MF2
- MF3
- MF4
Membership Functions

Doesn’t neglect “Rob’s” intuition, 30+ years of AMD research, or the real-time data…
Automated Outlet Treatment

RESULTS & DISCUSSION
# pH Control – Experimental Tests

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Simulated Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal field Operations under steady state conditions</td>
</tr>
<tr>
<td>2</td>
<td>Unsteady flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Changing pH set point</td>
</tr>
<tr>
<td>4</td>
<td>Large surge in flow rate that interrupts flow recording device</td>
</tr>
<tr>
<td>5</td>
<td>Change in feed water pH</td>
</tr>
<tr>
<td>6</td>
<td>Removal of pond baffle</td>
</tr>
<tr>
<td>7</td>
<td>Multiple disturbances/perturbations</td>
</tr>
</tbody>
</table>

Define acceptable range as ±0.5 pH point.
pH Control – Steady State

- pH After Treatment
- pH Leaving System
- Setpoint
- Acceptable Range
pH Control – Varying Flow Rates & Set Point
pH Control – Change in Feed pH
Automated Outlet Treatment

ONGOING WORK & CONCLUSIONS
Ongoing Work

- Implementation of control scheme at AMD treatment site
Summary & Conclusions

- Environmental monitoring and treatment costs can be significant and require perpetual attention.
- Laboratory tests have shown that fuzzy logic is a feasible control option.
- The controller used in this testing was able to withstand multiple perturbations and maintain pH within ±0.5.
Questions?

For more information, please contact:

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Acknowledgements: