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Updated Chemical Effects Program (Basis and Status)

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PRESSURIZED WATER REACTOR OWNERS GROUP

Agenda

- Program Areas that Interact with Chemical Effects
- Original Plan and Initial In-Bag Testing
- Bag Issue
- Summary of Program Status
- Changes to Original Confirmatory Testing Plan
- Path Forward
- Schedule

Program Areas that Interact with Chemical Effects

How Chemical Effects Fit In (T/H Analyses)

- T/H Analyses
  - Performed for W Upflow, W Downflow, B&W, CE plant designs
  - Assumes k-factor associated with fiber and particulate, but no significant chemical effects, up to a certain point (0-4 hours, depending on plant type)
  - Assumes k-factor equivalent to full blockage (i.e. presence of significant chemical effects) after that point
  - Demonstrates acceptable long-term core cooling for both initial 0-4 hour period and after chemical effects initiate (4+ hours)

How Chemical Effects Fit In (Subscale Testing)

- Subscale Testing
  - Performed with fiber and particulate, but without any chemical surrogate
  - Assumes no significant chemical effects
  - Valid for period of time from start of accident to initial indication of presence of building chemical effects

How Chemical Effects Fit In (Overall)

- Chemical Effects testing, analysis, and evaluation are intended to demonstrate the timing of initiation of significant chemical effects.
- If the timing determined from this work that is applicable to a specific plant is > 4 hours into the transient:
  - The subscale testing is valid for at least 4 hours into the transient.
  - The assumptions/inputs of the T/H analysis applicable to that plant are demonstrated to be appropriate, and the T/H analysis is valid for that plant.
- As long as a plant meets the debris limits determined by the program, where subscale testing is a significant input, adequate core cooling is demonstrated by the T/H analysis.

Test Objectives

Original Test Objective

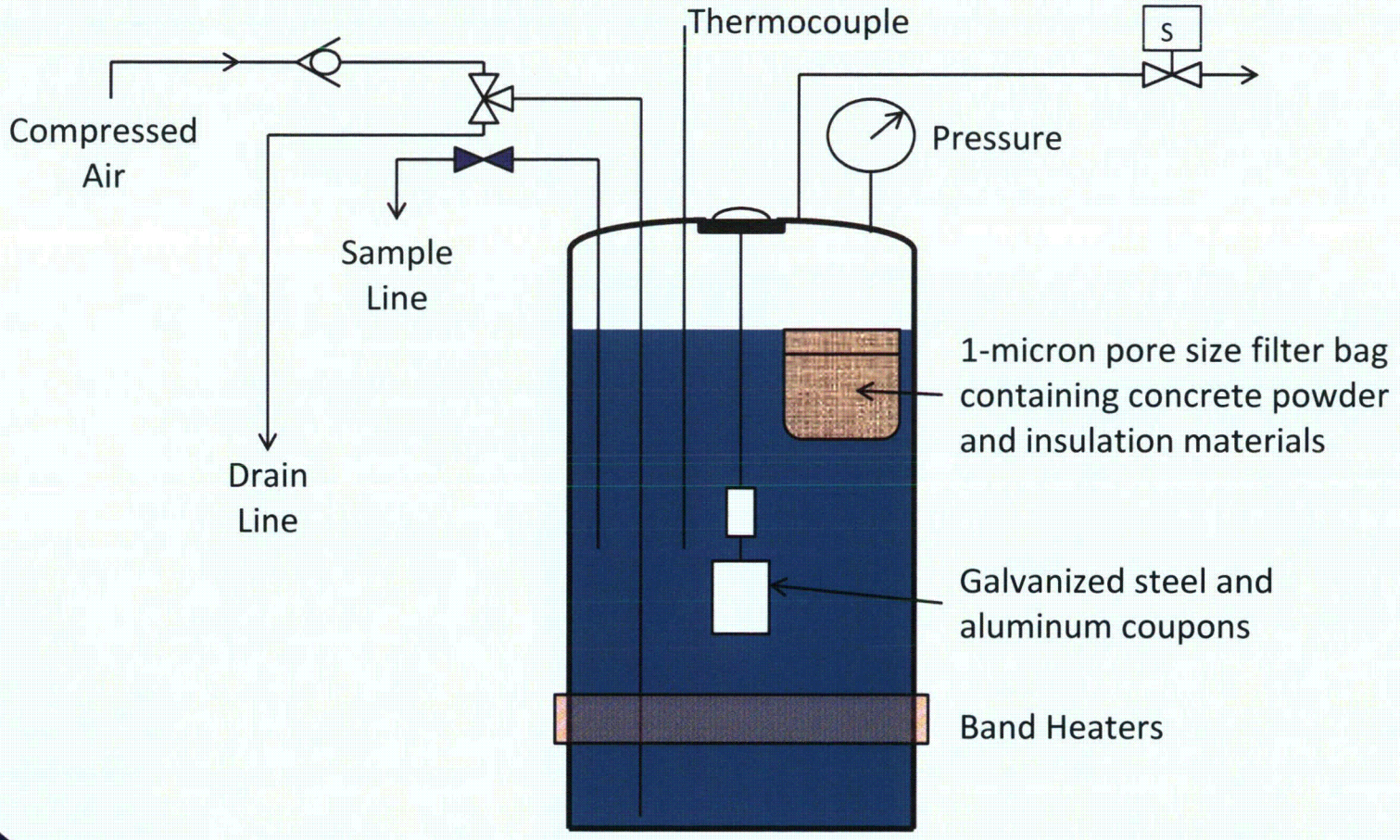
- Objective: Demonstrate that chemical products do not form until after a critical time, when the core could tolerate inlet blockage
- Test groups selected to be representative, and are based upon plant survey results.
- Plants assigned to a number of categories, based upon the test results:
  - Category 1: No early chemical effects
  - Category 2: Chemical products are adequately represented by WCAP 16530 surrogates.
  - Other category(ies): Chemical products can be represented by new surrogate(s) that is/are being developed
- Resolution path to GSI-191 would be recommended based on category

Test Apparatus

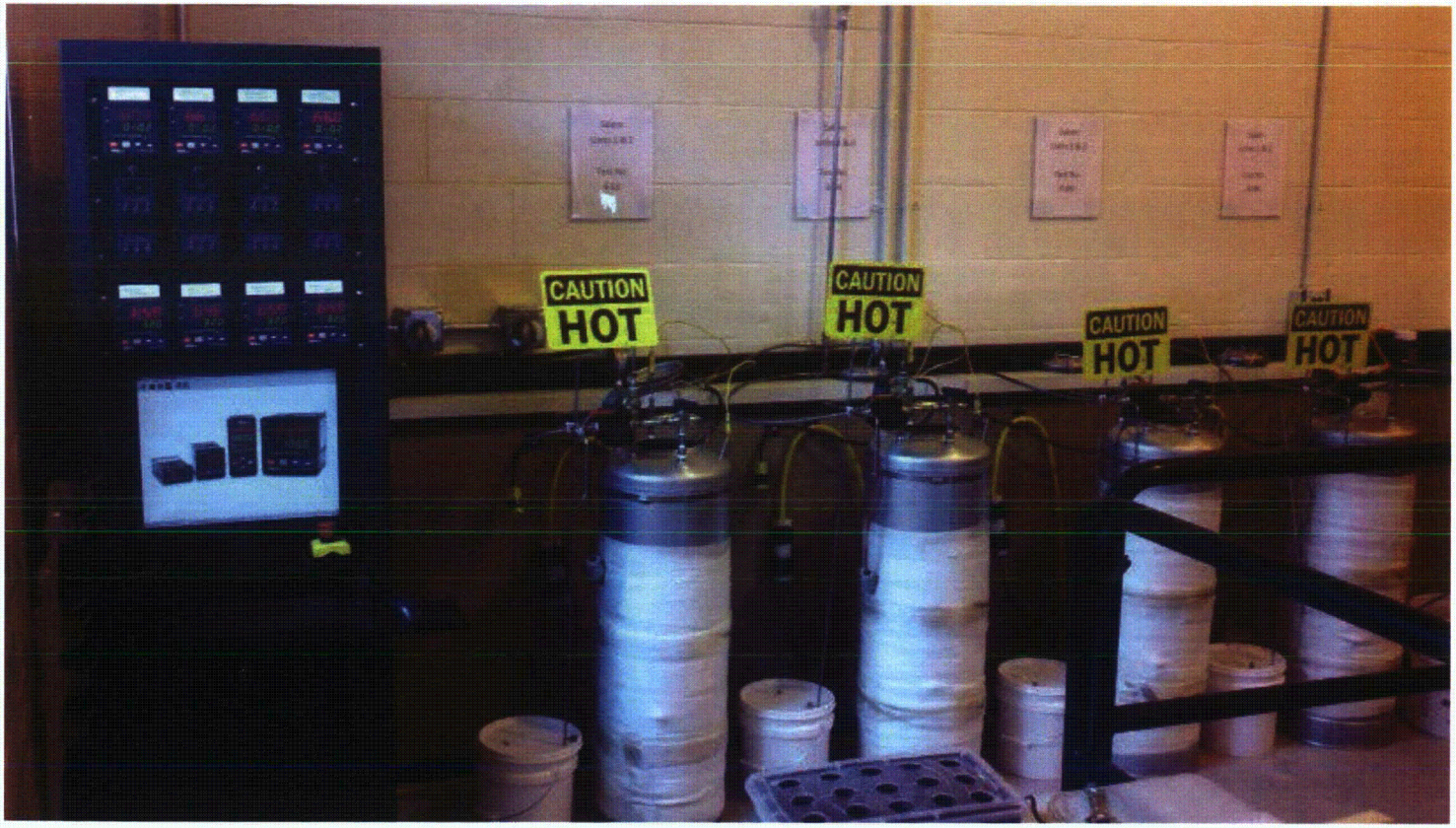
Test Apparatus

- Four 60 liter autoclaves follow plant temperature evolution
- Coolant chemistry and temperatures determined from plant surveys
- Sodium carbonate added in proportion to the containment volume to simulate CO_2 absorption
- Galvanized steel and pure Al added as submerged coupons
- Concrete and insulation materials added in polymer filter bags
- Solution stirred every 30 minutes with compressed air bursts
- Samples taken from the middle of each autoclave at 2, 4, 6, 8 and 24 hours after start of test

Test Apparatus (cont.)



Test Apparatus (cont.)



Temperature Control

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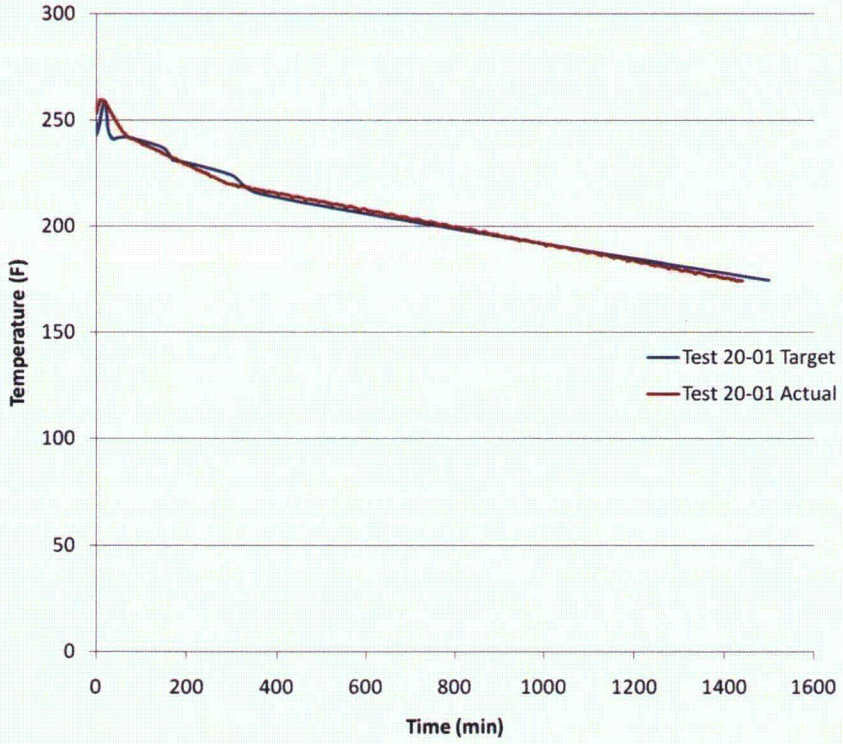
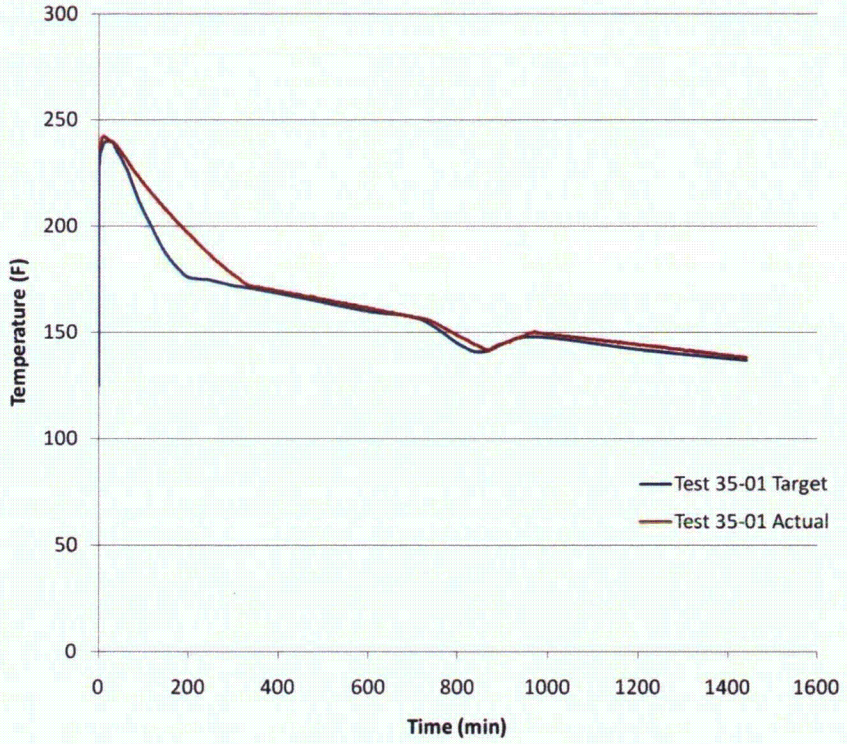




Experiment Design

Experimental Design/Test Matrix

- Screening test groups-
  - A total of 45 groups representing a single unit or small group of similar units
    - 24 represent one unit
    - 18 represent two units
    - 2 represent three units
    - 1 represents four units
  - At least one test was run for each group.
  - Using maximum reported pH values and a temperature profile running from the maximum to minimum reported sump temperature
- Additional matrix tests examine reproducibility and pH effect

Relevant Test Procedure Details

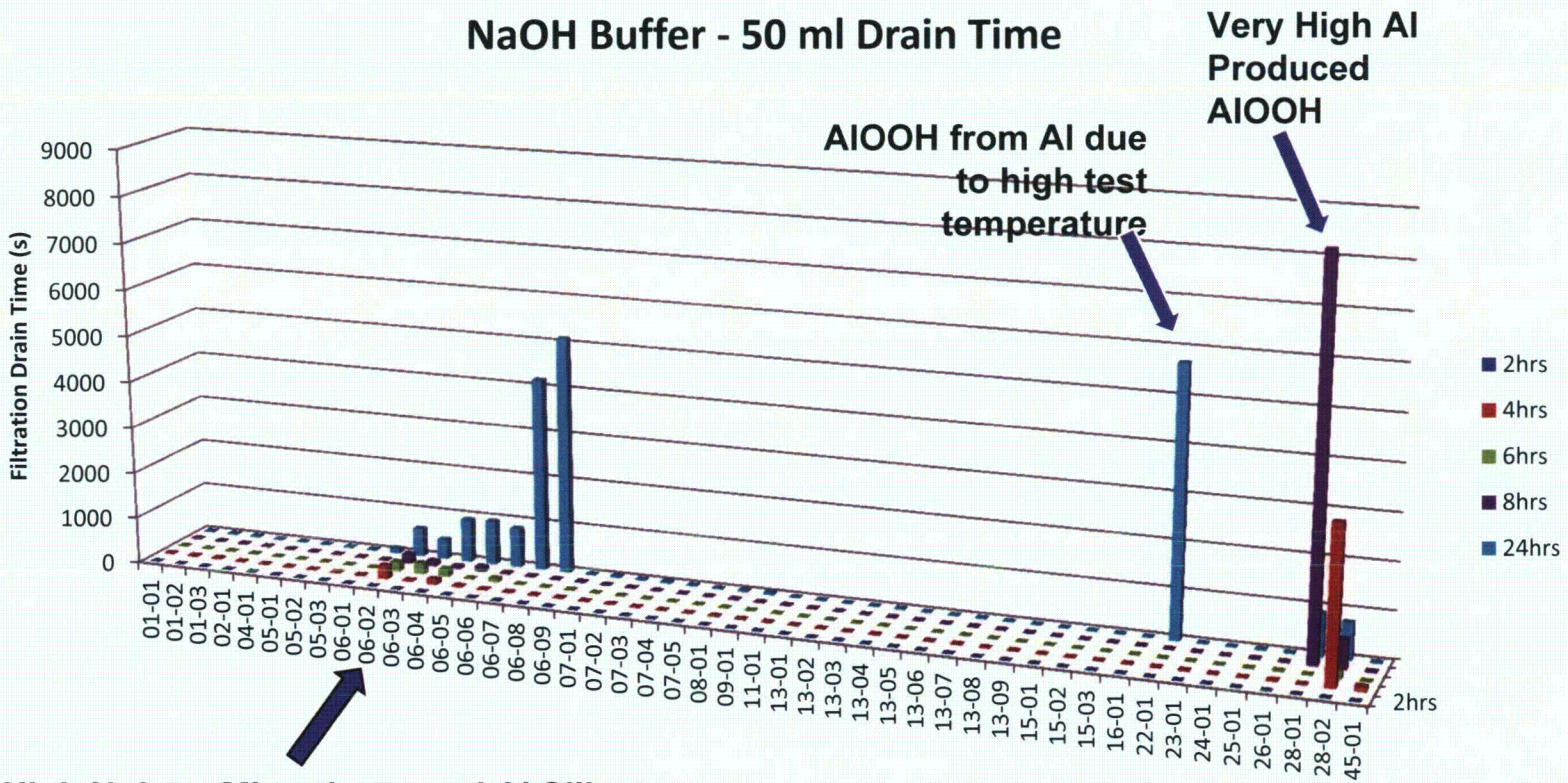
- Staged Addition of Debris for NaTB and TSP Plants
  - Low pH portion of the accident was simulated for sodium tetraborate and trisodium phosphate coolants
    - Debris added to 2700 ppm B solution at 200 ˚F with frequent air mixing
    - Buffer chemical added after 30 minutes and temperature profile started
- The delayed buffering allowed for increased dissolution of calcium compounds
  - Lower temperature addition of calcium-containing debris conservative for solubility, but non-conservative for dissolution rate.

Results: Filtration Times

Results: Completion Summary

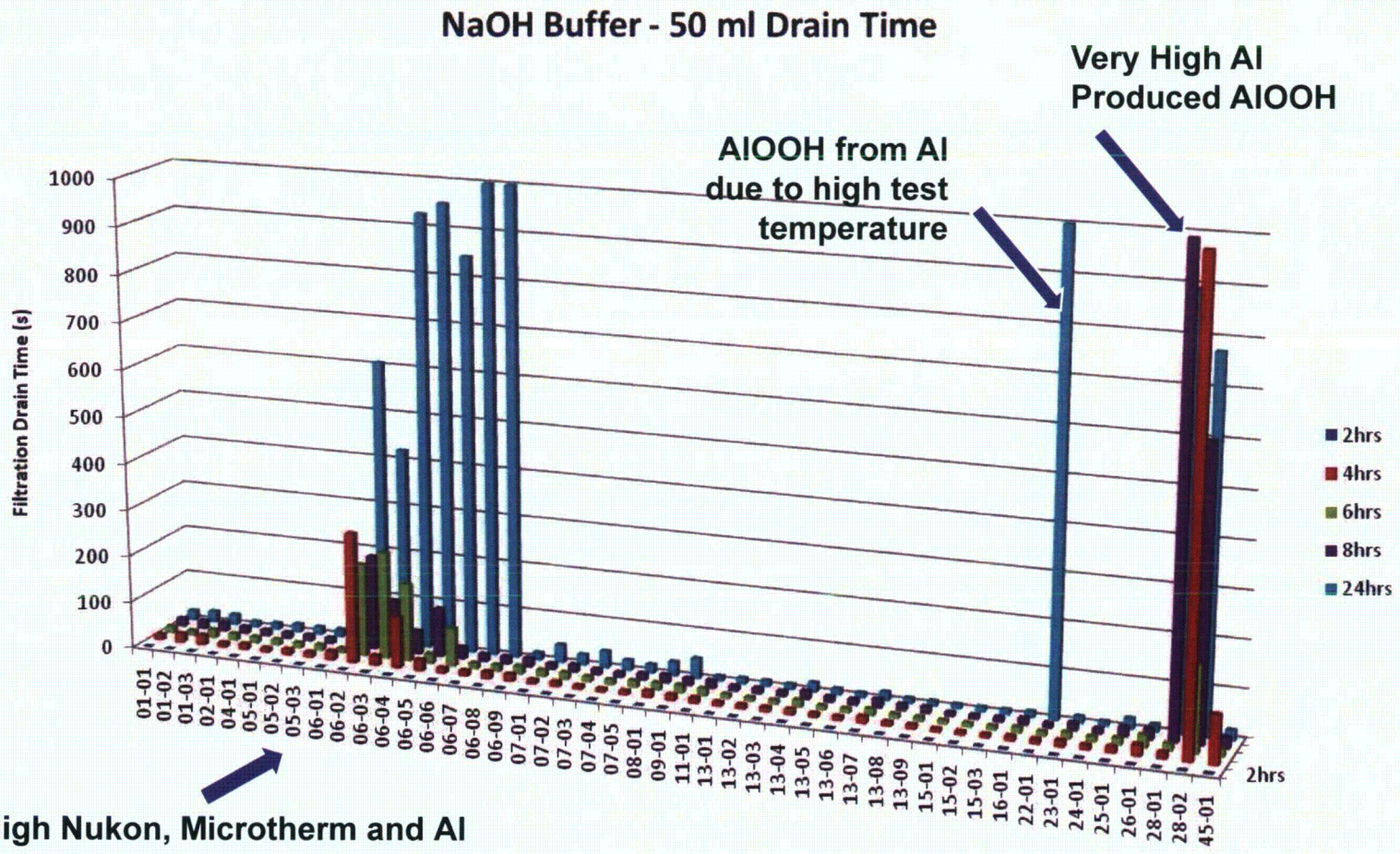
- Testing completed for all plant "bins"
- Most tests show essentially zero or negligible early (<24 hours) chemical effects
- Some bins show immediate or delayed chemical effects
- Chemical analysis completed

Results: Filtration Time - NaOH



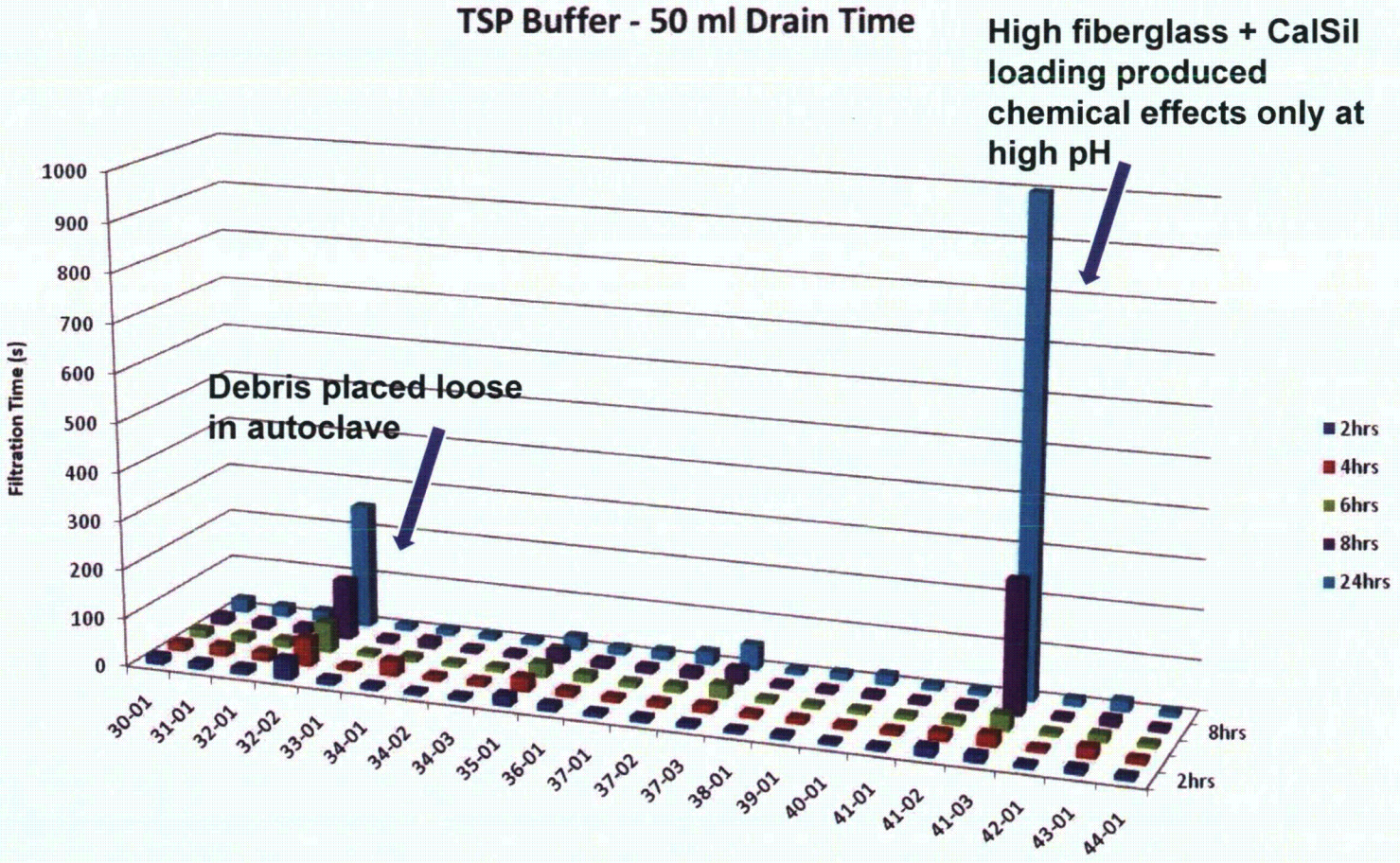
High Nukon, Microtherm and Al Silicate resulted in sodium aluminum silicate formation, especially at high pH

Results: Filtration Time - NaOH

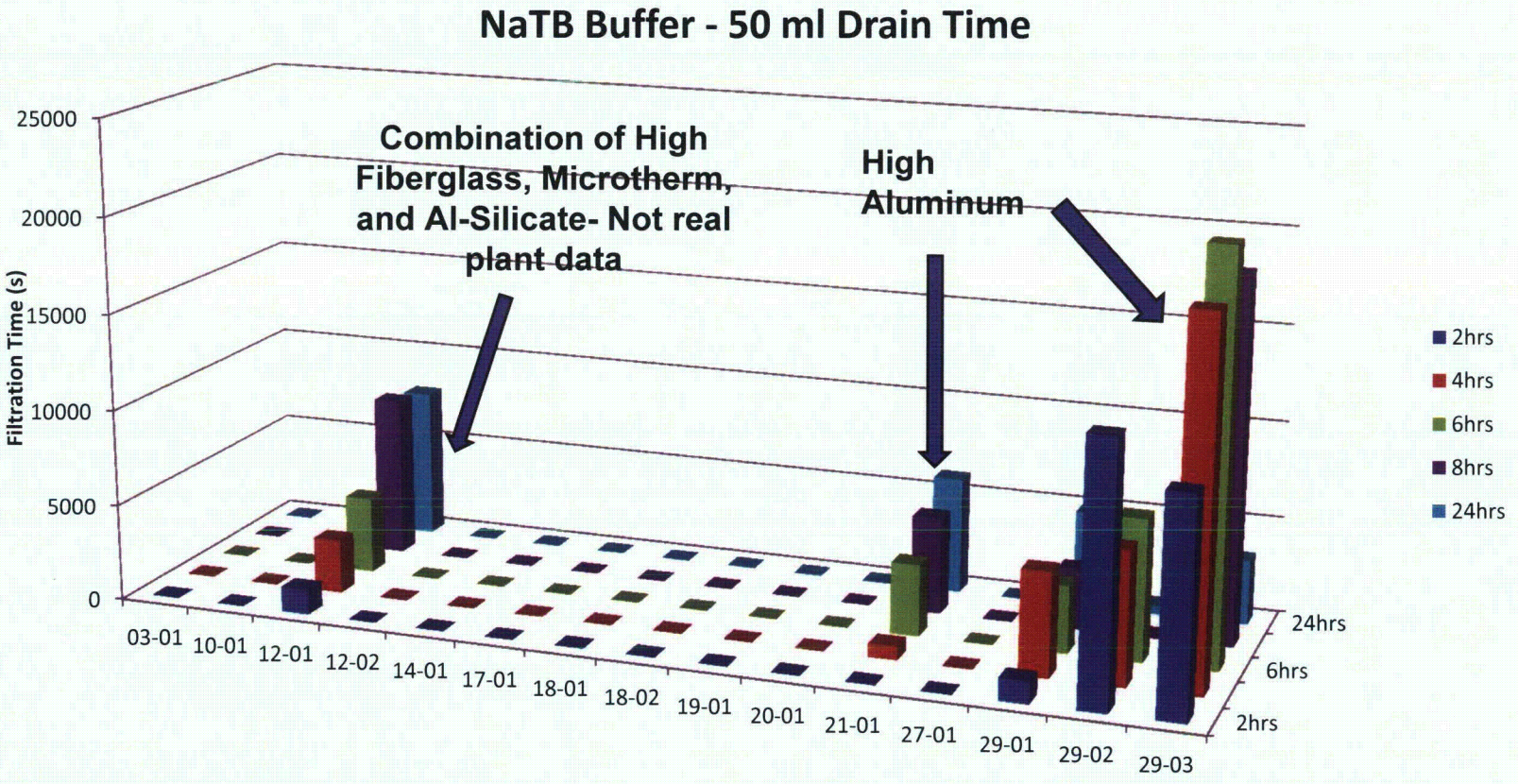


High Nukon, Microtherm and Al Silicate resulted in sodium aluminum silicate formation, especially at high pH

Results: Filtration Time - TSP



Results: Filtration Time - NaTB



Filtration Time Results Summary

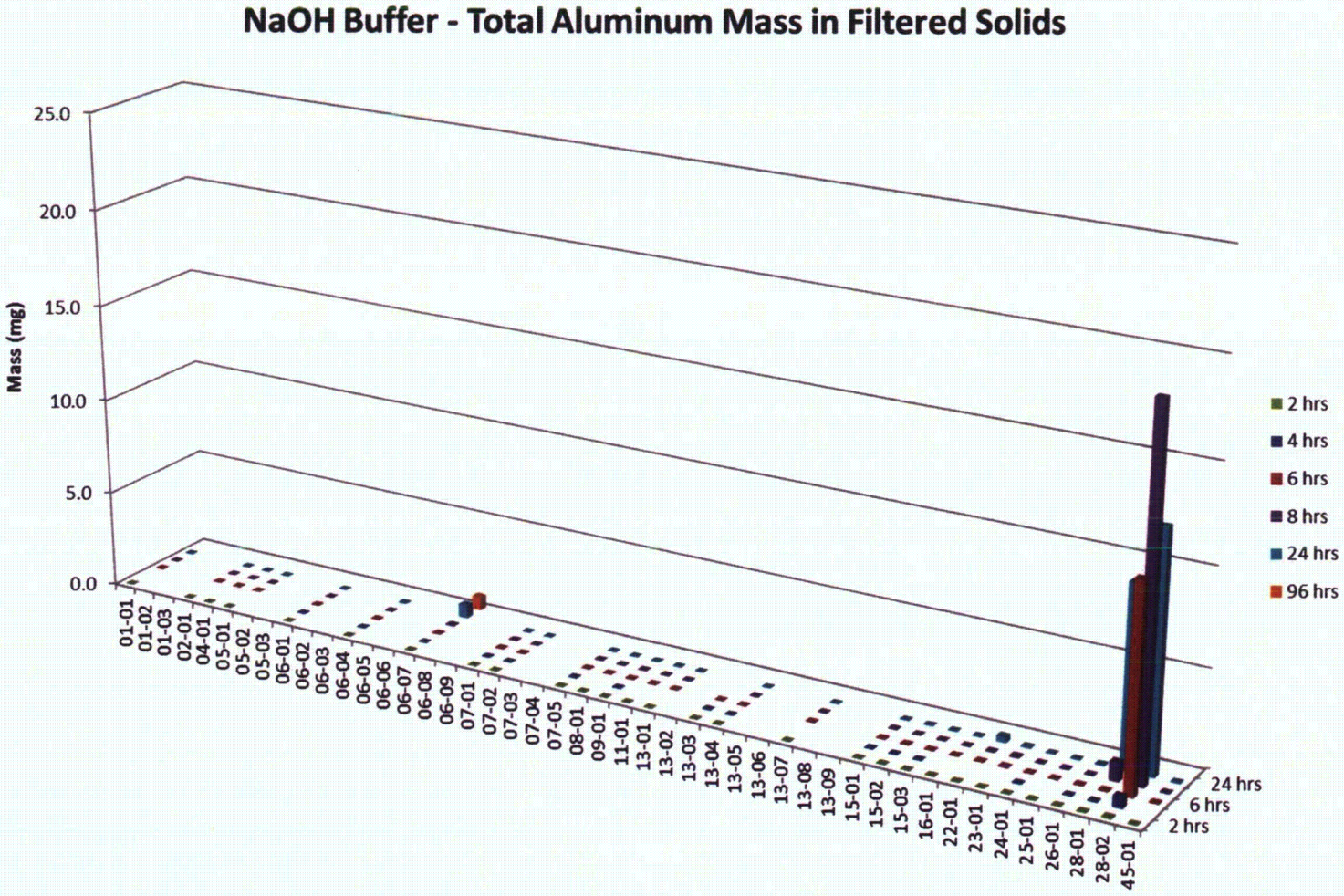
- Filtration times over approximately 1 minute indicative of some chemical effects
- Majority of test groups did not experience chemical effects
  - 18 tests with chemical effects in 9 groups
  - Of those that did experience effects, only two started at 2 hrs
- High levels of aluminum typically led to chemical effects
- High levels of insulation debris typically led to chemical effects
  - Particularly e-glass and CalSil
- Higher pH typically led to more effects
  - In one case, the higher pH postponed the effects

Results: Chemical Analysis

Results: Chemical Analysis

- Chemical analysis conducted on chemistry sample and on one filter at each time step
  - Solids on filter or chemistry sample digested with acid
  - Analyzed by inductively-coupled plasma mass spectroscopy (ICP-MS)
- Analyzed elements: Mg, Al, Ca, Fe, Zn, and Si
- Calculated:
  - Mass on filter
  - Mass in autoclave
  - Total concentration in autoclave
  - Mass of suspended solids
  - Release rates
  - etc.

Results: Mass on the Filter - Aluminum



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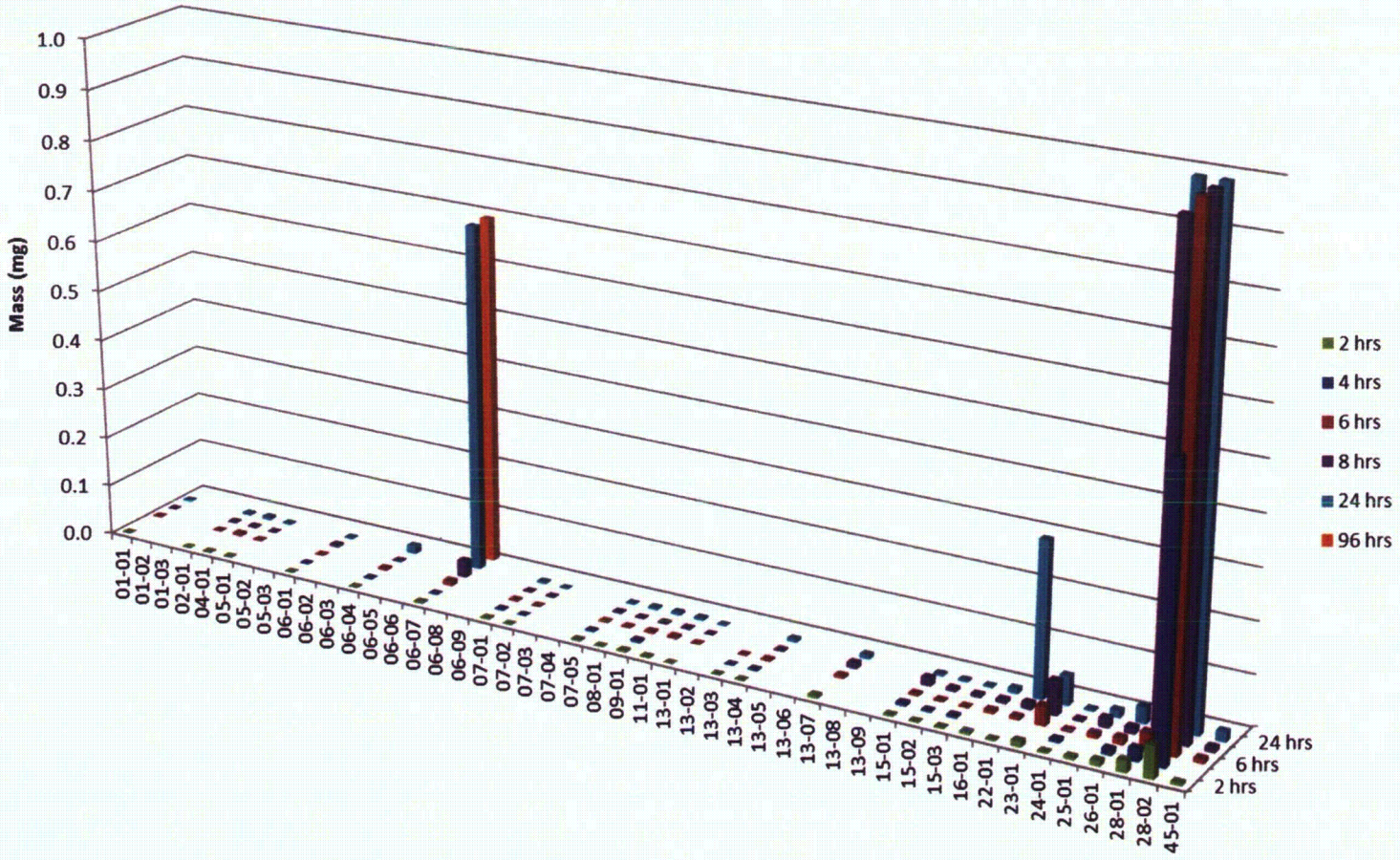

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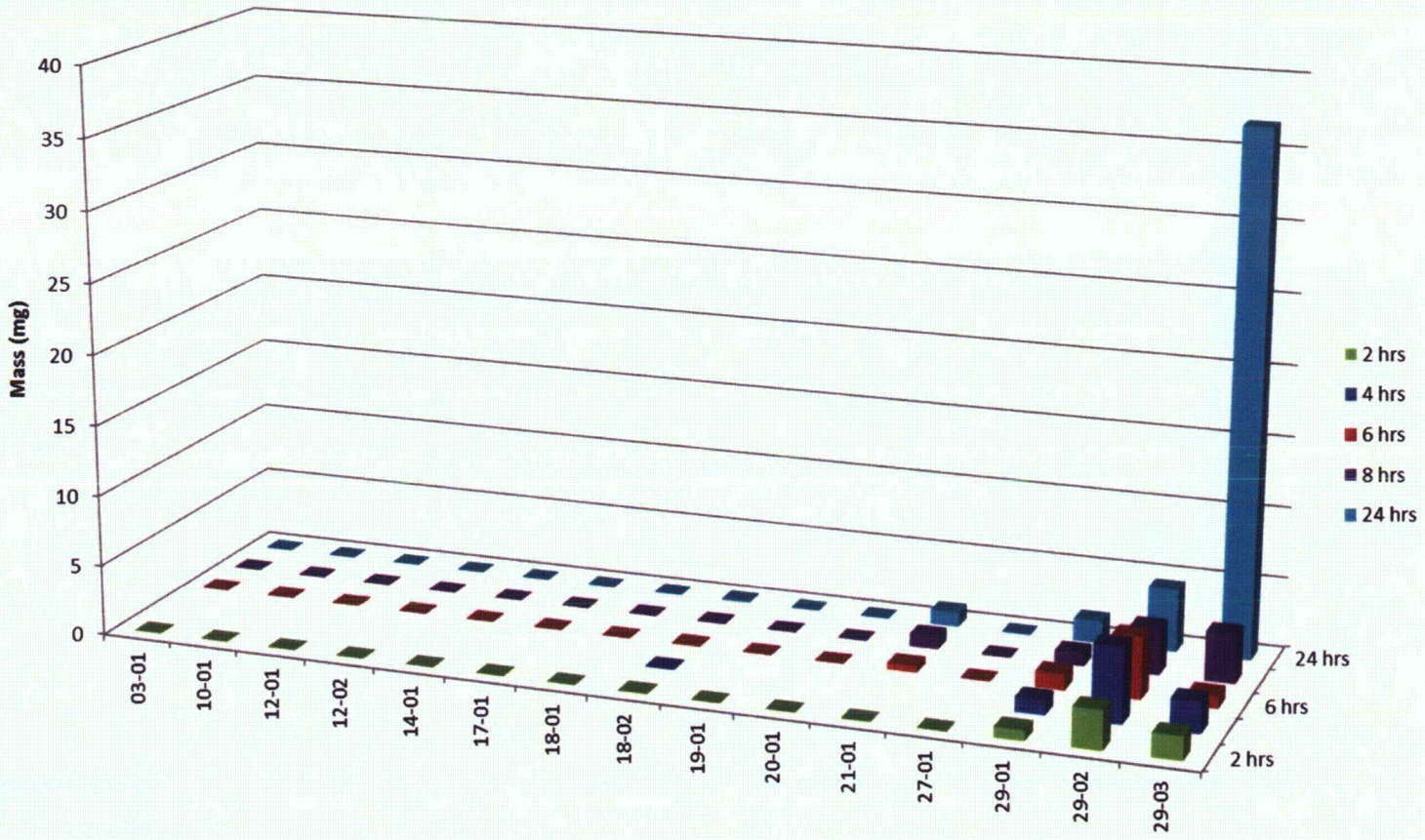

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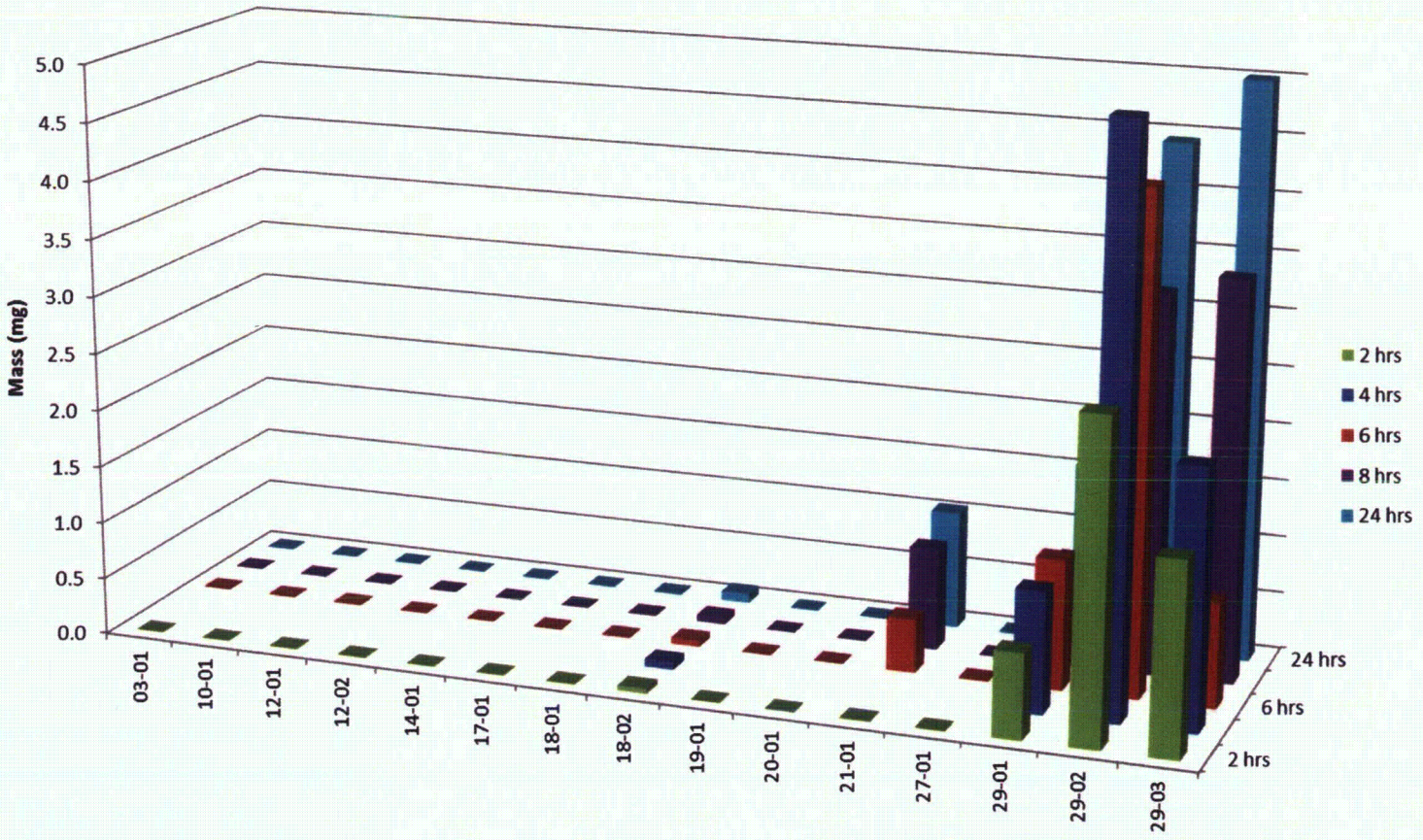

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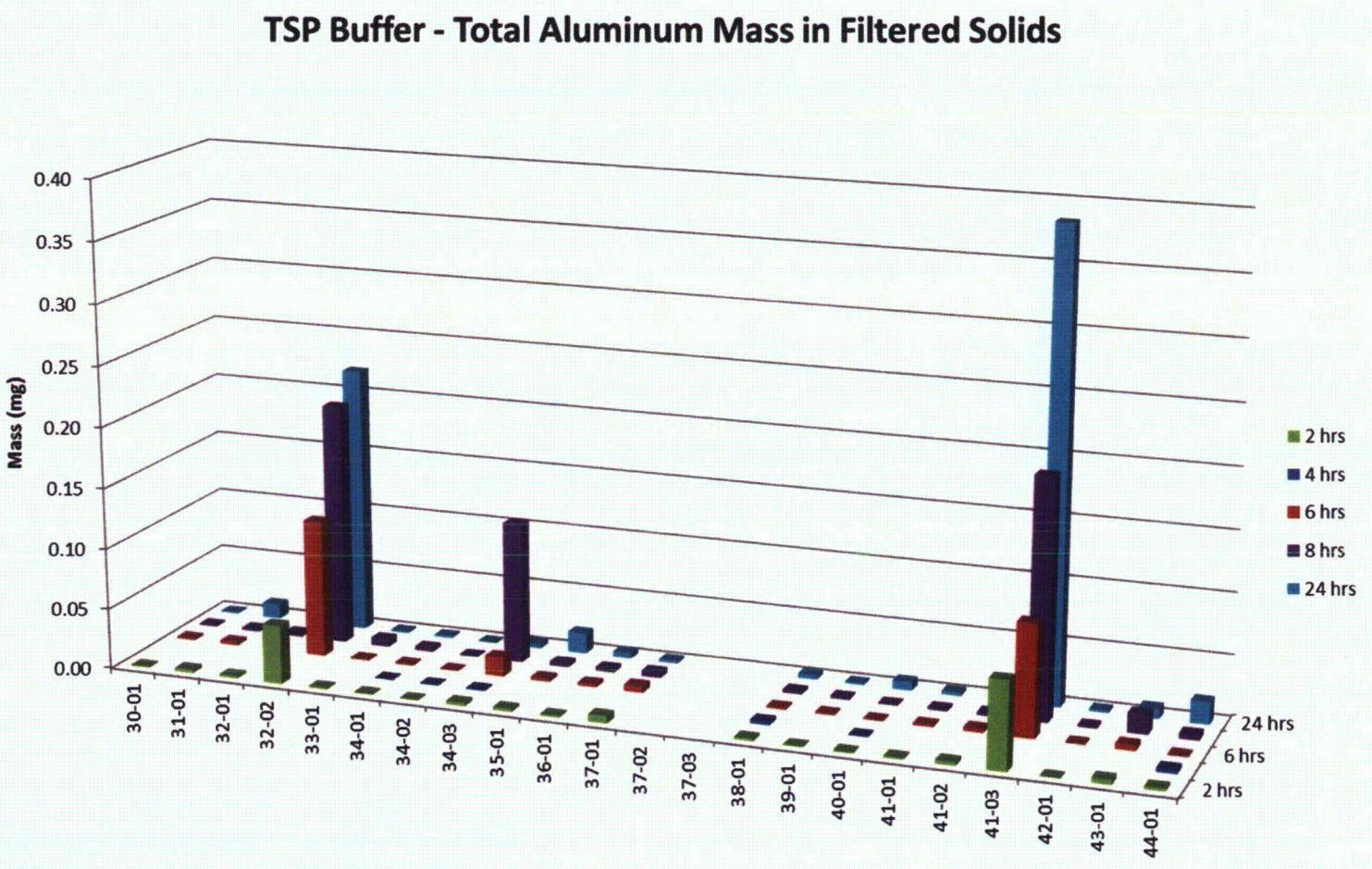
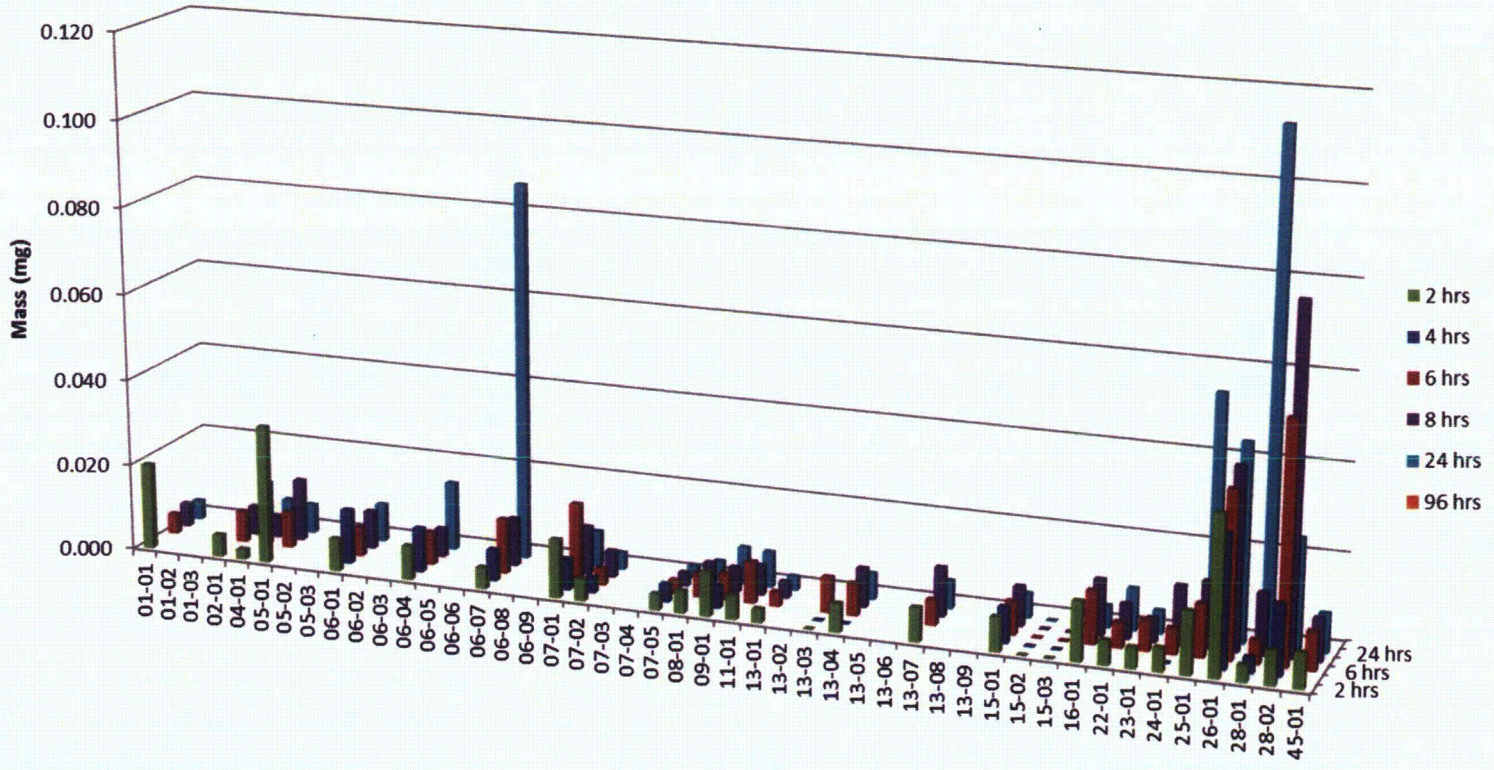


Results: Mass on the Filter - Silicon



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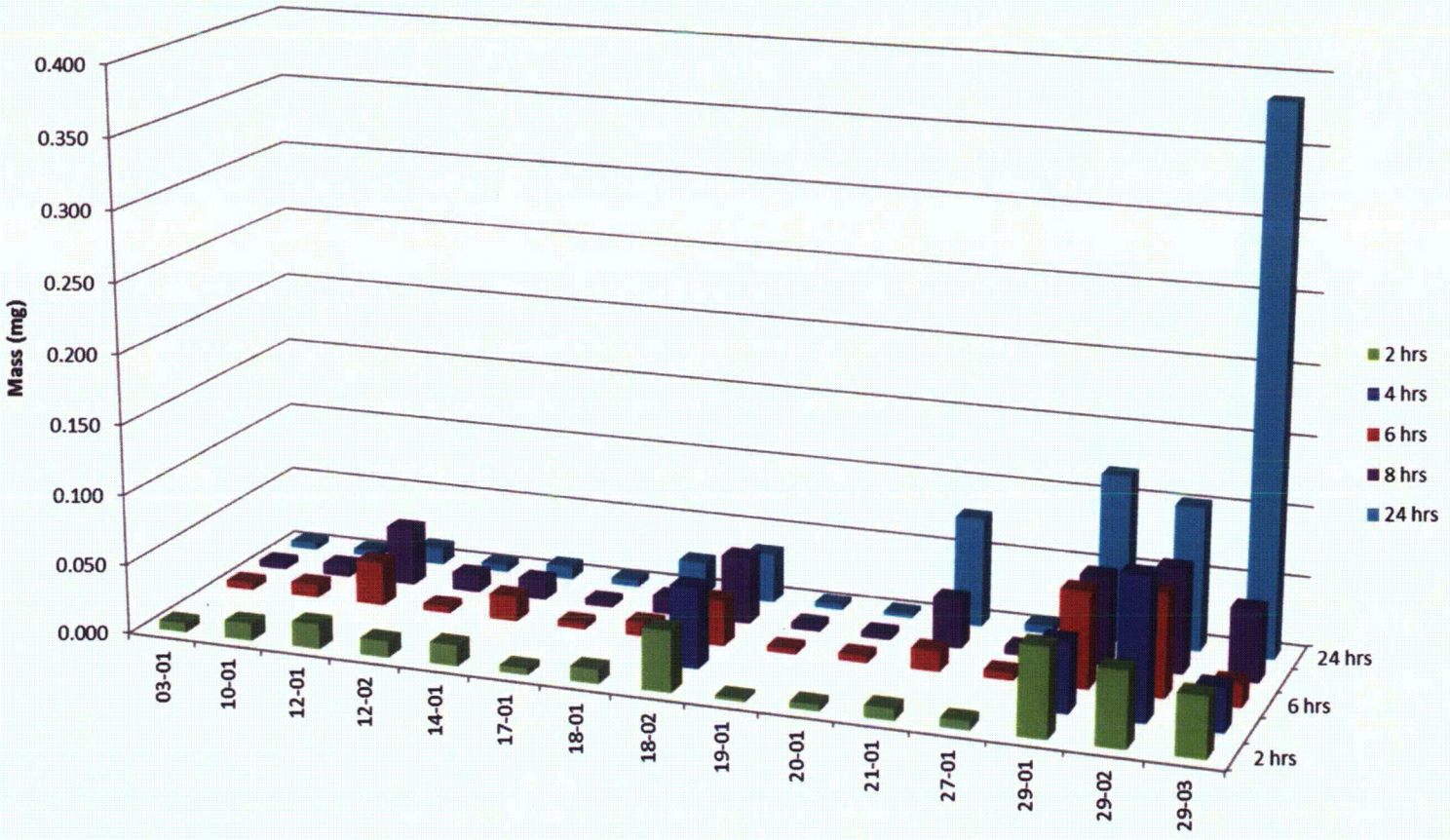

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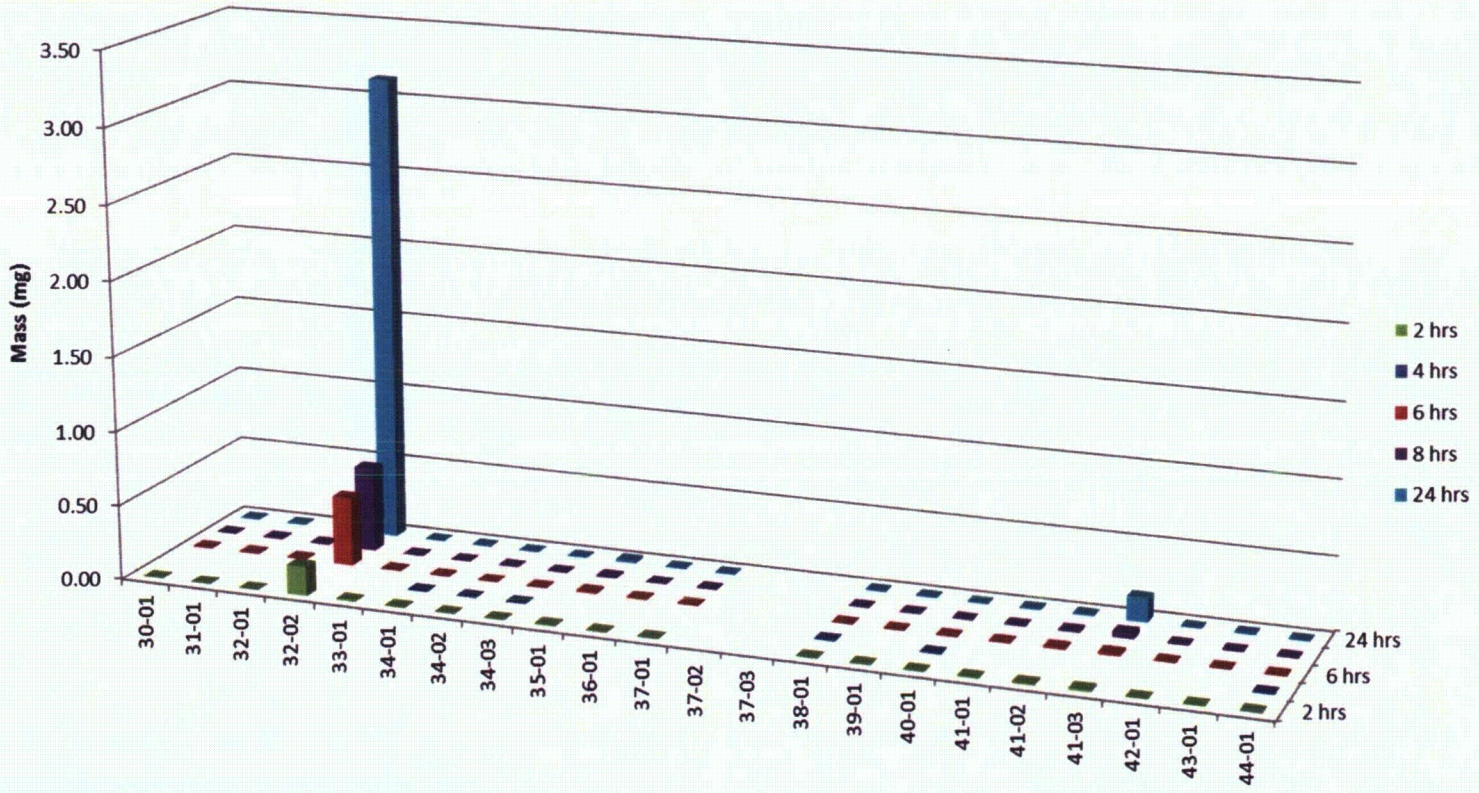
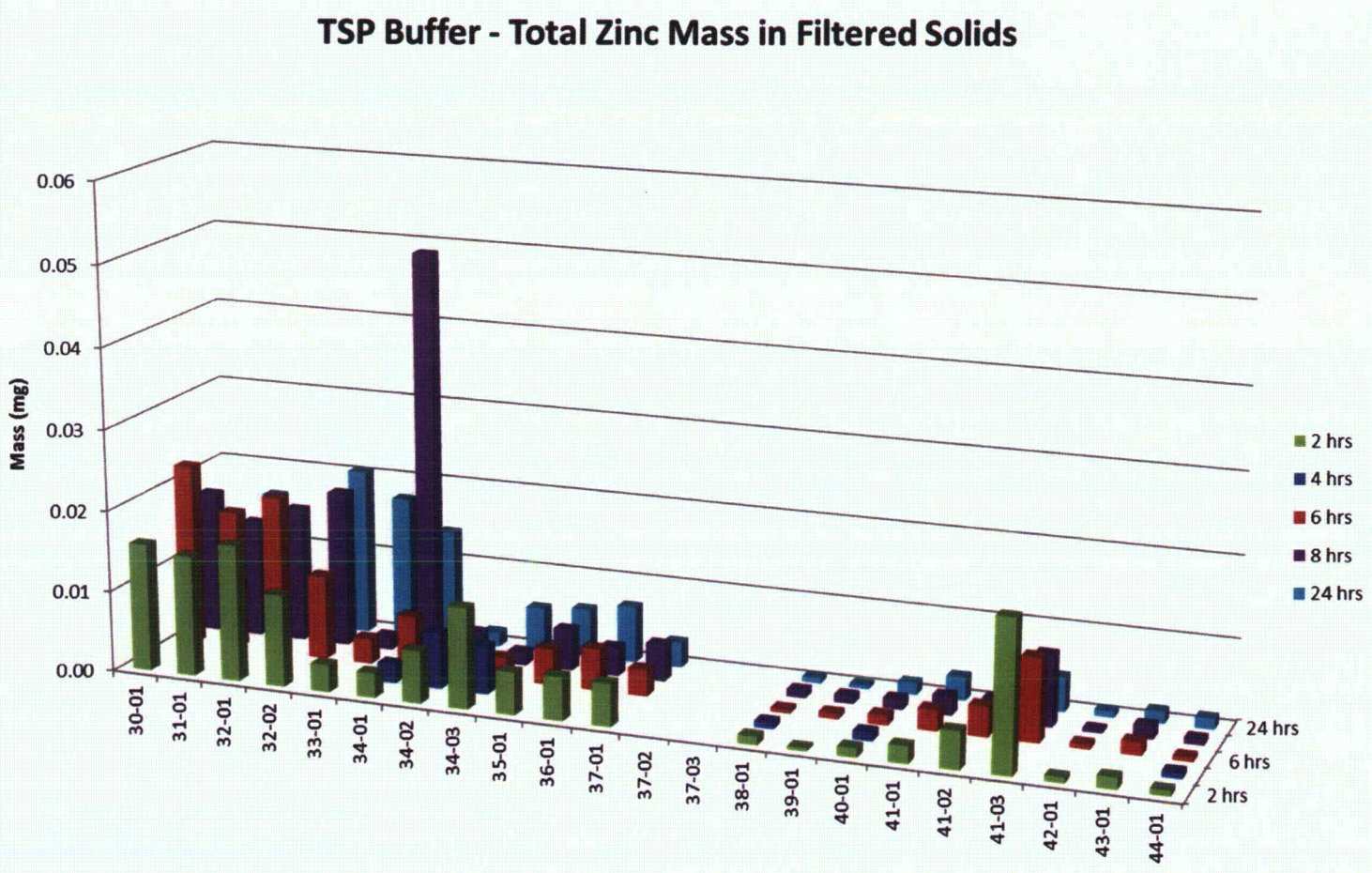
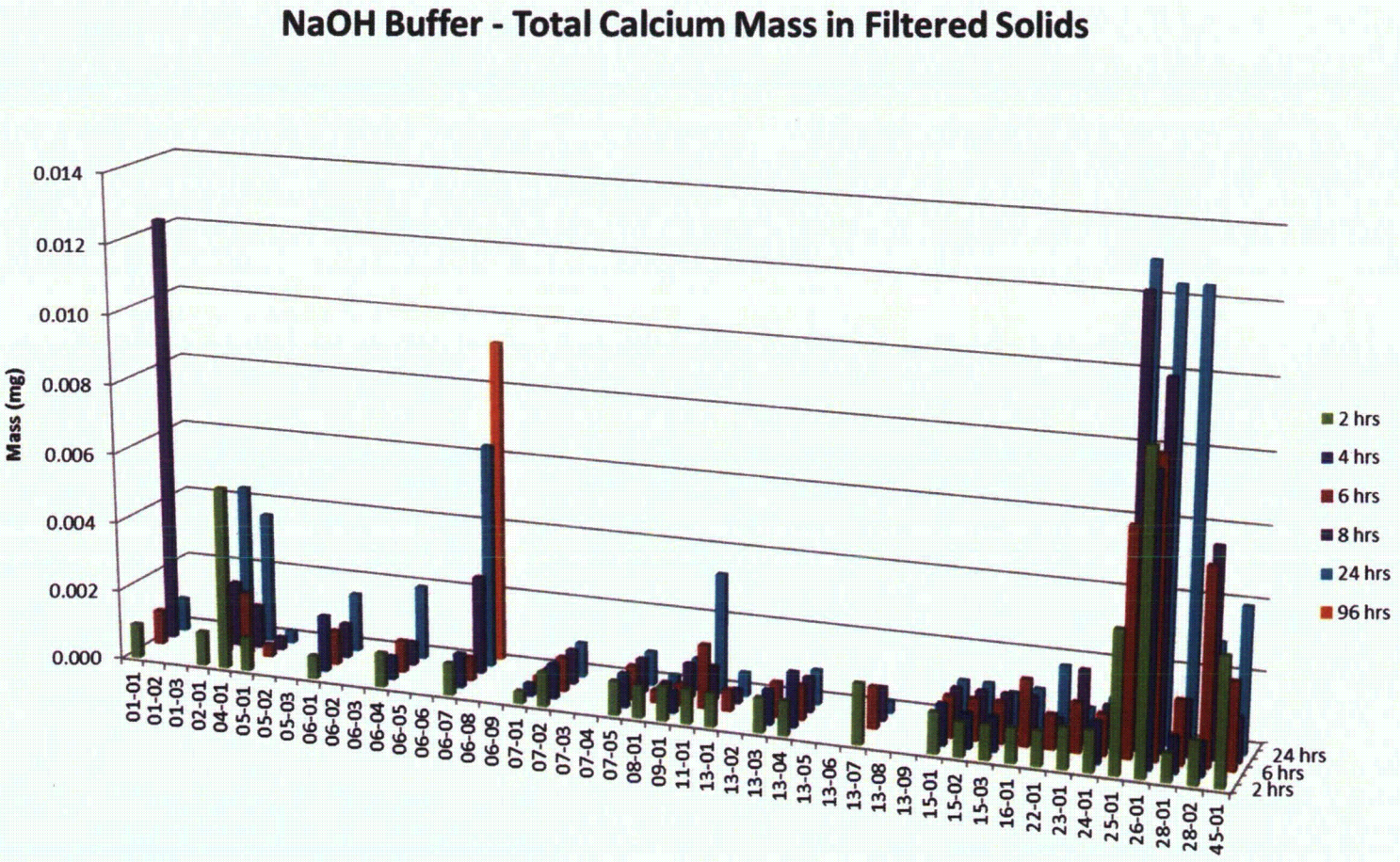


Results: Mass on the Filter - Zinc



Results: Mass on the Filter - Calcium



Initial Chemistry Results

Initial Chemistry Results

- Consistent with Filtration results:
  - High mass on filters with long filtration times
  - Elemental mass measured from a filter consistent with the solids mass being less than 1 mg in most cases
- Elemental results make sense
  - Aluminum mass the highest
  - Silicon mass next highest
  - Zinc elevated on the low pH tests
- TSP and NaTB are less aggressive towards aluminum in general than NaOH
- Little precipitation is occurring