# Study of Disinfectant Penetration in a Drinking Water Storage Tank Sediment Using Microelectrodes

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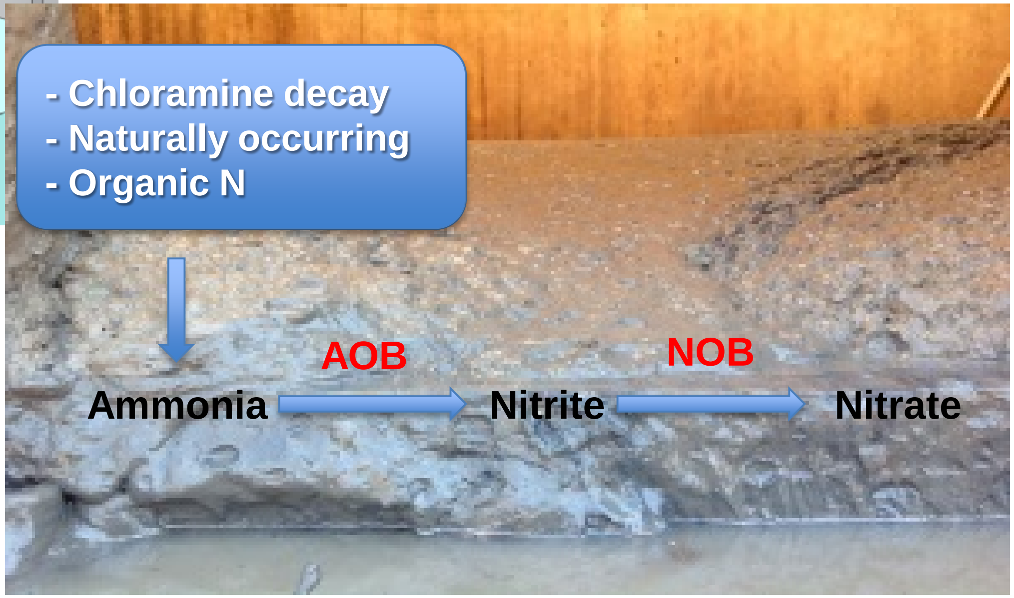
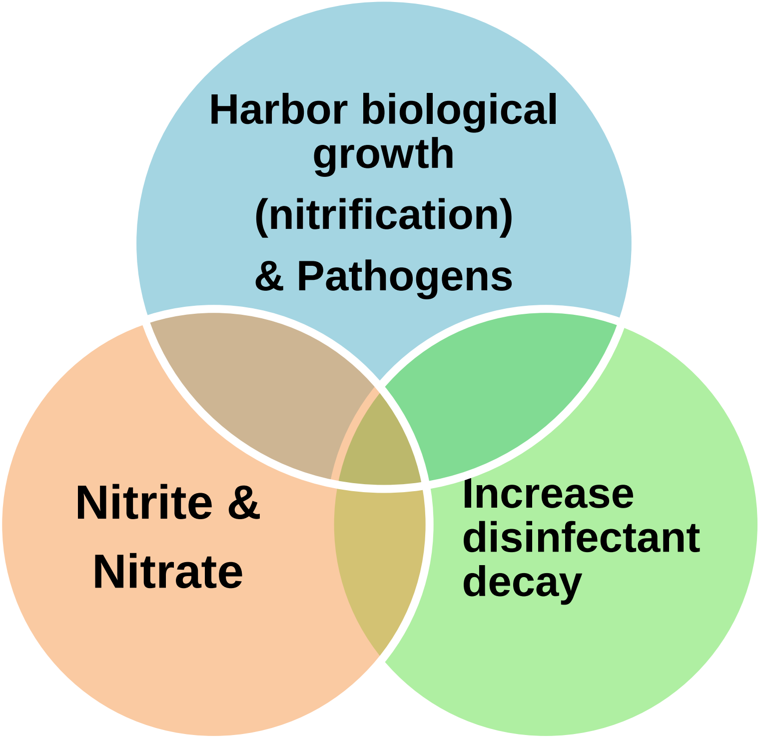
# Nitrification in Drinking Water Storage Tank Sediment

## Water Storage Tanks Accumulate Sediment Over Time and Provide a Good Habitat for Bacteria Growth

# Research Motivation

**Sediment accumulation causes water quality degradation issues:**




**Disinfectant penetration within water storage sediments is largely uncharacterized**

# Overall Research Objective

- **Use microelectrodes to evaluate disinfectant and water quality within a drinking water tank sediment**
  - ❑ **Monochloramine & free chlorine penetration profiles over time**
- **Evaluate impact of switching disinfectants**
  - ❑ **Monochloramine → free chlorine → monochloramine**
- **Investigate the relationship between disinfectant penetration and microbial activities within the sediment**
  - ❑ **Dissolved oxygen (DO), ammonium, nitrite, nitrate, & pH profiles over time**

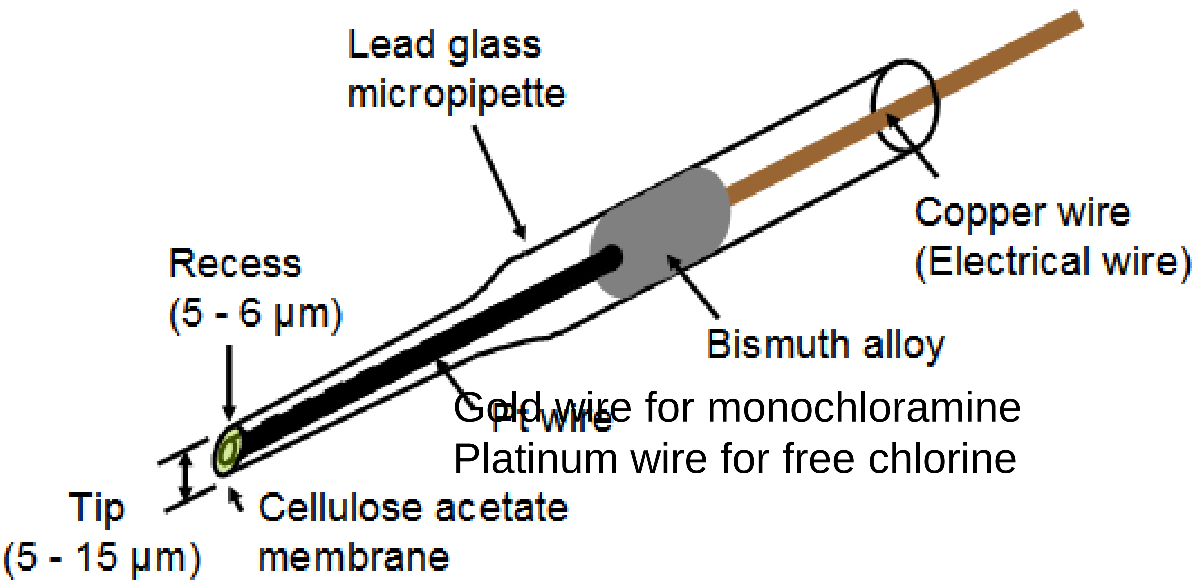
# Research Approach – Microelectrode Fabrication

**Microelectrodes used in this research:**

**Amperometric type:**
- Dissolved oxygen (DO), monochloramine, free chlorine, and nitrite

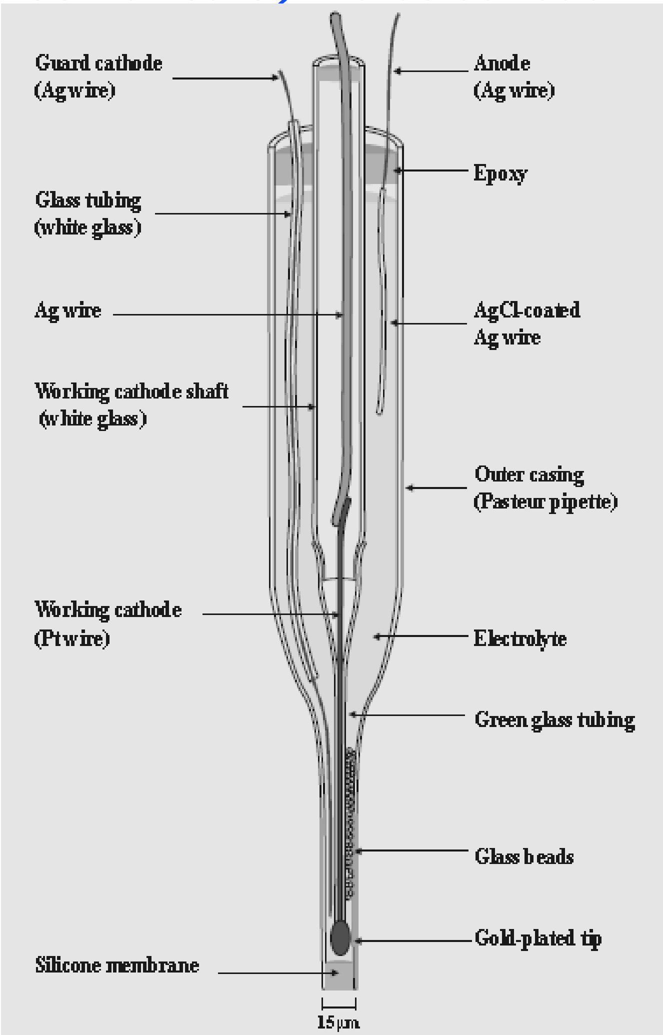
**Potentiometric type:**
- pH, ammonium, and nitrate

## Monochloramine & Free Chlorine Microelectrodes



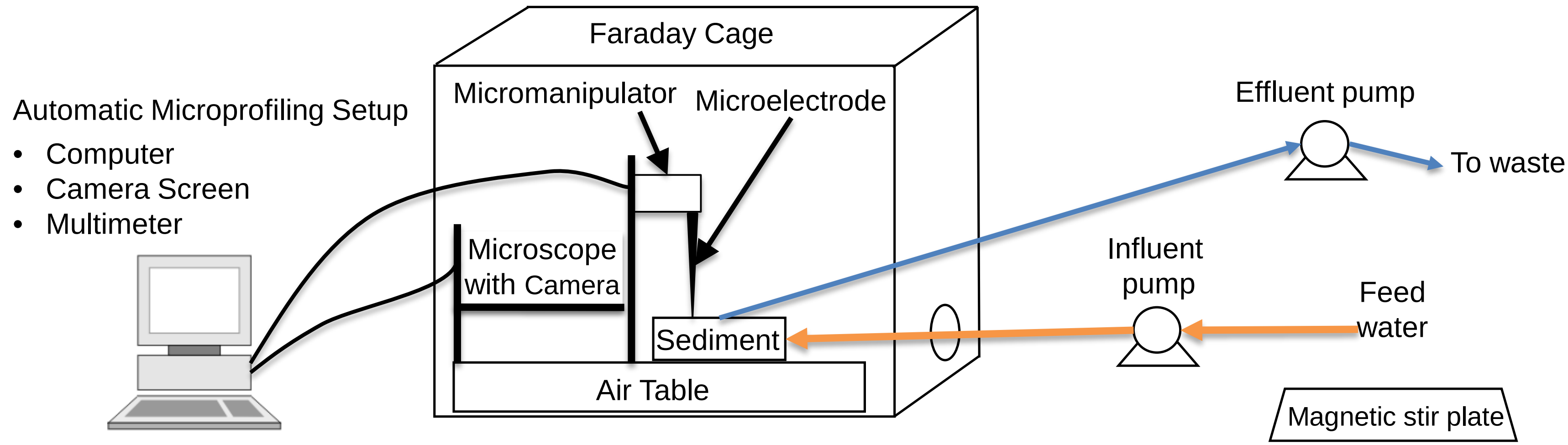

Gold wire for monochloramine
Platinum wire for free chlorine

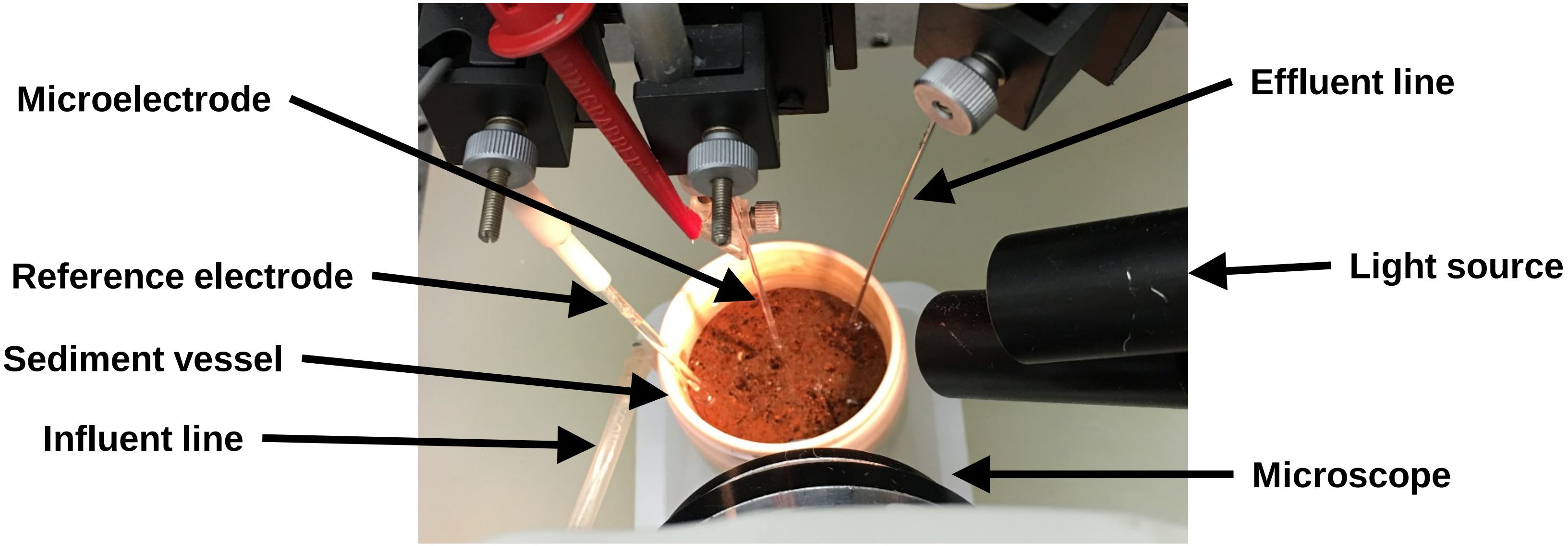
## Combined $O_2$ Microelectrode




Cited From Lu, R and Yu, T. 2002

# Research Approach – Microelectrode Measurement



# Disinfectant Application Scenario

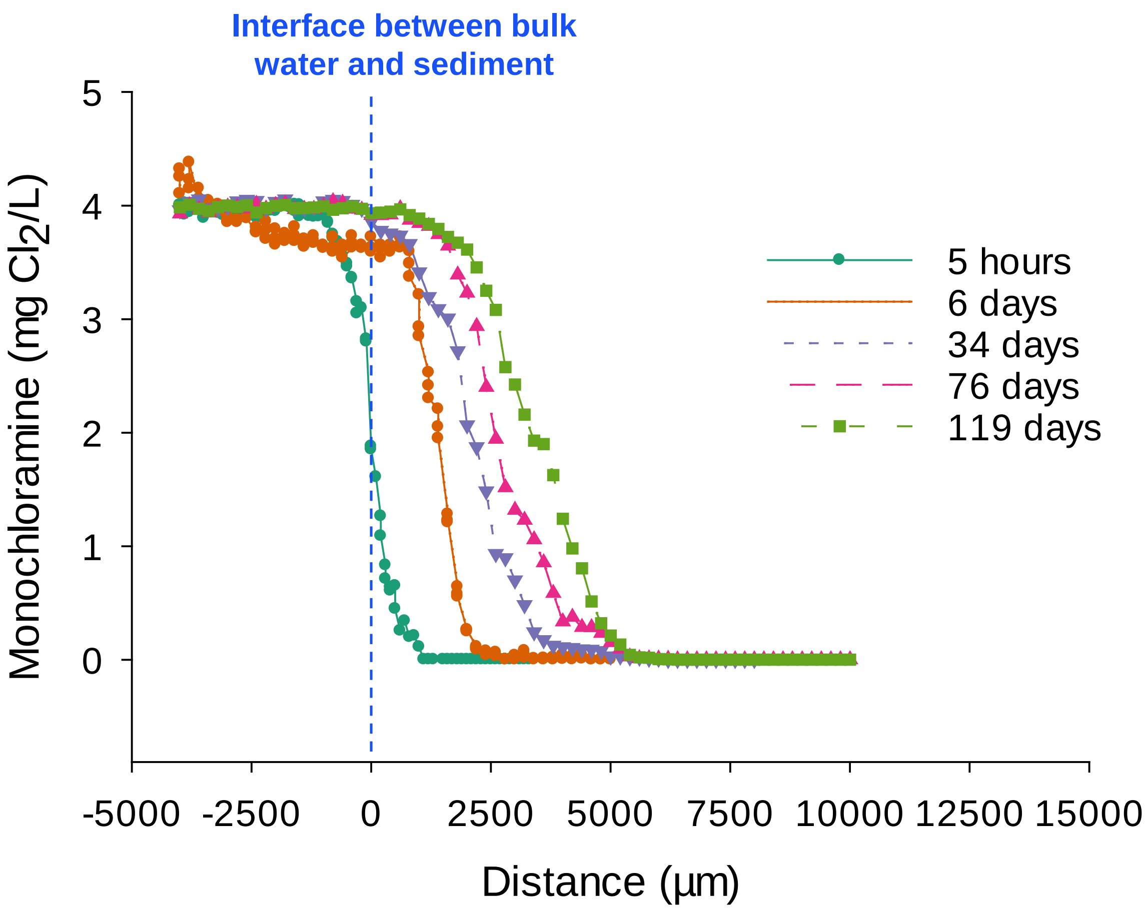
- 5 cm diameter x 4 cm deep teflon cup
  - 2.0 cm (20,000 µm) sediment depth
  - 0.5 cm (5,000 µm) water depth over sediment
- 5 mL/min flowrate
  - 2 minute hydraulic residence time
  - 4 mg $Cl_2$/L monochloramine (4:1 $Cl_2$:N) or free chlorine
  - 5 mM borate buffer (pH 8.0)

**Phase 1 (120 days):** Monochloramine

**Phase 2 (60 days):** Free chlorine

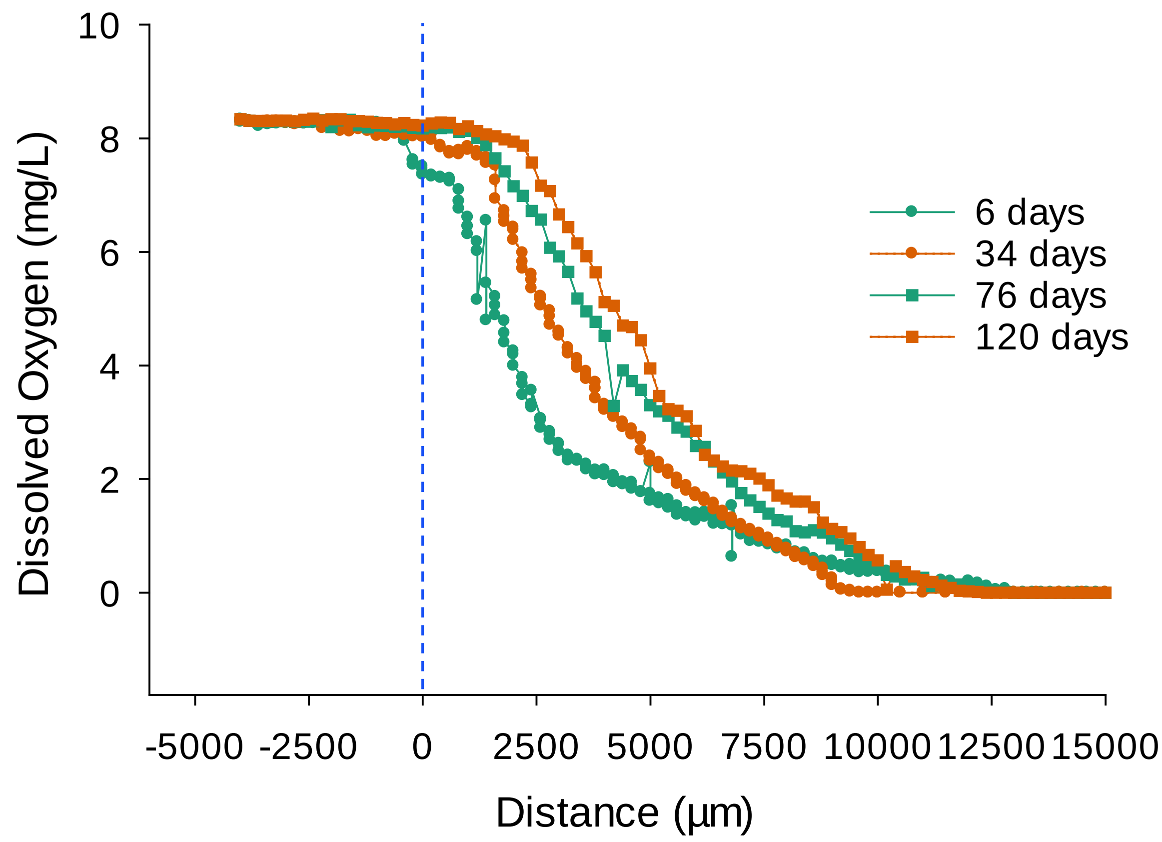
**Phase 3 (60 days):** Monochloramine

# Phase 1 Monochloramine - Monochloramine Profiles



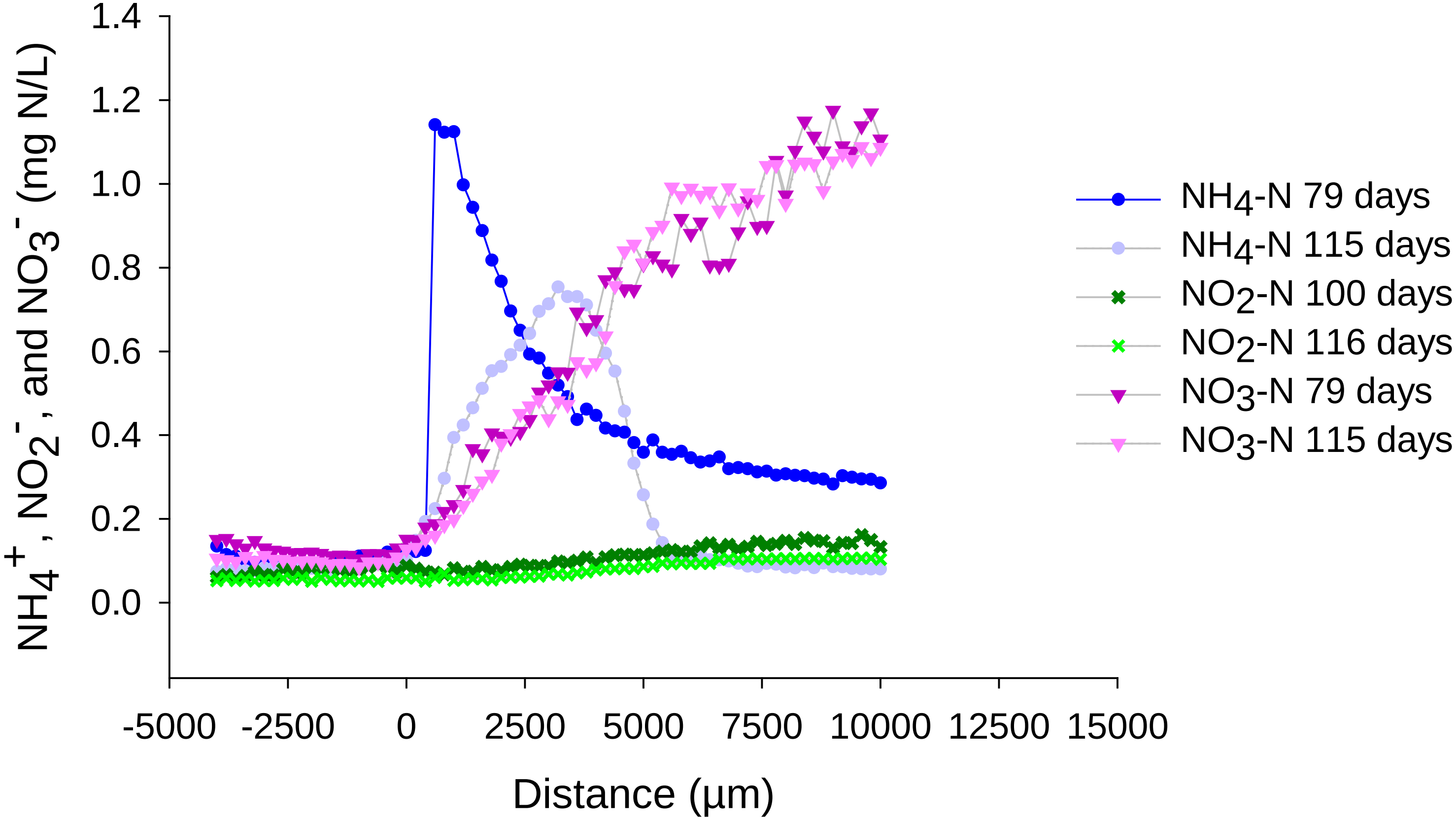

- **After approximately 5 hours, a 2 mg $Cl_2$/L monochloramine concentration reached the sediment's surface, but after 119 days, the 2 mg $Cl_2$/L monochloramine concentration only reached to a depth of 3,200 µm.**
- **No monochloramine was measurable at sediment depths greater than 6,200 µm.**

# Phase 1 Monochloramine – Dissolved Oxygen Profiles



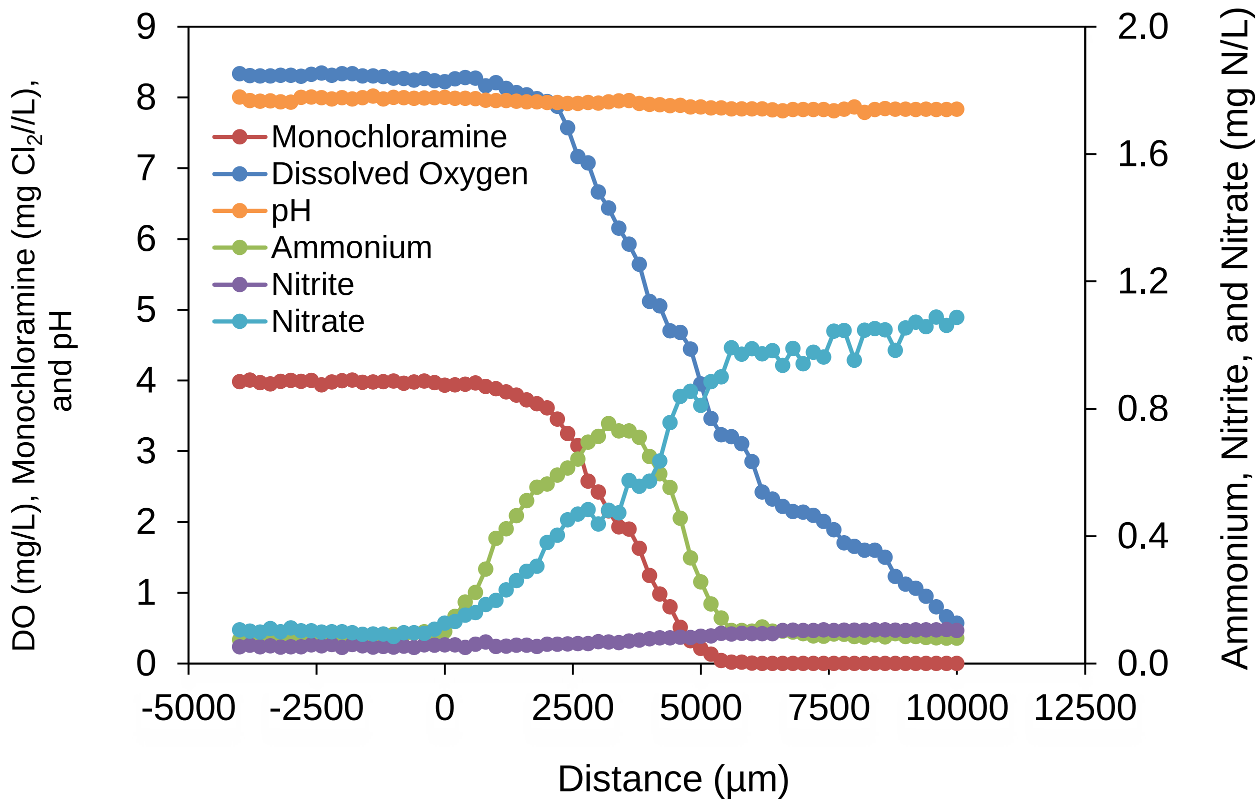

- **DO progressed inward during the 120 day period.**
- **4 mg/L of DO reached 5,000 µm below interface after day 120 with 52% of the bulk DO consumed.**
- **No DO was measurable at sediment depths greater than 12,500 µm.**

# Phase 1 Monochloramine – Nitrogen Profiles



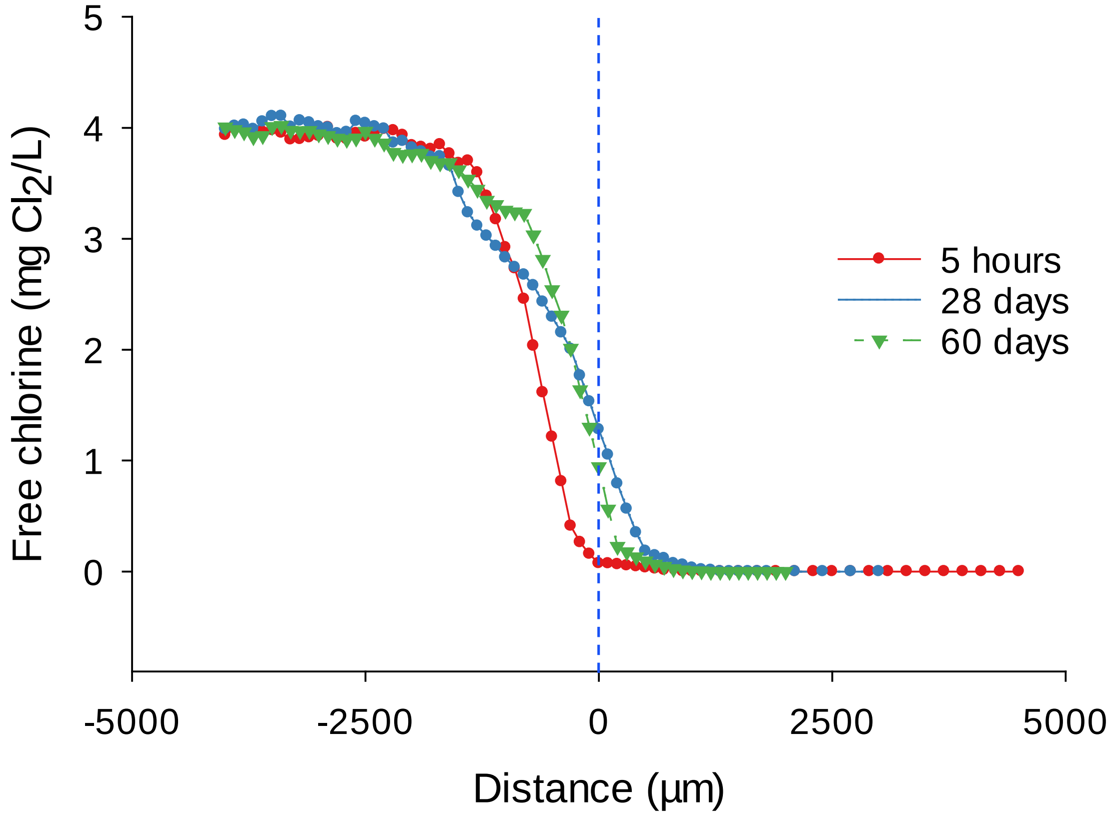

- **Nitrate increased with a concurrent decrease in ammonium with sediment depth.**
- **Minimal nitrite accumulation, indicating complete nitrification occurred in the sediment.**

# Phase 1 Monochloramine – Final Profile Summary



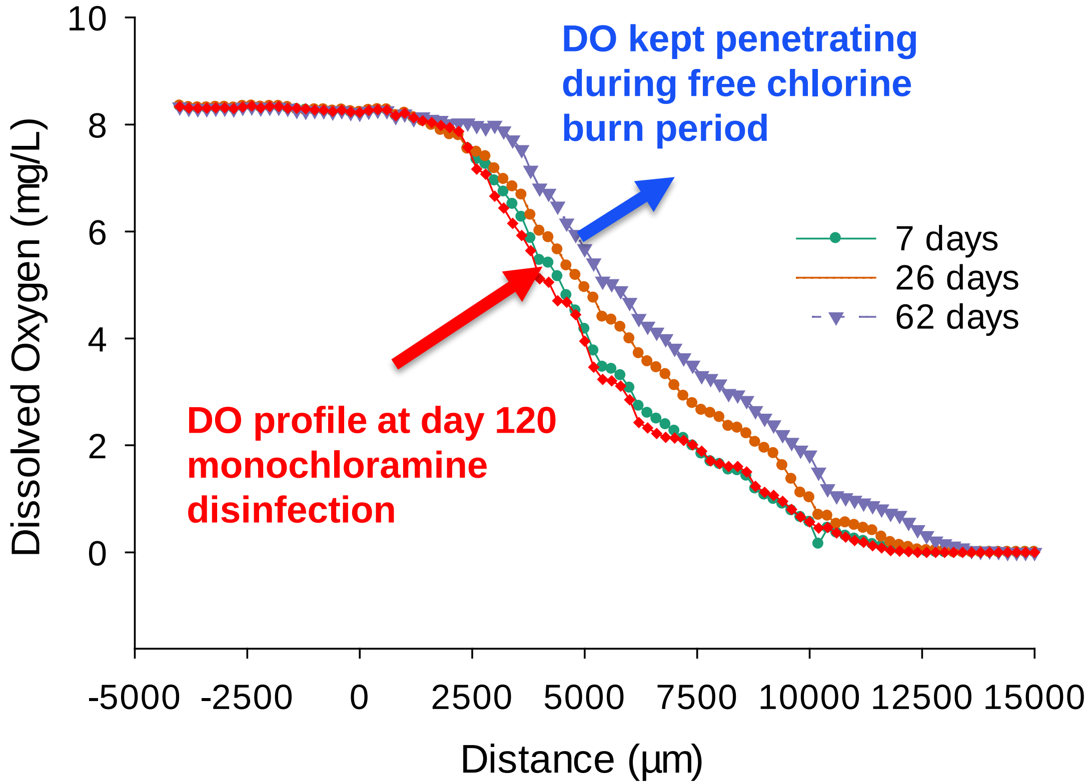

- **Start of DO consumption corresponded with monochloramine decrease.**
- **Complete nitrification → oxygen consumption corresponds.**
- **DO consumption continued after ammonia removal → heterotrophic activity.**

# Phase 2 Free Chlorine – Free Chlorine Profiles



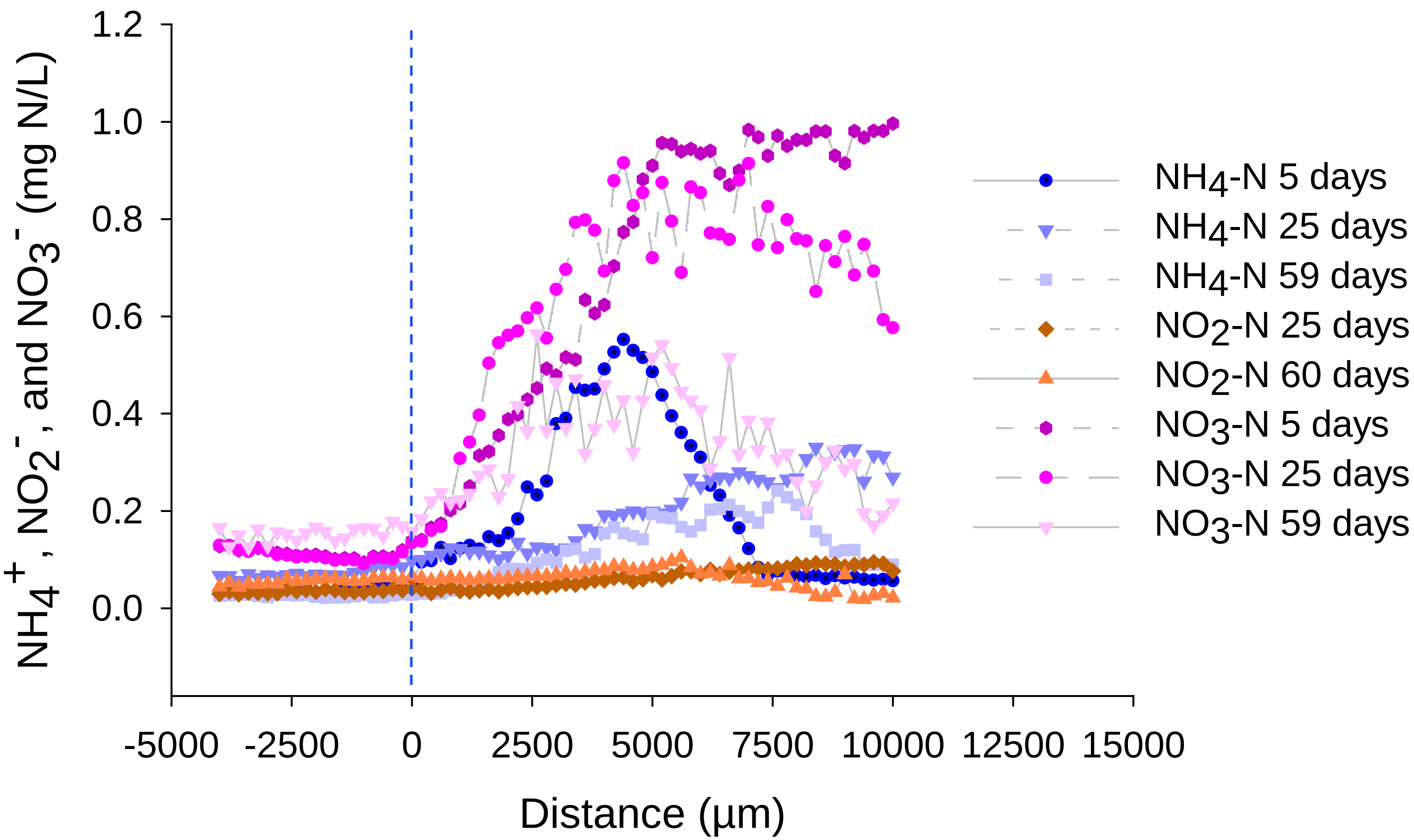

- **Free chlorine penetrated the sediment very slowly, resulting in minimal penetration within the 2-month free chlorine application period.**
- **Only a 0.2 mg/L free chlorine concentration penetrated to a 500 µm depth after one month, and it appears no further penetration occurred during the subsequent month.**

# Phase 2 Free Chlorine – Dissolved Oxygen Profiles



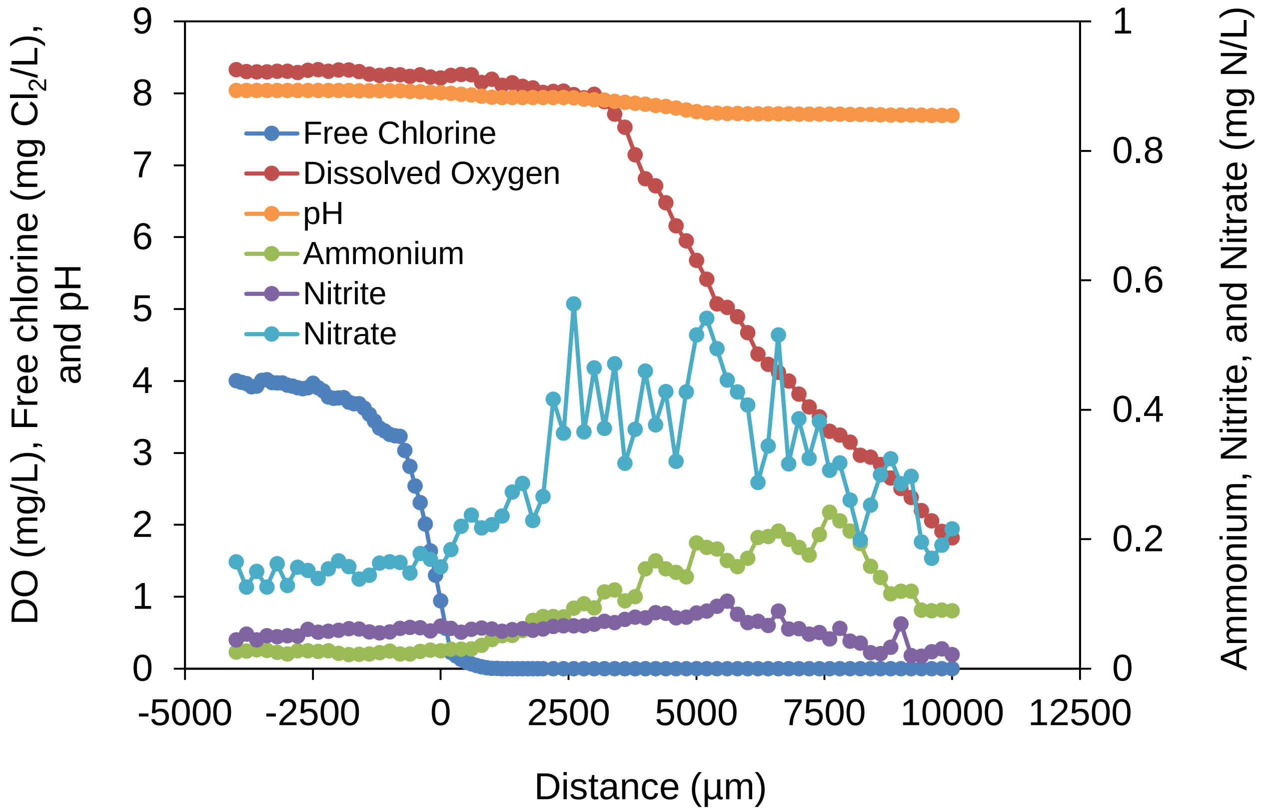

- **As compared to the 4 mg/L DO at a 5,000 µm depth after 120 days of monochloramine application, 4 mg/L of dissolved oxygen penetrated to a 6,800 µm depth after 62 days of free chlorine application.**
- **No DO was measurable at sediment depths greater than 13,500 µm.**

# Phase 2 Free Chlorine – Nitrogen Profiles




- **Ammonium and nitrate nitrogen continuously decreased over 60 days of free chlorine exposure.**

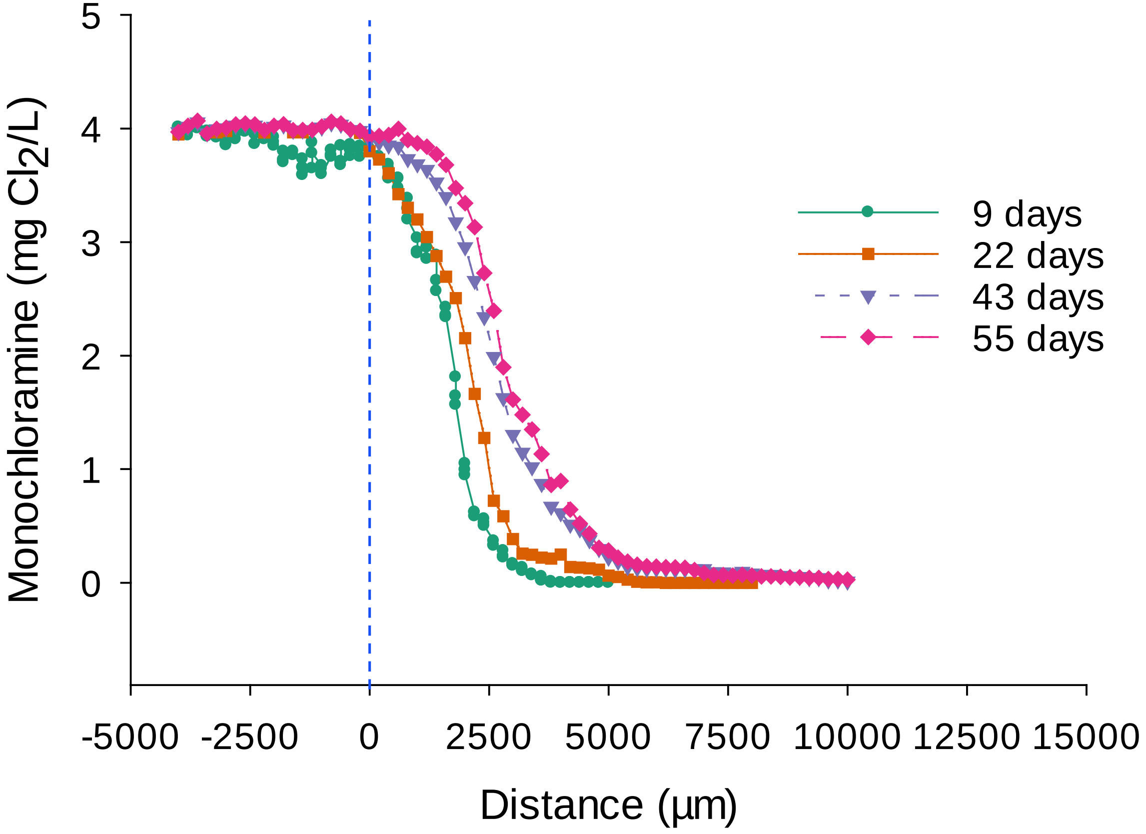
# Phase 2 Free Chlorine – Final Profile Summary




- **After a 2-month free chlorine application, both ammonium and nitrate decreased to some extent, but the DO consumption and the continued presence of ammonium and nitrate indicated that there was still microbial activity within the sediment.**

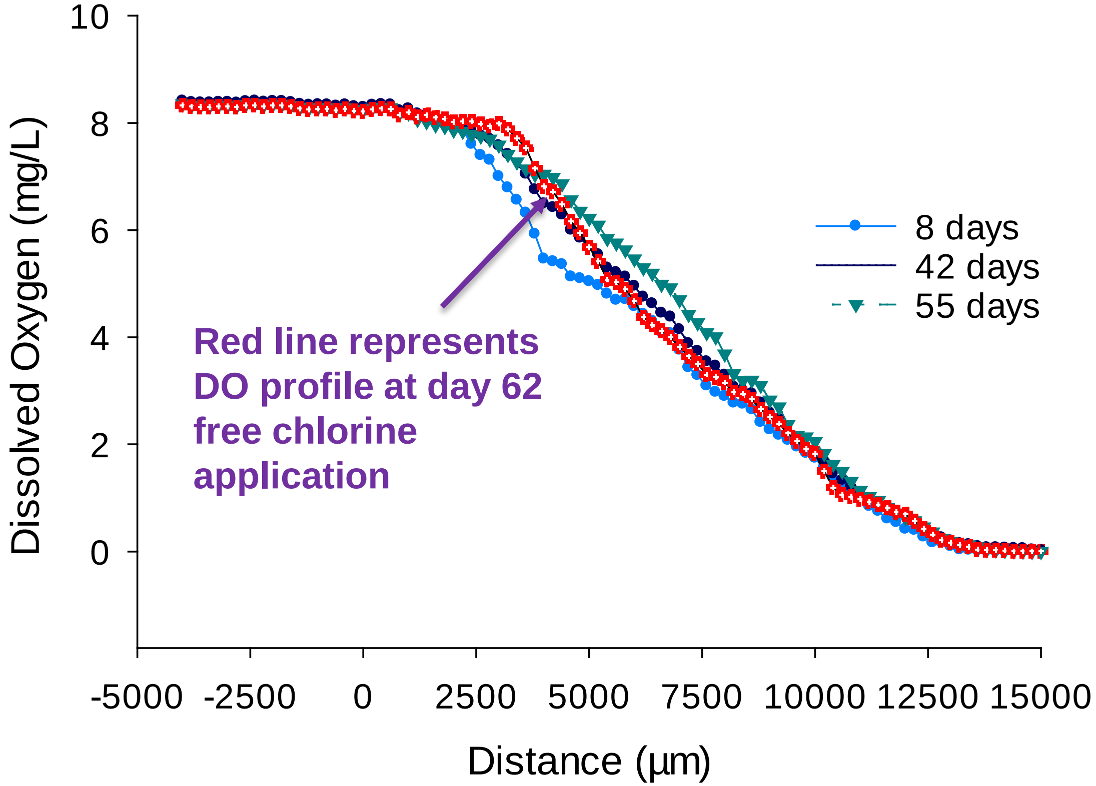
- **A decrease in pH from 8 to 7.7 was seen.**

# Phase 3 Monochloramine - Monochloramine Profiles



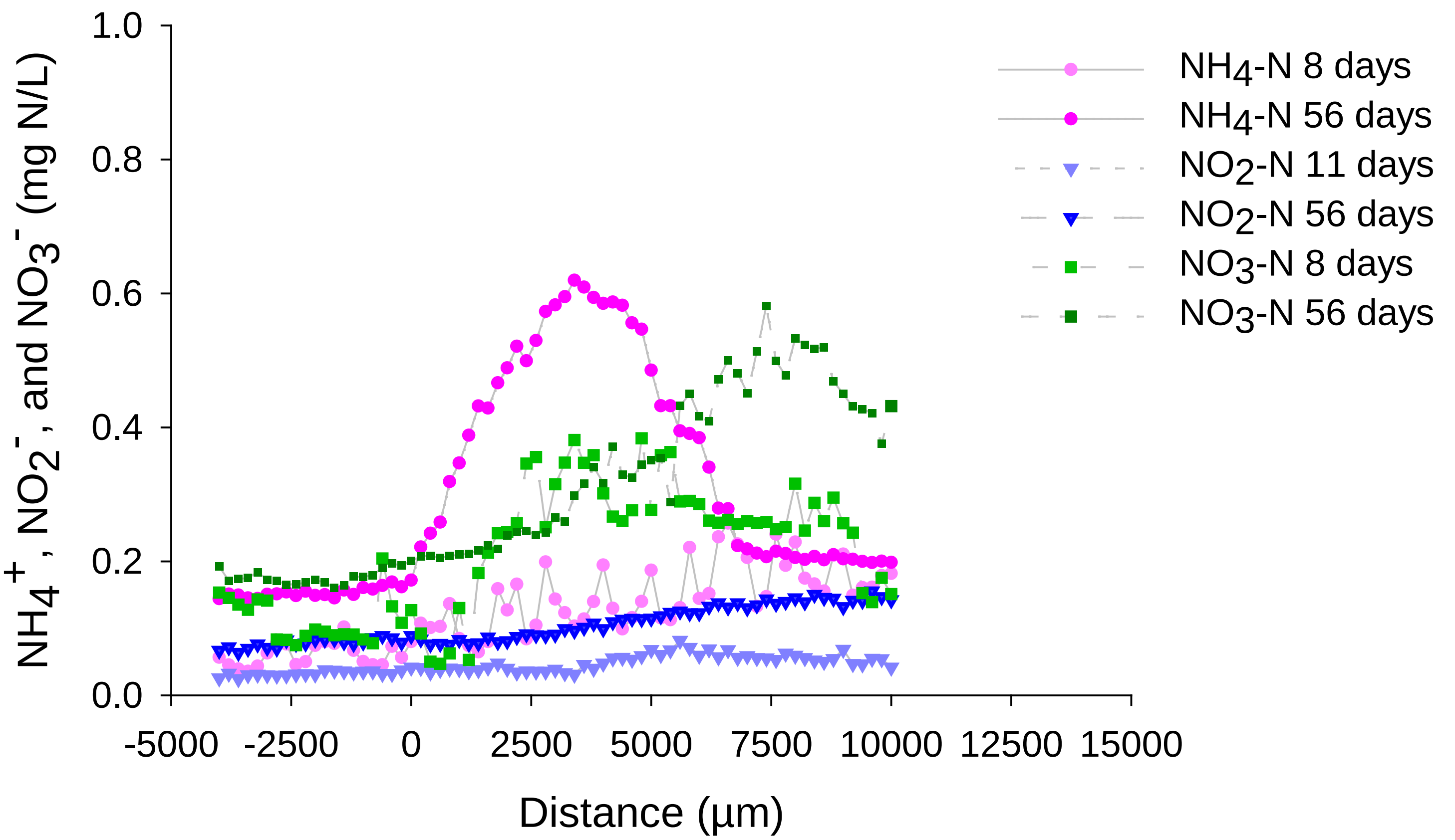

- **A 2 mg $Cl_2$/L monochloramine reached to a similar depth (2,800 µm) as in Phase 1 (3,200 µm).**
- **Monochloramine appears to penetrate further (7,500 µm) than was seen in Phase 1 (6,200 µm).**

# Phase 3 Monochloramine – Dissolved Oxygen Profiles



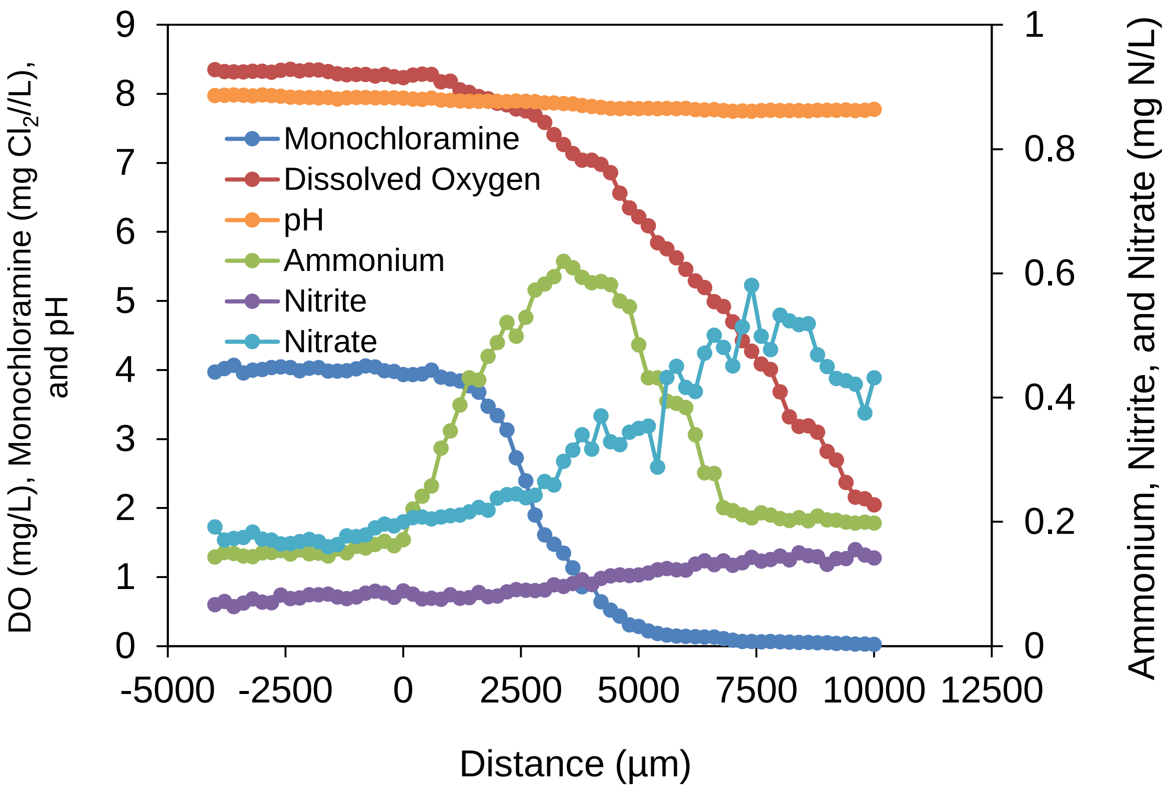

- Compared to the DO profile at the end of Phase 2, DO utilization increased within the first 30 days.
- After day 42, DO penetrated further.

# Phase 3 Monochloramine – Nitrogen Profiles




- **After day 56, 0.6 mg N/L of ammonium substrate accumulated in the sediment at 3,400 µm and then decreased with a concurrent increase of nitrate, implying complete nitrification had resumed.**

# Phase 3 Monochloramine – Final Profile Summary




- **Once switched back to monochloramine, ammonium substrate was brought into the sediment and nitrification resumed.**
- **The return to chloramination following a free chlorination period led to subsequent nitrification within a short period of time.**

# Conclusions

- Microelectrodes were a useful tool for determining chemical variability within a drinking water storage tank sediment.
- Even with extended periods where the maximum regulatory allowed chloramine residual was maintained in the bulk water, complete monochloramine penetration was not obtained into the sediment and biological activity remained.
- Free chlorine progressed inward into the sediment very slowly, resulting in minimal penetration within a 2-month free chlorine application period and microbial activity remained.
- Nitrification resumed upon a switch back to monochloramine.
- Findings support periodic cleaning of sediments from water storage tanks.

# Acknowledgements

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