EPA/600/R-01/021
March 2001

Laboratory Study on the Oxidation of Arsenic III to Arsenic V

by

Ganesh Ghurye
Dennis Clifford
University of Houston
Houston, TX 77204-4791

EPA Contract 8C-R311-NAEX

Project Officer

Thomas Sorg
Water Supply and Water Resources Division
National Risk Management Research Laboratory
Cincinnati, OH 46268

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Disclaimer

The information in this document has been funded by the United States Environmental Protection Agency (EPA) under Contract No. 8C-R311-NAEX to the Department of Civil and Environmental Engineering at the University of Houston. It has been subjected to the Agency's peer and administrative reviews and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

Foreword

The United States Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement action leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and groundwater; and prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by the EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

A one-year laboratory study was performed to determine the ability of seven oxidants to oxidize As(III) to As(V). These included chlorine, permanganate, ozone, chlorine dioxide, monochloramine, a solid-phase oxidizing media, and 254 nm ultraviolet light.

Chlorine and permanganate rapidly oxidized As(III) to As(V) in the pH range of 6.3 to 8.3. Dissolved manganese, dissolved iron, sulfide and TOC slowed the rate of oxidation slightly, but essentially complete oxidation was obtained in less than one minute with chlorine and permanganate under all conditions studied.

In the absence of interfering reductants, ozone rapidly oxidized As(III). Although, dissolved manganese and dissolved iron had no significant effect on As(III) oxidation, the presence of sulfide considerably slowed the oxidation reaction. The presence of TOC had a quenching effect on As(III) oxidation by ozone, producing incomplete oxidation at the higher TOC concentration studied.

Only limited As(III) oxidation was obtained using chlorine dioxide, which was probably due to the presence of chlorine (as a by-product) in the chlorine dioxide stock solutions. The reason for the ineffectiveness of chlorine dioxide was not studied.
Preformed monochloramine was ineffective for As(III) oxidation, whereas limited oxidation was obtained when monochloramine was formed in-situ. This showed that the injected chlorine probably reacted with As(III) before being quenched by ammonia to form monochloramine.

Filox, a manganese dioxide-based media, was effective for As(III) oxidation. When dissolved oxygen (DO) was not limiting, complete oxidation was observed under all conditions studied. However, when DO was reduced, incomplete oxidation was obtained in the presence of interfering reductants. The adverse effect of interfering reductants was completely eliminated by either (a) supplying enough DO or (b) increasing the contact time. In addition to oxidizing As(III), the Filox media also removed some arsenic by adsorption, which diminished greatly as the media came into equilibrium with the As(III)-spiked synthetic water.

UV light alone (254 nm) was not very effective for As(III) oxidation. Significant oxidation was observed only at very low flow rates representing 0.6 - 2.5% of the rated capacities of the two UV sterilizer units tested. However, as reported in a patented process, complete oxidation by UV light was observed when the challenge water was spiked with 1.0 mg/L sulfite.

Contents

Figures

Page

Tables

Abbreviations and Acronyms

AWWA	American Water Works Association
DO	Dissolved Oxygen, mg/L
DPD	N,N-diethyl-p-phenylenediamine
EBCT	Empty Bed Contact Time (media volume/flow rate), min
EPA	US Environmental Protection Agency
FIAS	Flow Injection Analysis Hydride Generation System
GFAAS	Graphite Furnace Atomic Absorption Spectrophotometer
GPM	Gallons/min
HDPE	High Density Polyethylene
IR	Interfering Reductant
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
NPT	Nominal Pipe Thread
NRMRL	National Risk Management Research Laboratory
PAO	Phenyl Arsenic Oxide
PRV	Pressure Relief Valve
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
SDWA	Safe Drinking Water Act
SM	Standard Methods
SR	Stoichiometric Ratio, µg oxidant/µg reductant
TOC	Total Organic Carbon
UH	University of Houston
UV	Ultraviolet
WAL	Work Assignment Leader
WAM	Work Assignment Manager

Acknowledgments

This research was funded by the US EPA under EPA Order Number 8C-R311-NAEX. The authors are grateful for the technical and administrative support of Tom Sorg, US EPA Research Engineer. Anthony Tripp, a doctoral candidate at the University of Houston is gratefully acknowledged for serving as the QA/QC Officer and for his considerable technical assistance throughout this study.