Surface Decontamination with Aqueous-Based Surfactant Solutions

(Overview of "Improved Decontamination: Interfacial, Transport, and Chemical Properties of Aqueous Surfactant Cleaners"; Project 64912)

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Research Objectives

- **Gain understanding needed to improve cleaning systems using aqueous cleaners**
  - organic contamination
  - associated radionuclides, heavy metals, etc.

- **Improve two aspects of aqueous-based cleaning**
  - surface decontamination involving oil removal
  - separation of waste from process materials

- **Fundamental and applied research**
  - Develop improved approaches for cleaning at laboratory scale
  - Test by application to realistic systems

Motivation

- **Facilities throughout DOE have widespread needs for removal of organics (oils, PCBs, etc.) and associated contaminants from solid substrates**
  - particularly metal surfaces (ductwork, pumps, blowers, tools, gloveboxes, etc.)

- **Chlorinated/fluorinated solvents have been banned or are being phased out because of hazards**
  - ozone-depleting
  - carcinogens

- **Aqueous-based cleaners are attractive because of low chemical hazard**
  - improved worker safety
  - greater environmental acceptability

Linkages to Site Needs

- **This research is applicable to organic and particulate contamination related to the following site needs:**

- Science Need ID

  ID-S.2.06: Understanding the Physics and Chemistry of Metal Decontamination

- Project Need IDs:

  AL-07-01-12-DD: Decontaminate and Decommission Radioactively Contaminated Facilities

  AL-07-01-13-DD: Decontamination of Difficult Access Interior Contamination

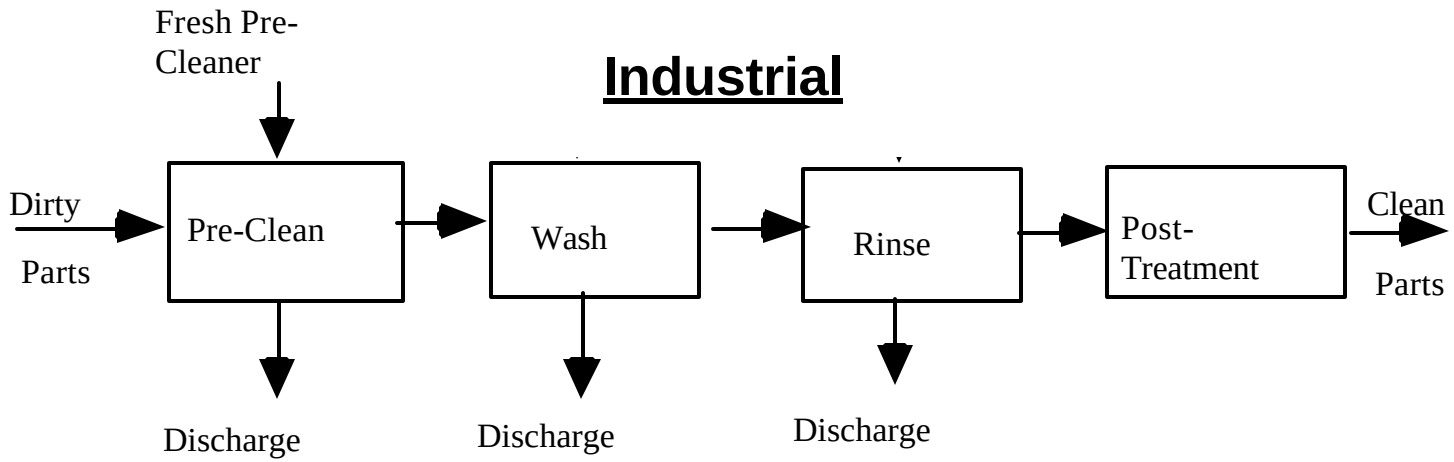
  ID-7.2.24: Decontamination of Metal Debris

  ID-7.2.25: Decontamination of Metal Pipes

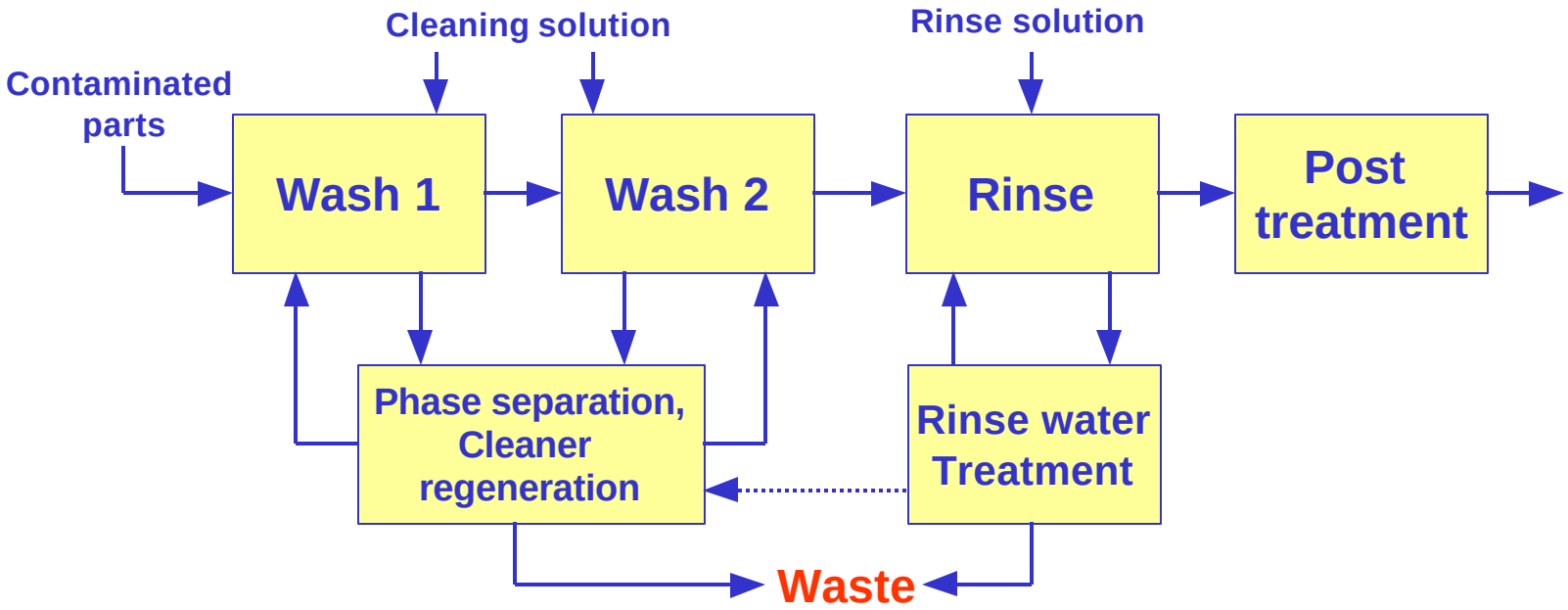
  ID-7.2.26: Decontamination of Metal Walls, Floors, Ceilings, and Corners

  OR-DD02: Improved Decontamination of Equipment, Machinery, Fabricated Metals and Other Materials

Aqueous Cleaning



Removal of Organics from Contaminated Materials



Ultimate Goals

- To provide safe and environmentally sound cleaning/degreasing technology
  - Deliver appropriate solution to substrate
  - Minimize waste
  - Reuse process materials
  - Environmentally benign process materials

Keys to Improved Decontamination

- **Improve removal of soils (organics and particulates) from contaminated surfaces**
  - chemistry of cleaners
  - process conditions

- **Improve phase separation/cleaner regeneration/water reuse**
  - allow recycle/waste reduction
  - adjust solution chemistry, process conditions

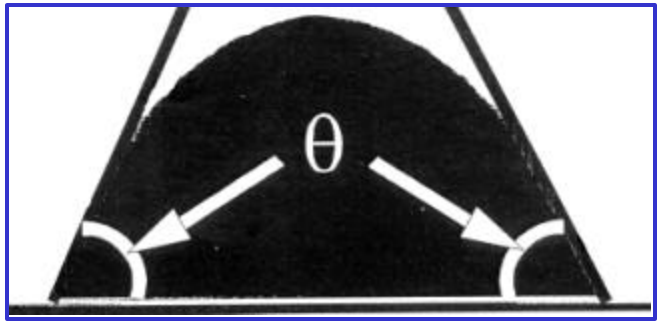
- **These two coupled issues are considered in our current studies**

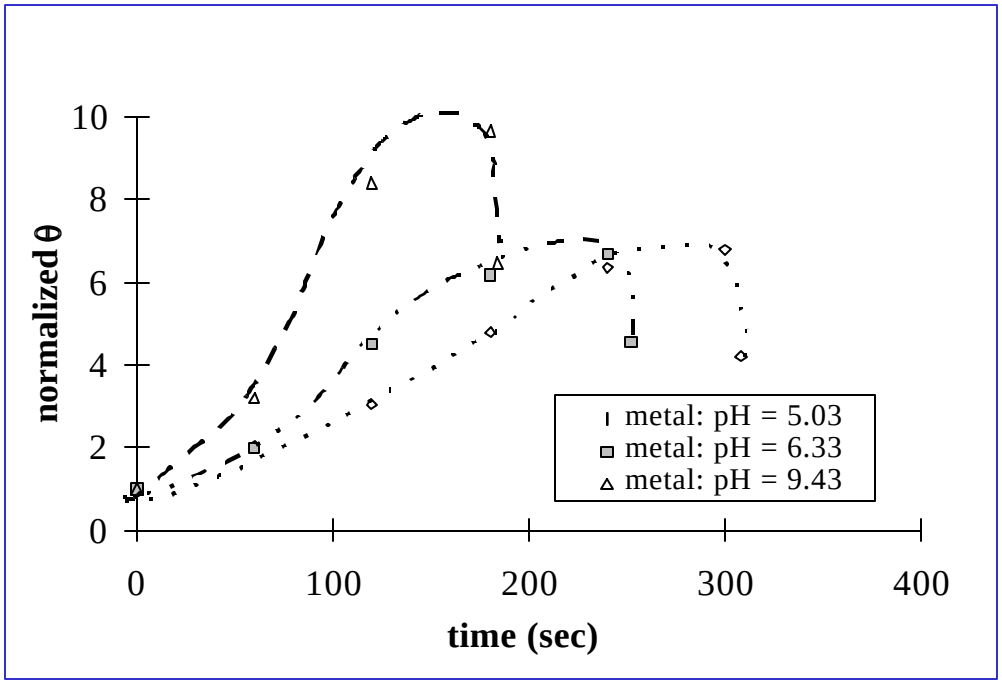
Research Status

- Conducting laboratory-scale research
- Have made significant progress; one invention disclosure
- A commercial firm has expressed interested for industrial applications; progress pending non-disclosure agreement
- Made presentations at
  - DOE ORO EMSP Workshop
  - D&D Focus Area site visit to Oak Ridge
  - no connections with end users yet made

Single-Droplet Experiments

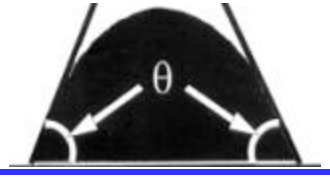
Detachment of oil droplets depends on solution chemistry



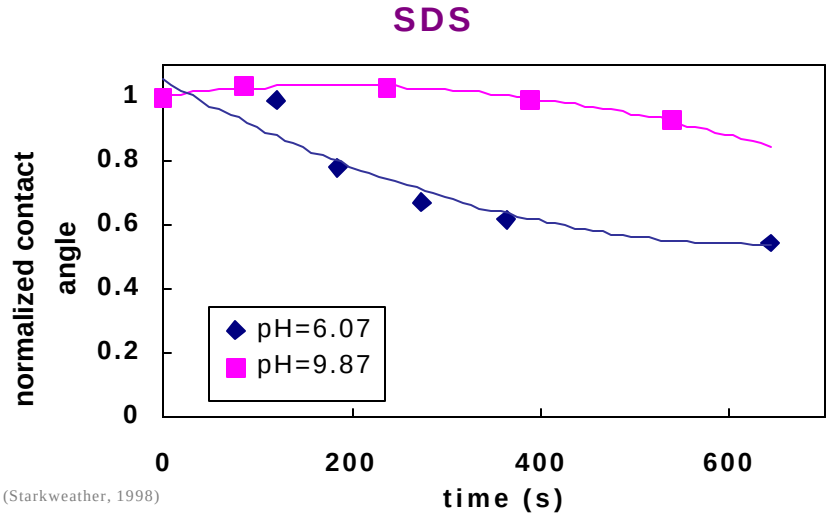


Detachment time is significantly affected by

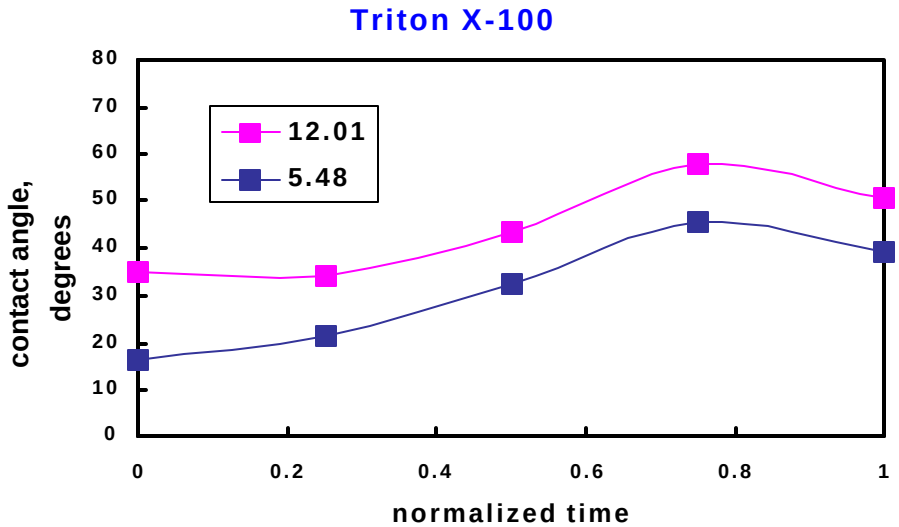
- **pH**
- **surfactant type and concentration**
- **ionic strength**

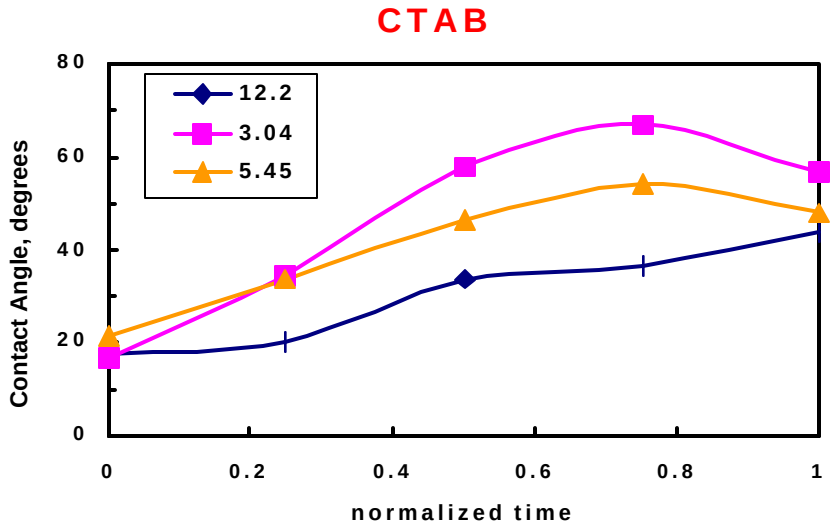


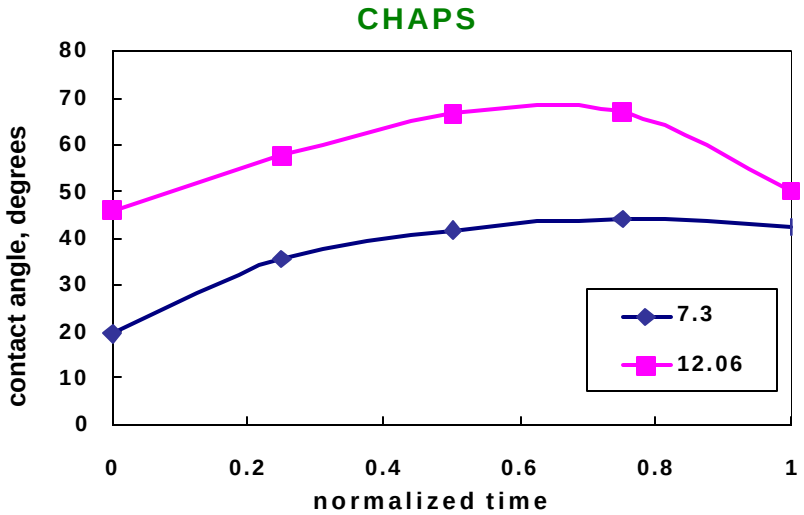
Contact Angle Measurements



(Starkweather, 1998)





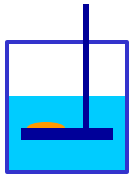


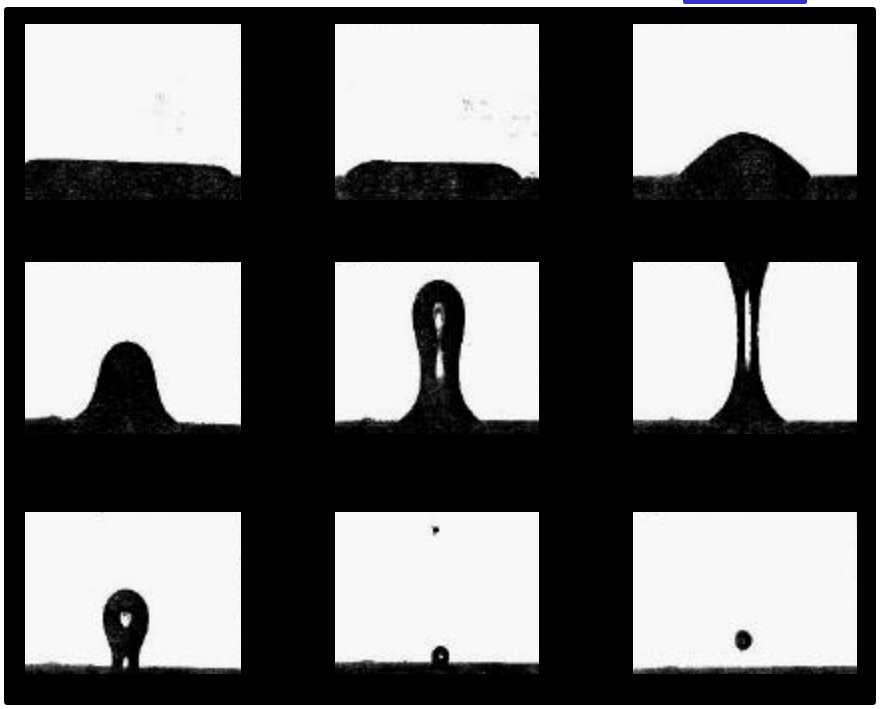
Triton X-100, SDS, and CHAPS exhibit similar trend: larger contact angle with increasing pH; CTAB exhibits opposite trend.

Single-Drop Studies: Faster and Cheaper

Single-droplet studies may speed optimization and reduce waste. Results compared with tests in prototypic industrial cleaning bath.

Single-Droplet Studies



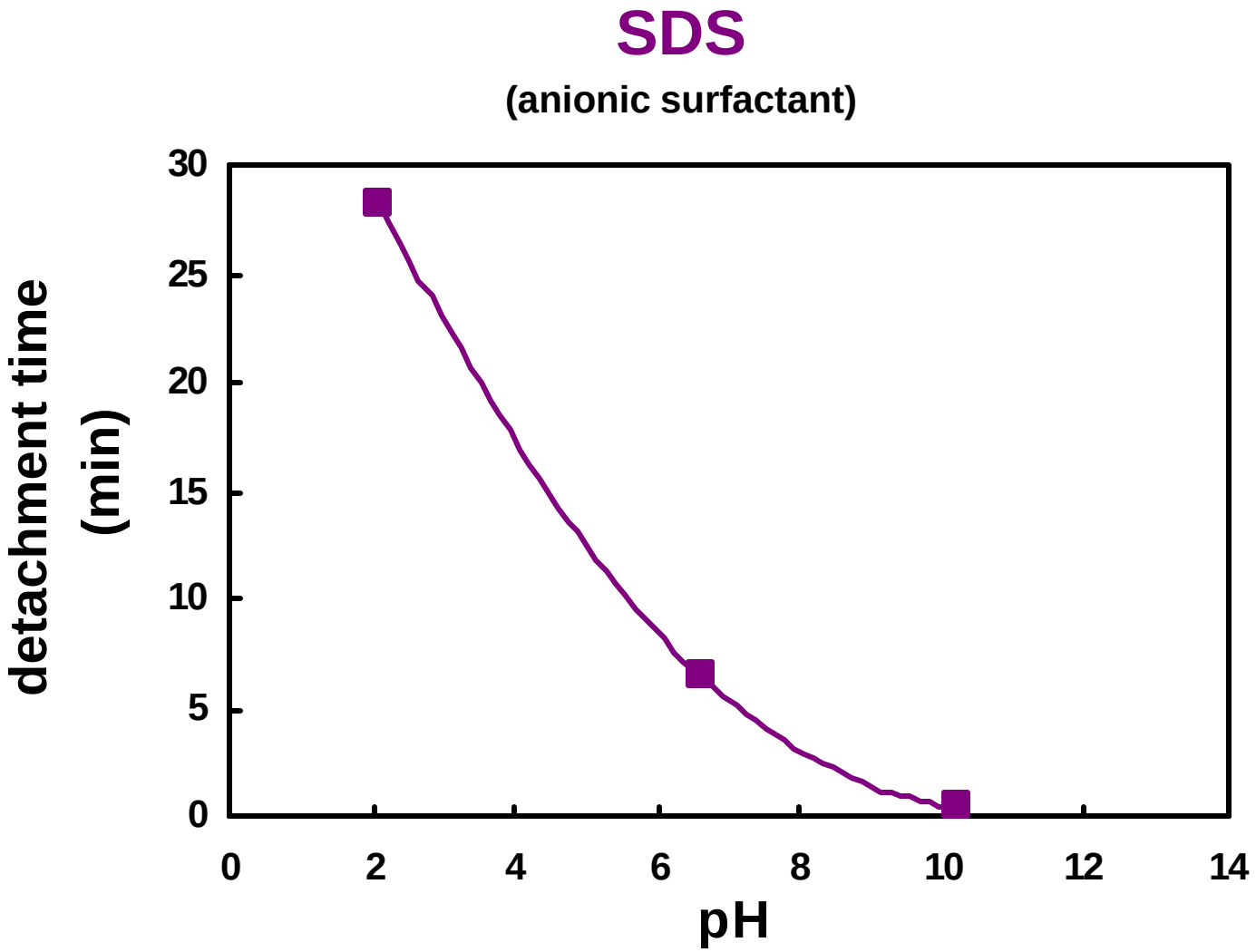


- Time for drop detachment measured
- Shapes of drops provide information on controlling factors

Ultrasonic Bath Experiments

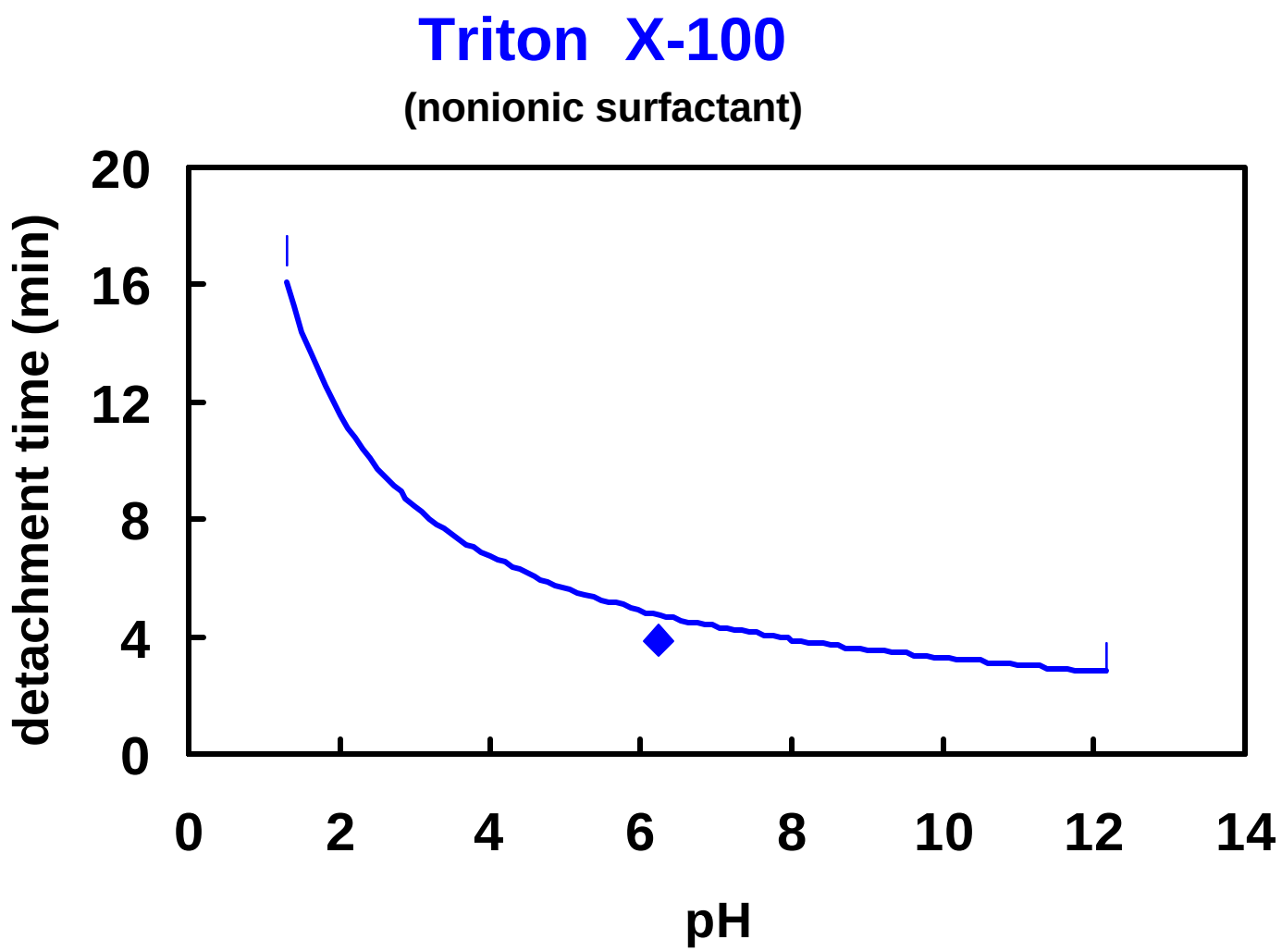
- Prototypic industrial cleaner
- Oil removal rate quantified to measure cleaning performance

Effect of pH - Single-Drop Detachment Experiments



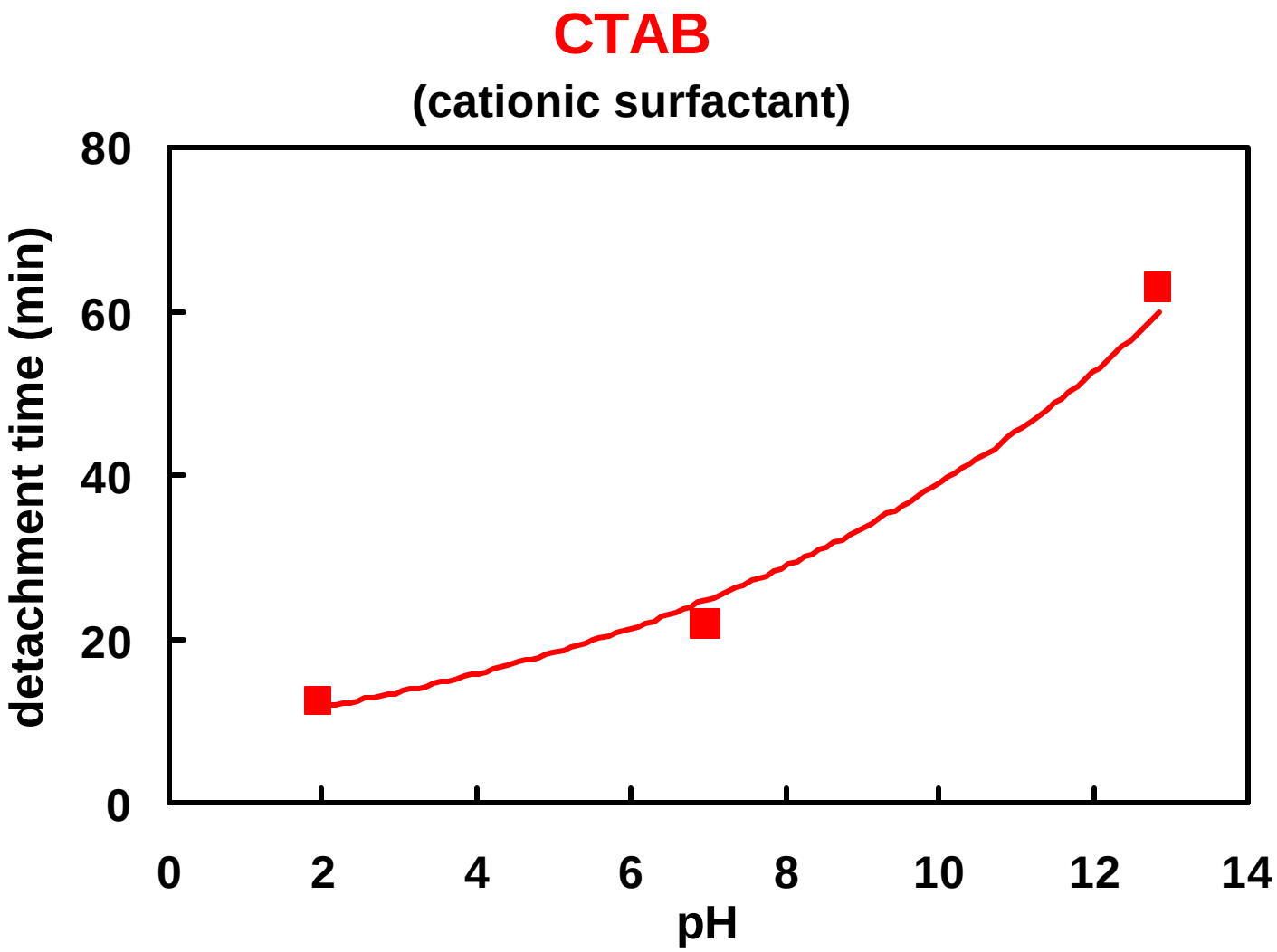
SDS: faster drop detachment with increasing pH.

Effect of pH - Single-Drop Detachment Experiments



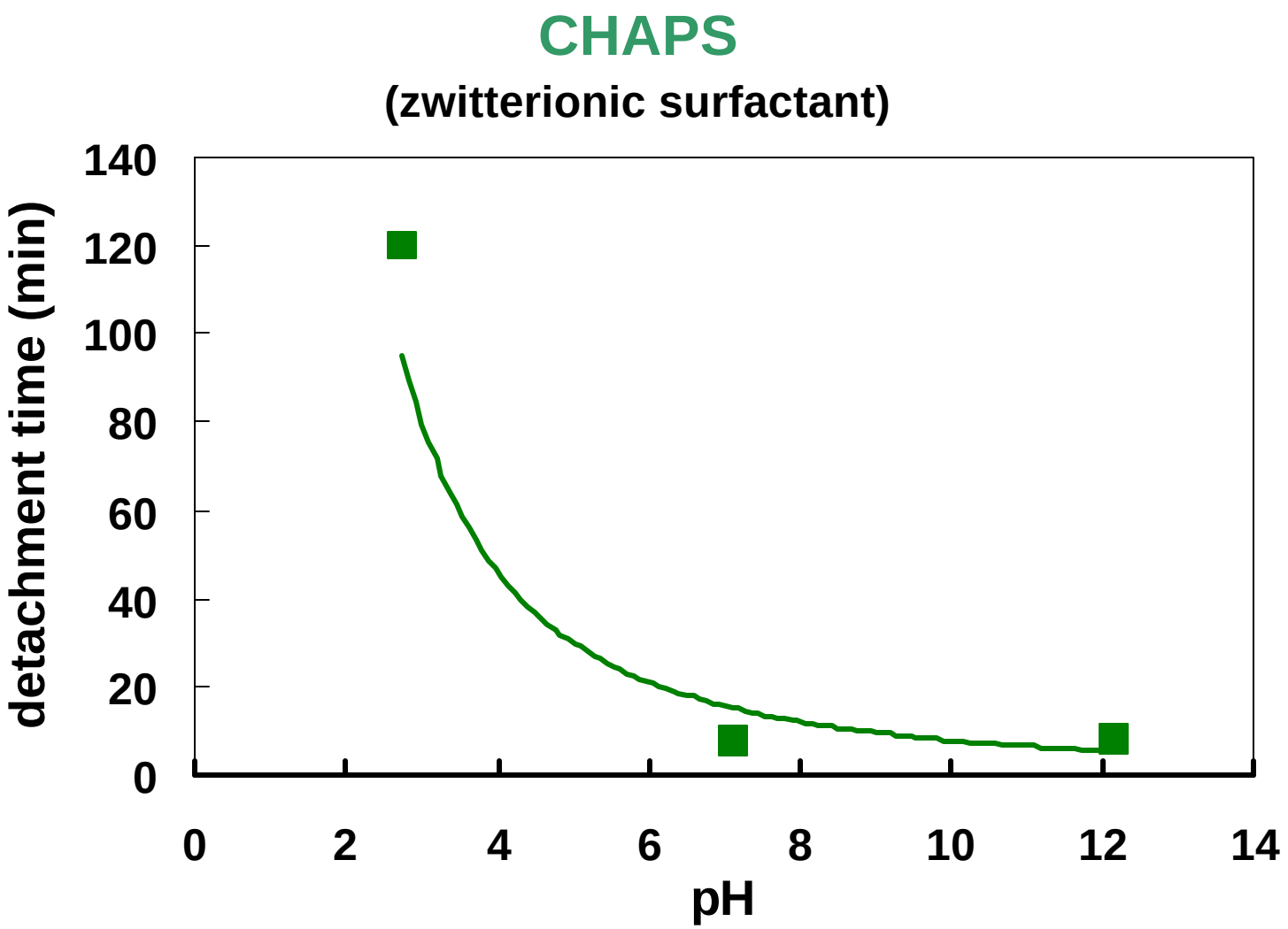
Triton X-100: faster drop detachment with higher pH.

Effect of pH - Single-Drop Detachment Experiments



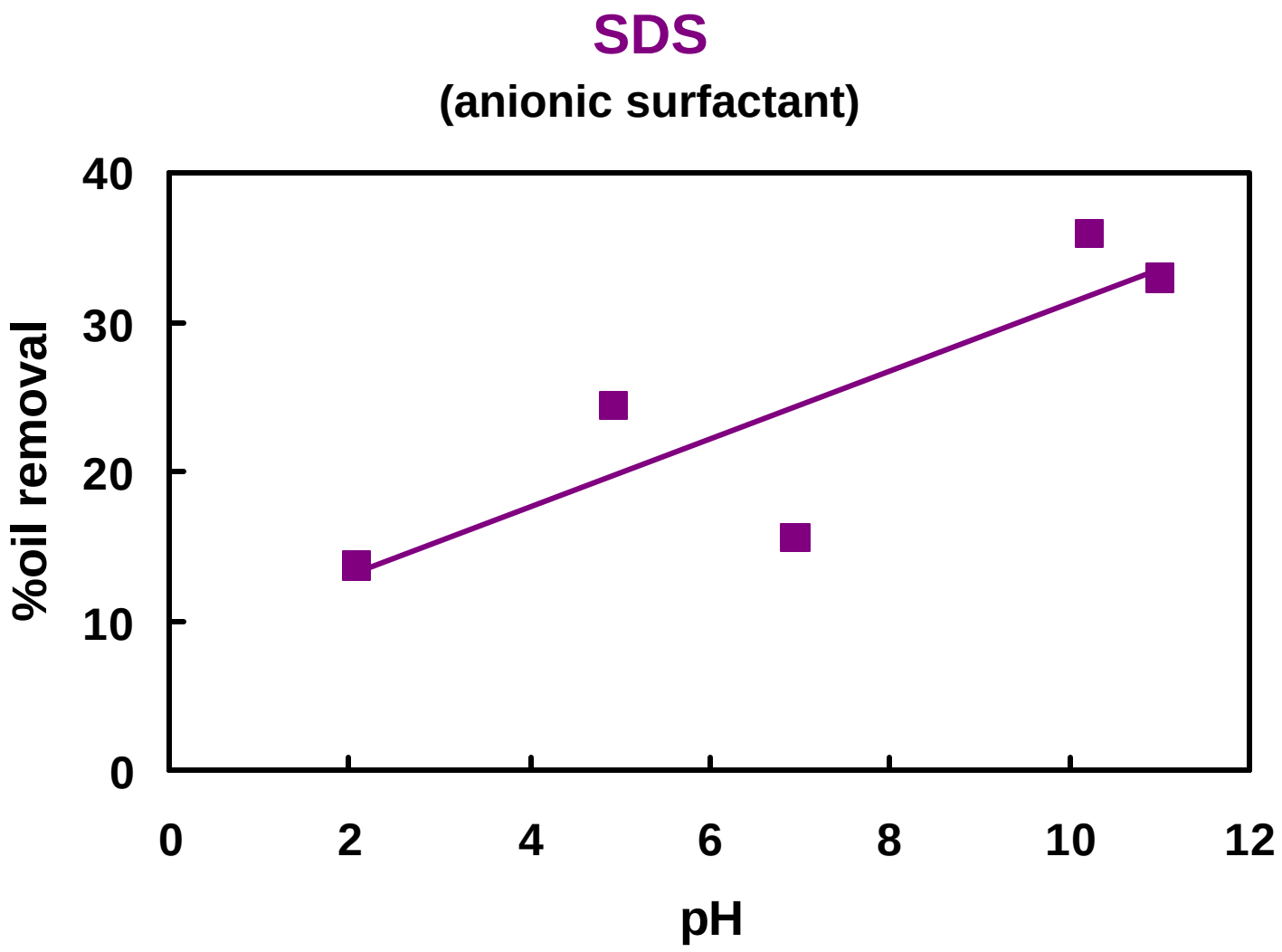
CTAB: Faster drop detachment at lower pH values.

Effect of pH - Single-Drop Detachment Experiments



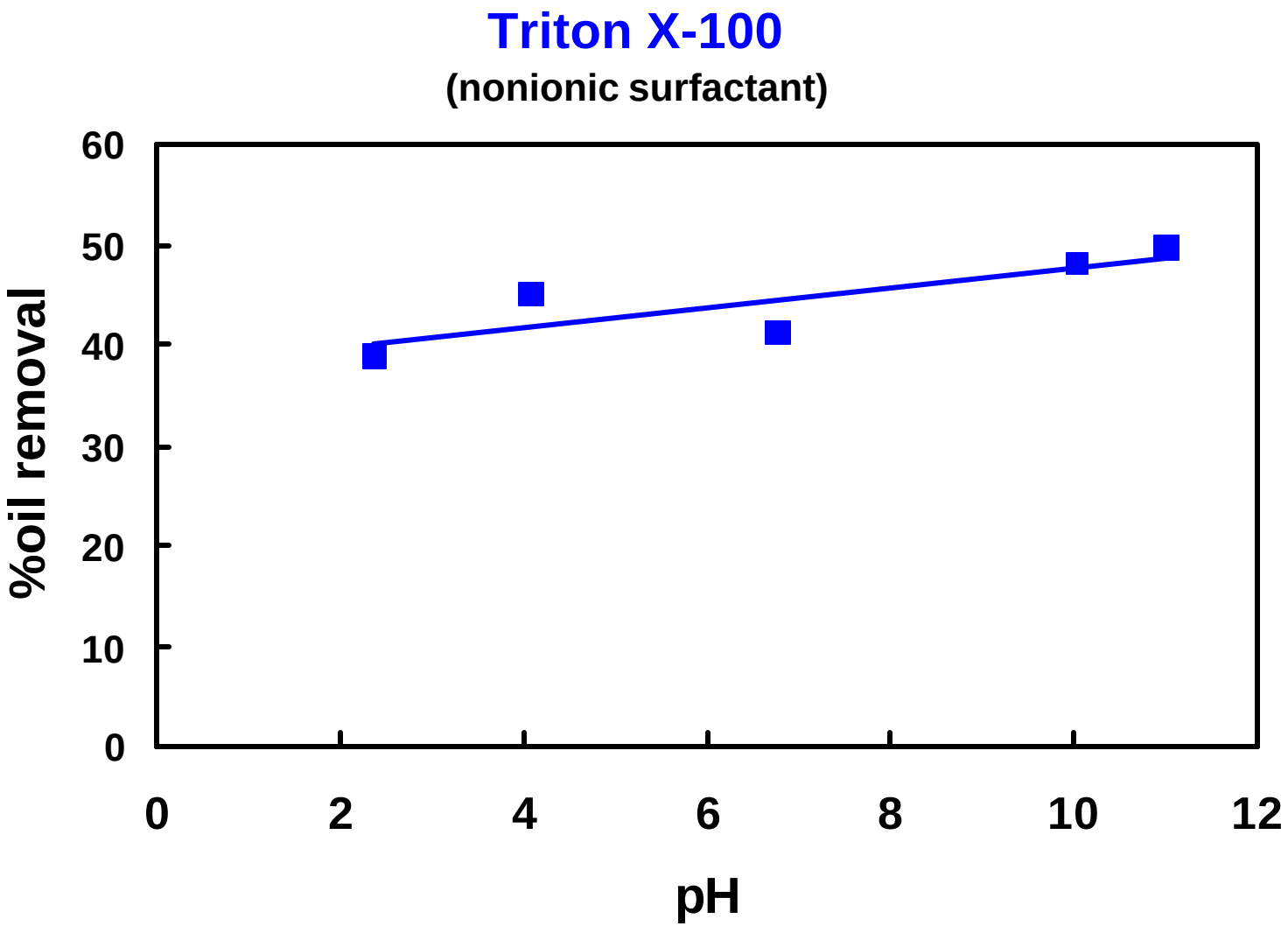
CHAPS: pH has a greater effect on drop detachment time

Ultrasonic Bath Cleaning Experiments



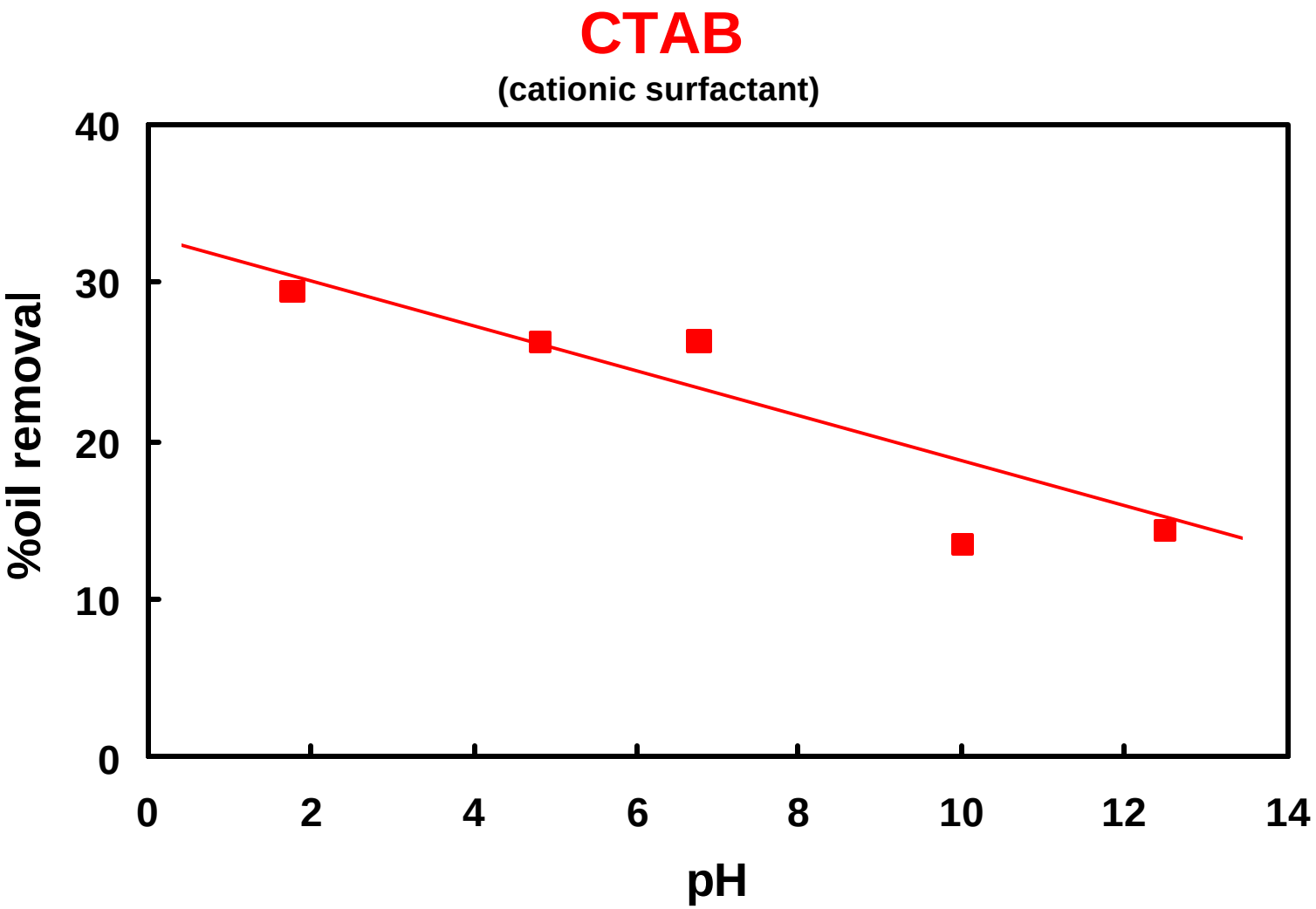
SDS: higher cleaning efficiency at higher pH.

Ultrasonic Bath Cleaning Experiments



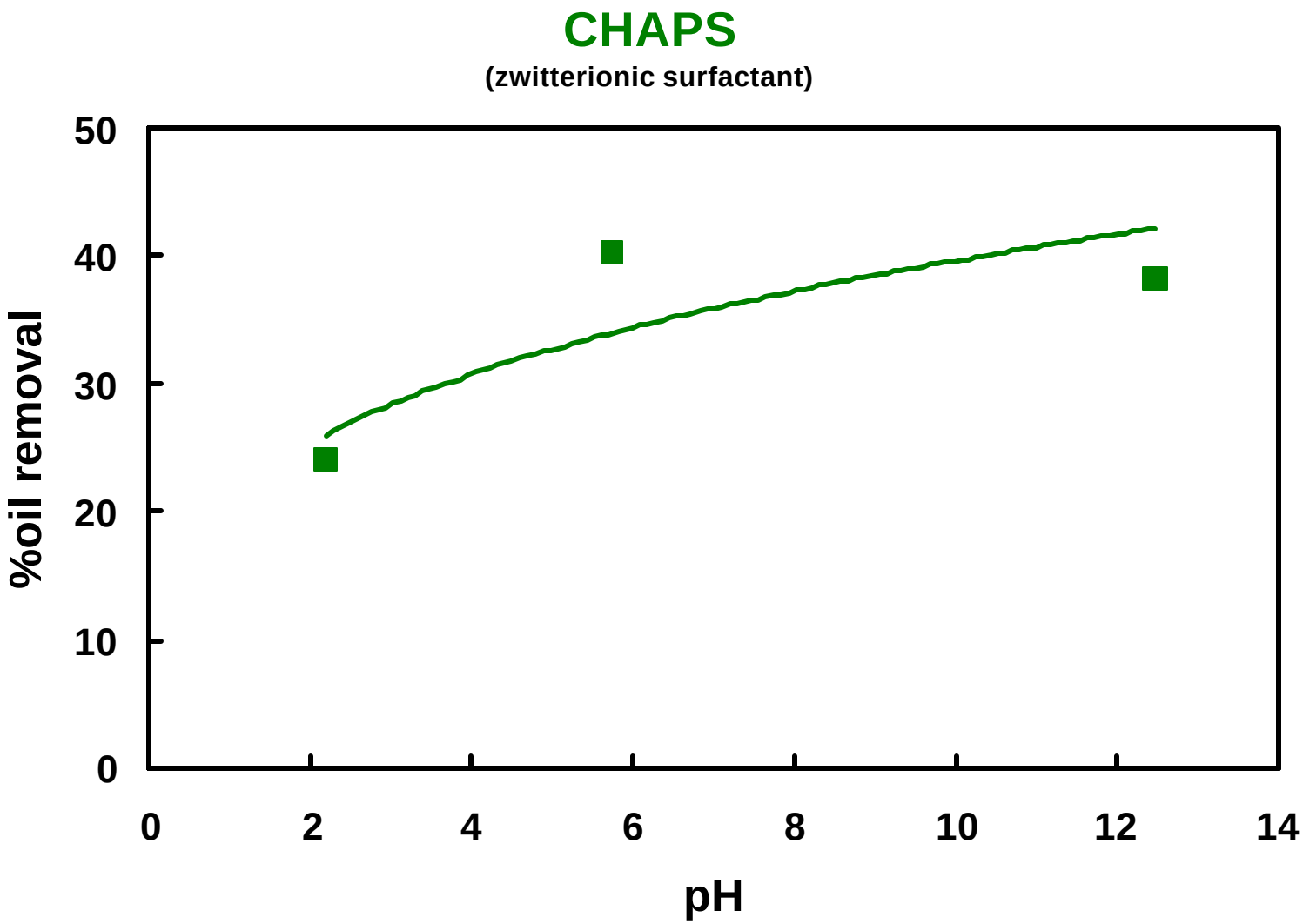
Triton X-100: slightly higher cleaning efficiency at higher pH

Ultrasonic Bath Cleaning Experiments



CTAB: higher percentage of oil removed at lower pH

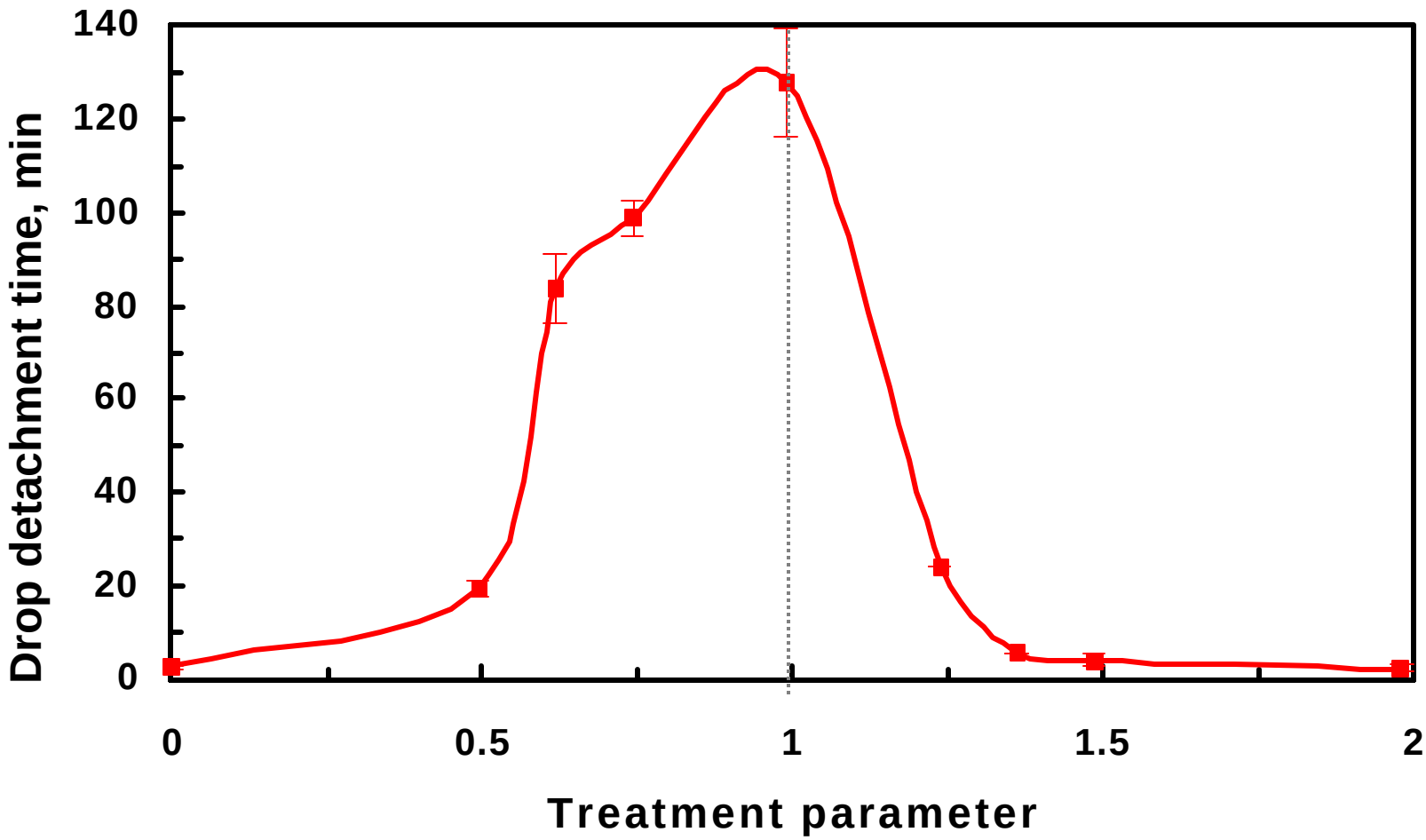
Ultrasonic Bath Cleaning Experiments



CHAPS: higher percentage of oil removed at higher pH

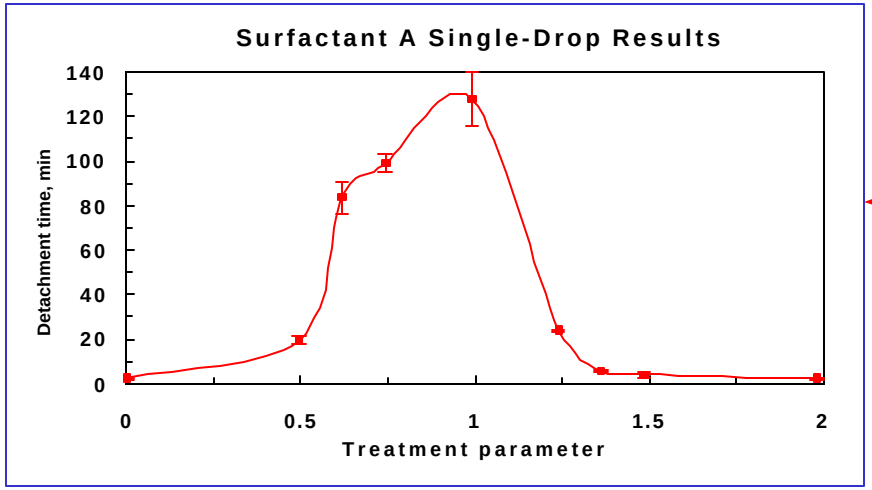
Highlight: Novel Approach Significantly Improves Removal

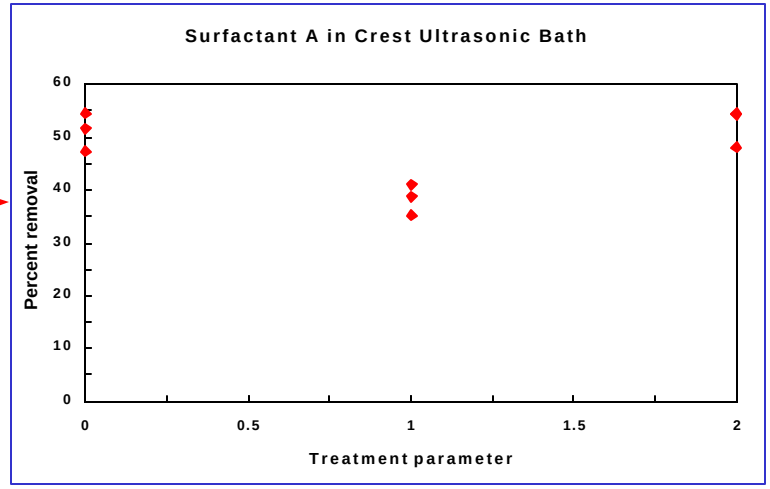
Approach involves a simple, inexpensive process modification

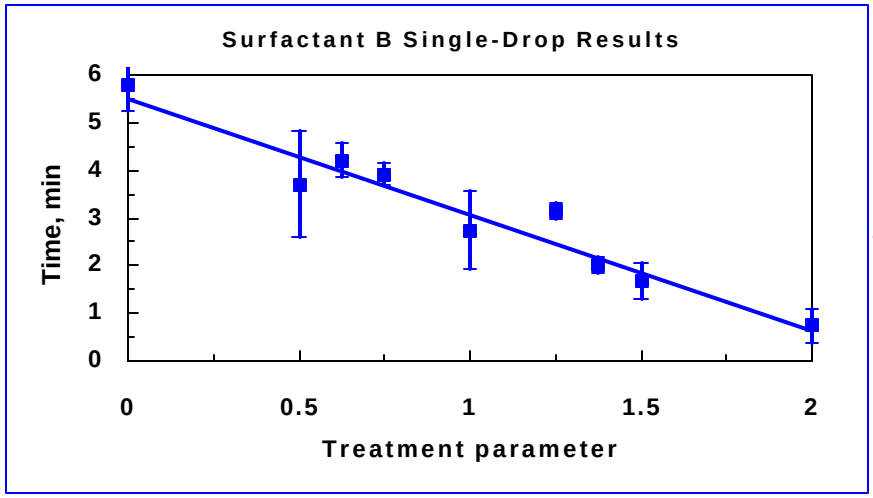


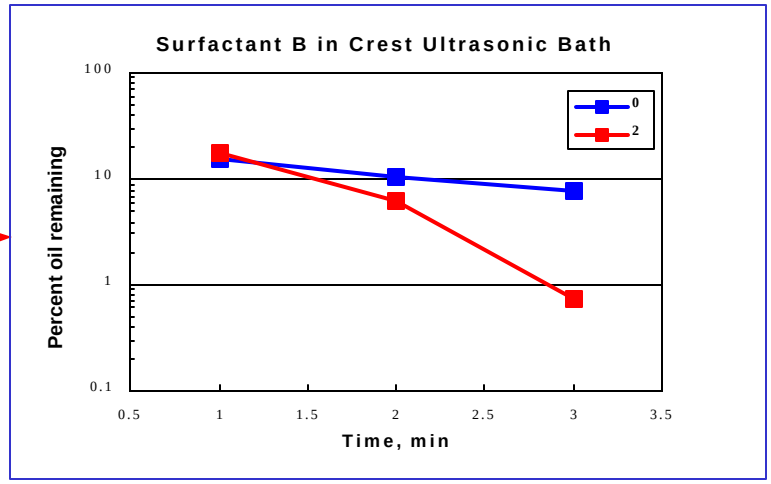
Droplet tests can be used to efficiently optimize cleaning

Similar trends in single-droplet studies and tests with contaminated coupons in prototypical commercial unit



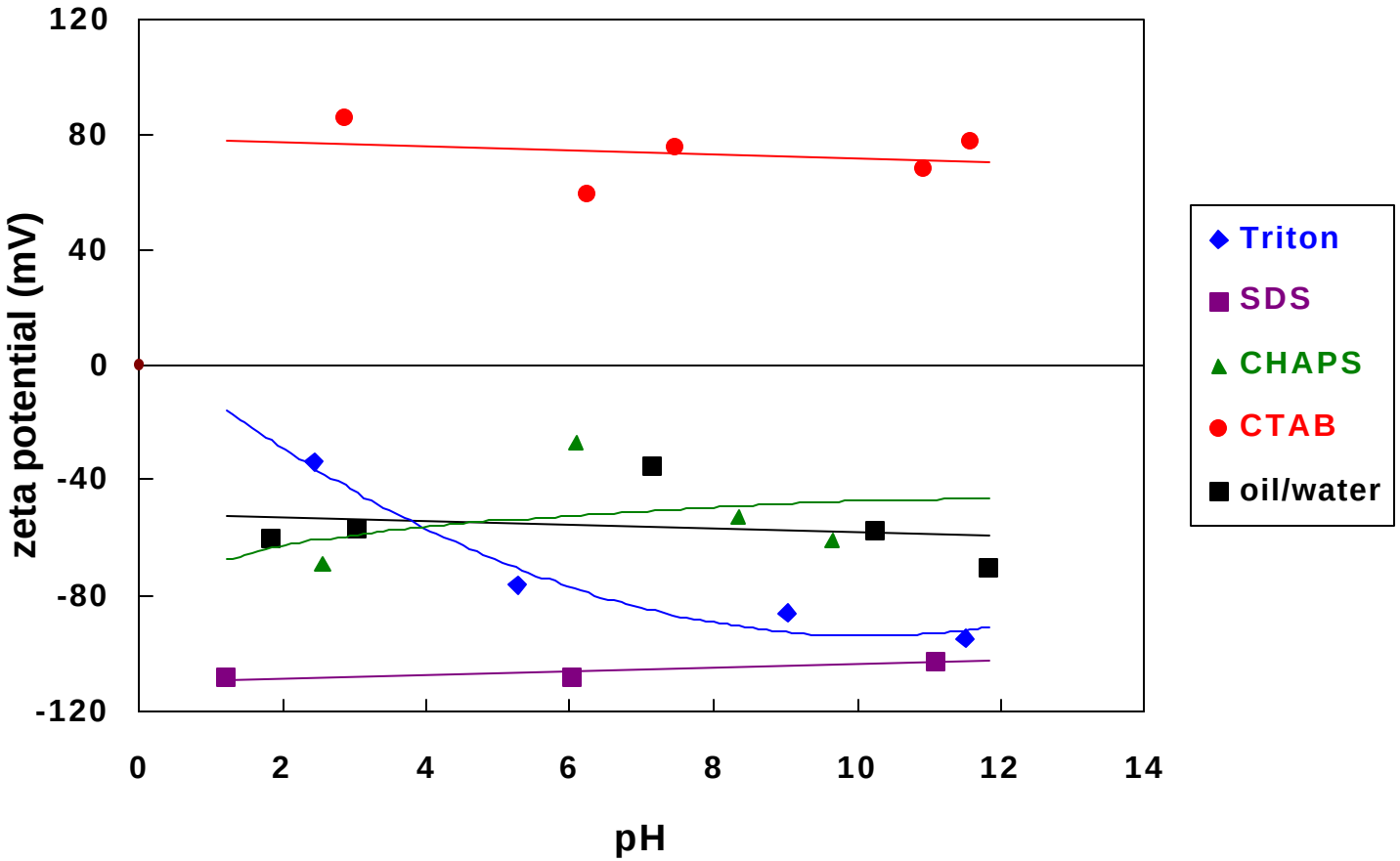






Zeta Potential Measurements

Zeta potential measurements of submicron oil drops suspended in aqueous surfactant solutions were made using a Lazer Zee Meter Model 501.



Oil droplets in solutions of SDS, CHAPS, and Triton X-100 exhibit negative surface charge; oil droplets in CTAB are positively charged.

Phase Separation Studies

- **Optimizing phase separation**
  - minimize waste
  - decrease process size and cost
- **Balancing cleaning and phase separation operations**
  - cleaning solution is designed to solubilize and/or suspend organics
  - to recycle, must separate oil from aqueous solution
- **Phase separation tests are currently being conducted**
  - determine controlling factors
  - develop ways to design efficient separation systems

Process Parameters in Phase Separation

- **Variables in simple experiments**
  - surfactant type
    - cationic (CTAB), nonionic (Triton X-100), anionic (SDS)
  - solution chemistry
    - pH
    - ionic strength
  - oil type

- **Quantify the effect of**
  - oil properties
    - viscosity
  - interfacial properties
    - interfacial tension
    - surface charge

Phase Separation Studies

- Measured amounts of oil and aqueous surfactant solution in beaker
- Stirred for a certain period of time (5, 20, 60 minutes)
- Measured variation of layer heights during settling

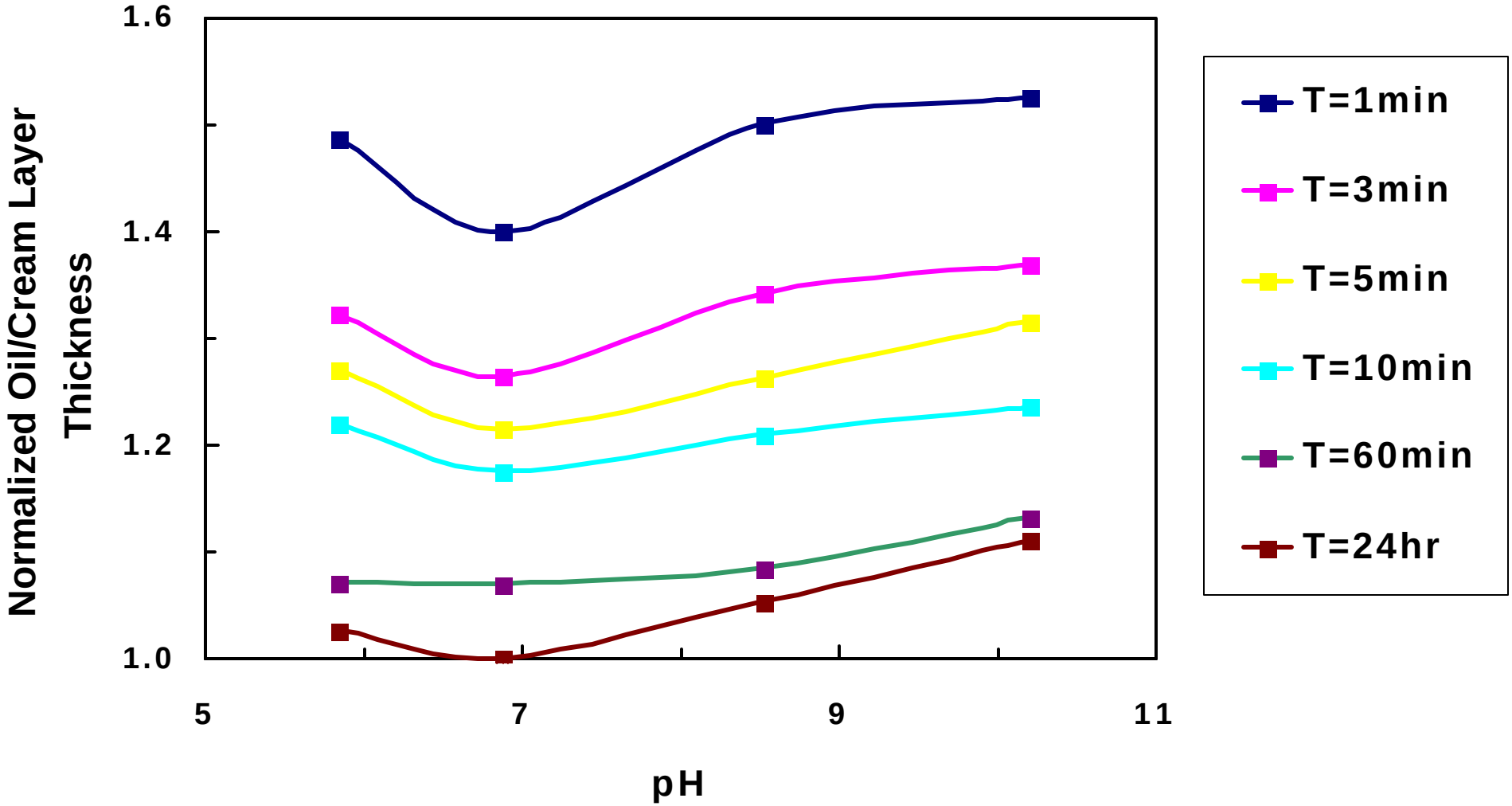
Start of experiment

During stirring

Measuring oil/cream layers

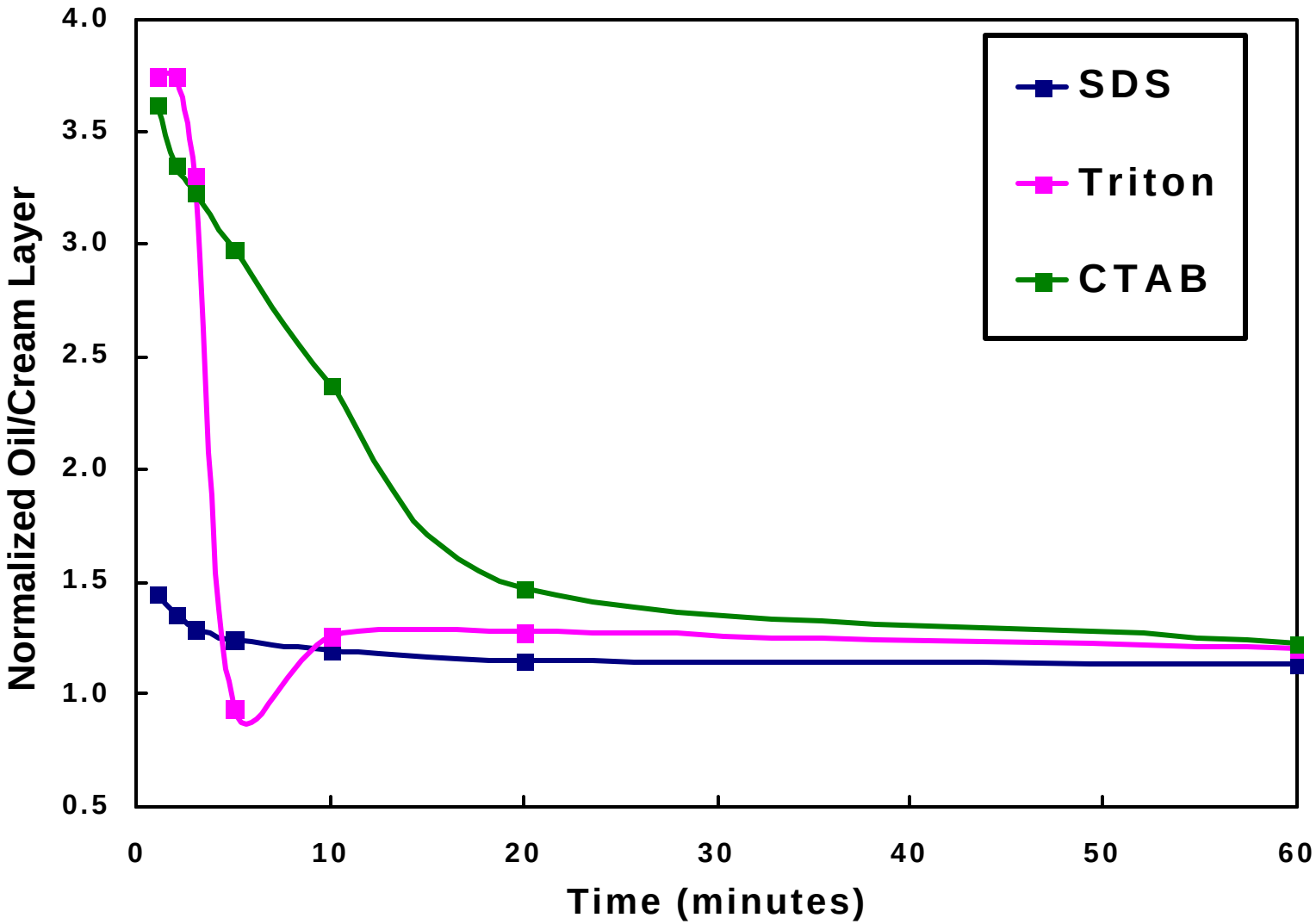
After 5 minutes of settling

Phase Separation Results



Studies will help to define optimum separation conditions

Phase Separation with Different Surfactants



Conditions: 10W oil, 60 minute stirring, using baffles

Summary of Research

- **Studies aimed at improved understanding of aqueous-based cleaning for removal of organic contamination**
- **Two areas of focus**
  - removal of oil from substrate
  - separation of oil from aqueous solution
- **Highlights of progress**
  - droplet detachment is significantly affected by solution chemistry
  - a novel process modification can drastically improve removal
  - similar trends in single-drop studies and industrial cleaning equipment may lead to efficient approach for optimization

How Can We Benefit From This Workshop?

- **Current studies are on generic systems**
  - quenching oil
  - single-surfactant solutions
- **To be useful, we need to be relevant to real problems (need to establish linkage to application)**
- **Searching for application with**
  - organic contamination on metals
  - possibility for surrogates initially
  - capability to get small samples for testing at ORNL
- **Positives:**
  - application currently using aqueous cleaners
  - willingness to sign nondisclosure agreement
  - willingness to participate in demos