Fuel and Fuel System Microbiology—Fundamentals, Diagnosis, and Contamination Control

Frederick J. Passman, Editor

ASTM Manual Series: Mnl 47
ASTM Stock No: MNL47

ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428-2959

Printed in the U. S. A.
Library of Congress Cataloging-in-Publication Data

Fuel and fuel system microbiology, fundamentals, diagnosis, and contamination control / Frederick J. Passman, editor.
ASTM manual; 47 p. cm.
Includes bibliographical references and index.
ASTM Stock Number: MNL47
1. Fuels—Microbiology. I. Passman, Frederick J.

QR53.5.P48F84 2003
662'.6'01576—dc21
2003045100

Copyright © 2003 ASTM International, West Conshohocken, PA.
All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Photocopy Rights

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by ASTM International (ASTM) provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923; Tel: 978-750-8400; online: http://www.copyright.com/.

NOTE: This manual does not purport to address (all of) the safety problems associated with its use. It is the responsibility of the user of this manual to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Printed in Mayfield, PA
June 2003
Foreword

This publication, *Fuel and Fuel System Microbiology—Fundamentals, Diagnosis, and Contamination Control*, was sponsored by ASTM International Committee D02 on Petroleum Products and Lubricants. The editor was Frederick J. Passman.
Contents

Preface ix
by Frederick J. Passman

Chapter 1—Introduction to Fuel Microbiology 1
by Frederick J. Passman

Introduction 1

Biodeterioration 1

Microbiology Basics 1
Microbiology Defined 1
Bacteria 2
Fungi 3

Microbial Activities 3
Nutrient Metabolism 3
Metabolites 4

Factors Affecting Microbial Activity 4
Air 5
Water 5
Temperature 5
pH 6
Nutrient Availability 6
Osmotic Pressure 7
Salinity 7
Operational Factors 7

Fuel System Microbial Ecology 8
Communities and Consortia 8
Biomass and Biofilms 9
Community Impact 12

Conclusions 12

References 13

Chapter 2—Sampling Methods for Detecting Microbial Contamination in Fuel Tanks and Systems 14
by Graham Hill

Introduction 14

Factors Affecting the Distribution of Microbes within Fuel Tanks and Systems 14
CONTENTS

Existing Guidance on Sampling as Part of a Microbiological Examination 16

Developing Sampling Plans for Microbiological Investigation 16
   Investigation of Tanks and Fuel Systems 16
   Investigation of Fuel Quality 18

Sampling Procedures 19
   Preparations for Transport of Samples and Analysis 19
   Labeling and Chain of Custody 20
   Sample Bottles and Containers 20
   Sampling Devices 20
   Sampling Cocks and Drains 20
   Taking Samples 22

Summary 22

References 22

Chapter 3—Remediation Techniques 24
   by Howard L. Chesneau

Introduction 24

Fuel Polishing 24
   Media Selection 25
   Filtration Strategies 25

Tank Cleaning 26
   Cleaning Process—General Principles 27
   Cleaning Process—Large Tanks (Entry Required) 27
   Cleaning Process—Small Tanks (Entry Not Required) 29

Antimicrobial Pesticides 29

Contamination Control Strategies 30
   Corrective Maintenance 30
   Preventive Maintenance (PM) 31
   Predictive Maintenance (PDM) 31

References 31

Standards

D 888-92R96 Standard Test Methods for Dissolved Oxygen in Water 32
D 1067-02 Standard Test Method for Acidity or Alkalinity of Water 40
D 1126-96 Standard Test Method for Hardness in Water 48
D 1293-99 Standard Test Methods for pH of Water 52
D 1426-98 Standard Test Methods for Ammonia Nitrogen in Water 61
D 4012-81R02 Standard Test Method for Adenosine Triphosphate (ATP) Content of Microorganisms in Water 74
D 4412-84R02 Standard Test Methods for Sulfate-Reducing Bacteria in Water and Water-Formed Deposits 78
D 6469-99 Standard Guide for Microbial Contamination in Fuels and Fuel Systems 81
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>vii</th>
</tr>
</thead>
<tbody>
<tr>
<td>E 1326-98 Standard Guide for Evaluating Nonconventional Microbiological Tests Used for Enumerating Bacteria</td>
<td>95</td>
</tr>
<tr>
<td>IP 385-99 Determination of the Viable Aerobic Microbial Content of Fuels and Fuel Components Boiling Below 390 °C—Filtration and Culture Method</td>
<td>98</td>
</tr>
<tr>
<td>IP 472-02 Determination of Fungal Fragment Content of Fuels Boiling Below 390 °C</td>
<td>105</td>
</tr>
<tr>
<td>Glossary</td>
<td>108</td>
</tr>
<tr>
<td>by Frederick J. Passman</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>111</td>
</tr>
</tbody>
</table>
Preface

Frederick J. Passman, Ph.D¹

The Manual on Fuel and Fuel System Microbiology—Fundamentals, Diagnosis, and Contamination Control augments Standard Guide D 6469². It is addressed to all liquid fuel production, transportation, and consumption stakeholders. The target audience includes management, supervisory, operational, quality assurance, maintenance, inspection, and technical personnel responsible for fuel quality, fuel handling equipment integrity, or both. The material presented in this Manual is equally applicable for gasoline, diesel (including biodiesel), aviation turbine, marine, industrial gas turbine, kerosene, gasoline, and aviation gasoline fuels. Much of the information is also applicable to other fuel grades ranging from bunker to natural gas.

This manual seeks to complement the Guide D 6469 in each of four areas. Chapter 1 provides an overview of the microbiological principles underlying fuel and fuel system biodeterioration. The information contained in this chapter will enable the reader to better understand why recognizing biodeterioration is difficult yet essential.

Sampling for microbial contamination detection presents unique challenges. Both the non-homogeneous distribution of microbes and the fact that they are living beings necessitate special handling, not discussed in Standard Practice D 4057 Manual Sampling of Petroleum and Petroleum Products³. Consequently, Chapter 2 provides the detailed information personnel need to collect and handle samples intended for biodeterioration diagnosis.

Chapter 3 provides specific, practical recommendations for disinfecting and removing microbial contamination from fuels and fuel systems.

As noted earlier, D 6469 recommends a variety of diagnostic tests, many of which do not appear in the Annual Book of Standards, Volume 5. Since quite a few of the tests examine bottom water properties, they aren’t run at fuel labs routinely. Nearly all of the methods that aren’t drawn from Volume 5 come from the Annual Book of Standards, Volumes 10, 11, or 14. By incorporating the Standards from these three volumes into this Manual, it was our intention to improve test method accessibility, which would expand the diagnostic capabilities of fuel quality labs.

Our objective in developing the Manual on Fuel and Fuel System Microbiology—Fundamentals, Diagnosis, and Contamination Control was to provide a broad range of stakeholders with a readable, accessible insight into the nature of fuel and fuel system biodeterioration, sampling requirements, test methods, and remediation practices.

As the Editor of this Manual and Chair of the D.02.14 Task Force on Microbial Contamination, I thank those ASTM International colleagues who have been indispensably helpful in the development of both D 6469 and this document. Harry Giles and Erna Beal, Chair and Secretary of D.02.E.05 and D.02.14 have been remarkably supportive since my friend and colleague Howard Chesneau first proposed inclusion of microbial contamination in each of the product standards under the cognizance of Subcommittees D.02.A, E, and J. I offer my sincerest thanks also to Howard Chesneau, Andy Pickard, and John Bacha, who each contributed tremendously to the development of the Guide and the Manual. Sadly, John Bacha’s untimely death in August, 2001 prevented him from seeing the publication of this manual. I dedicate this manual to him

¹President, Biodeterioration Control Associates, Inc., PO Box 3659, Princeton, NJ 08543-3659.
²Annual Book of ASTM Standards, Vol. 05.04.
³Annual Book of ASTM Standards, Vol 05.02.
in appreciation for his contributions and many years of dedication and commitment to fuel quality science.

Finally, without the guidance and support of ASTM Staff Members Kathy Dernoga, Monica Siperko, and Holly Stupak, the Manual would never have been created. Thank you all.

Fredrick J. Passman
Princeton, New Jersey, USA