Microbial Contamination of Fuel Systems - Prevention, Monitoring and Control

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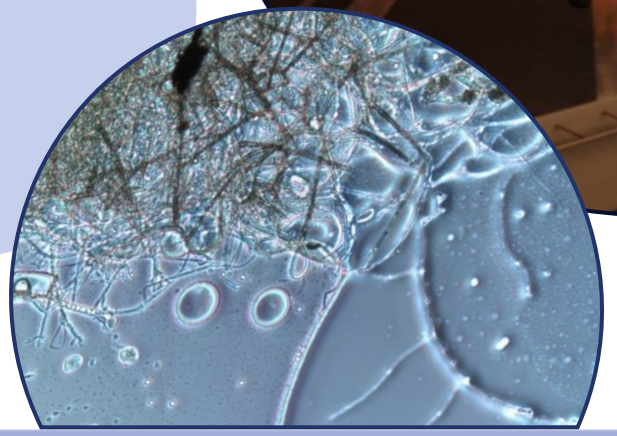


DLA Energy Worldwide

April 21-23, 2026
Arlington, Virginia

Who Are We And What Do We Do?

- ECHA MICROBIOLOGY have globally recognised expertise in the investigation, treatment and prevention of microbiological spoilage and corrosion
- Serve the Energy, Aviation, Marine & Engineering Industries

- Founded in 1983 as a spin off from Cardiff University
- Headquartered in Cardiff, Wales, UK
- Supply over 100 Countries
- Active involvement in developing industry best practice (IATA, ASTM, EI, JIG)

LABORATORY ANALYSIS & RESEARCH

CONSULTANCY SERVICES

MICROBIOLOGICAL TEST KITS

TRAINING COURSES

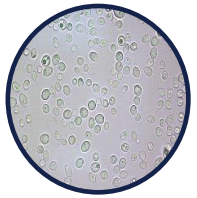
SITE SURVEYS

Microbial growth (MBG) can occur wherever water is found in fuel systems

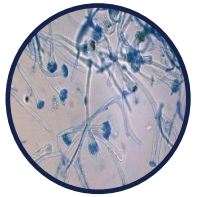
FOOD;
- Fuel
- Additives
- Dirt & contaminants

MICROBES

Bacteria



Yeast



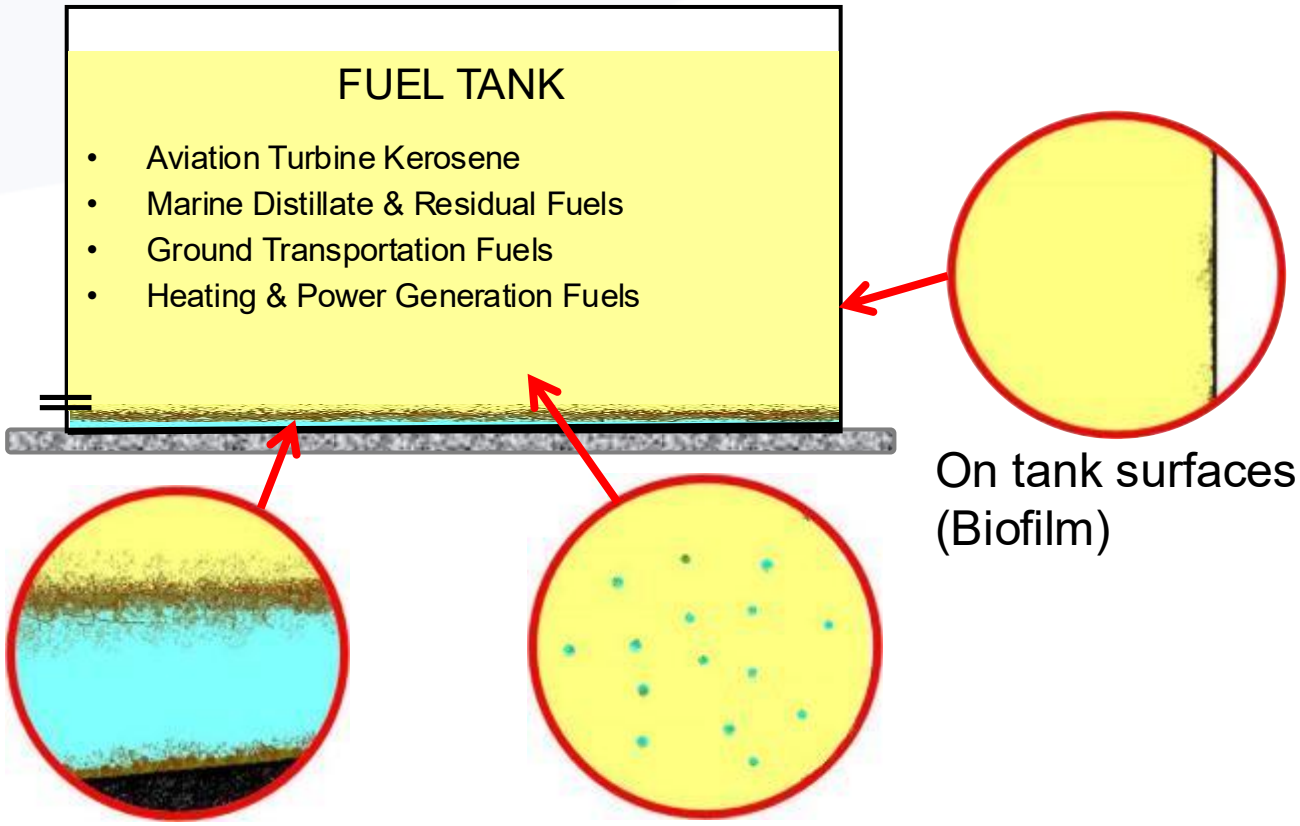
Mould

FUNGI

WATER

ENVIRONMENT;
- Temperature
- pH
- Water Activity / Salinity
- Oxygen availability
- Other electron acceptors
- Other electron donors

Microbial growth (MBG) can occur wherever water is found in fuel systems

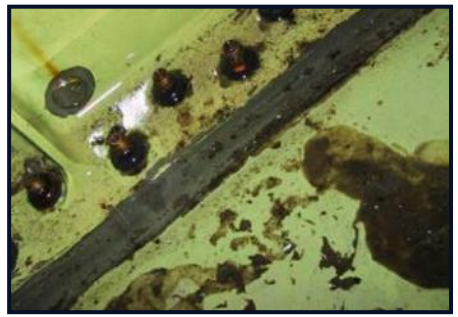


On tank surfaces (Biofilm)

On the tank bottom

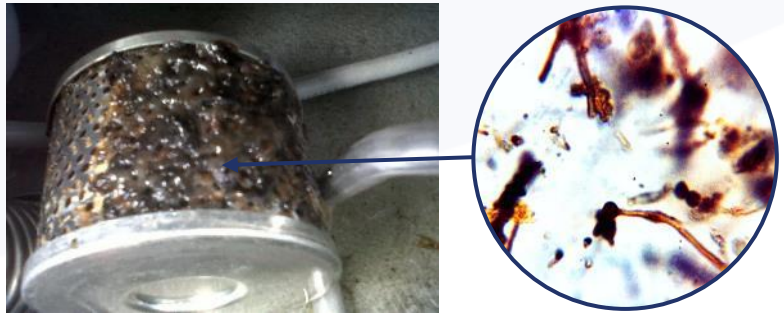
As droplets suspended in fuel

Aircraft fuel tanks

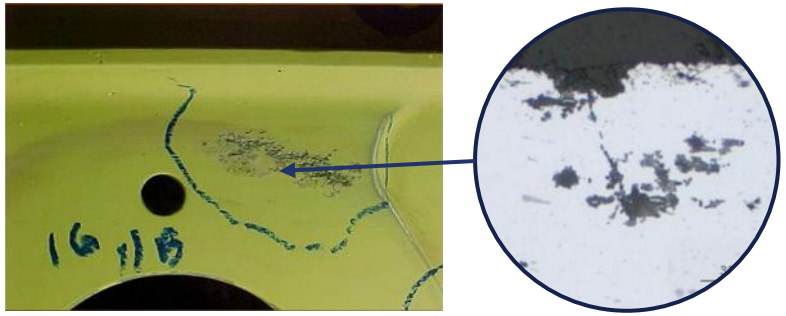


Ship's tanks

Fuel User Problems



Fuel Filter Clogging

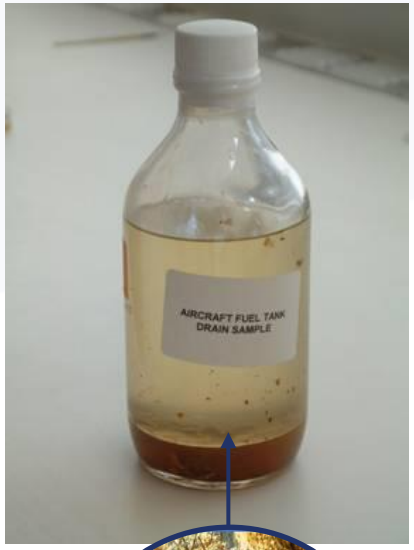


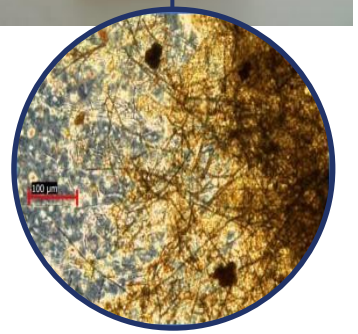
Corrosion of Aircraft Fuel Tank

Operational problems:

- Filter clogging and by-pass.
- Fuel starvation & power loss.
- FQIS malfunction - Erratic or erroneous fuel quantity indication.
- Severe rapid corrosion (MIC).

Fuel Supply & Distribution Problems





Microbial biomass in jet fuel

Emulsification at fuel water interface - Microscopic water droplets become suspended in fuel

Black/grey discolouration of water and fuel in tank bottoms due to sulphide generation by Sulphate Reducing Bacteria (SRB)

Operational problems:

- Off spec fuel due to:
  - Microbial biomass (particulate),
  - Bio-surfactants,
  - Sulphide.
- Biomass & biofilm (sludge) in storage tanks.
- Filter Water Separator disarming.
- Storage tank & pipeline corrosion.

Fuel Supply & Distribution Problems

Microbial biofilm in jet fuel storage tank

Operational problems:

- Off spec fuel due to:
  - Microbial biomass (particulate),
  - Bio-surfactants,
  - Sulphide.
- Biomass & biofilm (sludge) in storage tanks.
- Filter Water Separator disarming.
- Storage tank & pipeline corrosion.

Fuel Supply & Distribution Problems

Leopard spotting / fungal growth on Filter Water Separator elements (EI 1581)

Active microbial growth is not common on other types of aviation fuel filter, but they can be pre-maturely clogged by microbial particulates from contaminated fuel (e.g. microfilters (EI 1590), dirt defence filters (EI 1590), water barrier filters (EI 1588)

Operational problems:

- Off spec fuel due to:
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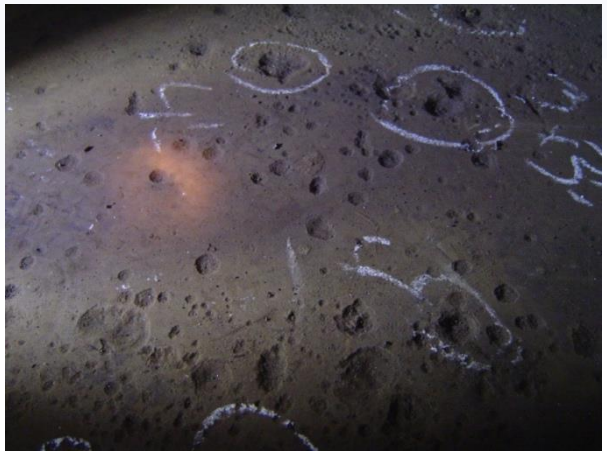
Fuel Supply & Distribution Problems



SRB pitting corrosion of tank floor

SRB pitting corrosion of pipeline flange end

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  - Sulphide.
- Biomass & biofilm (sludge) in storage tanks.
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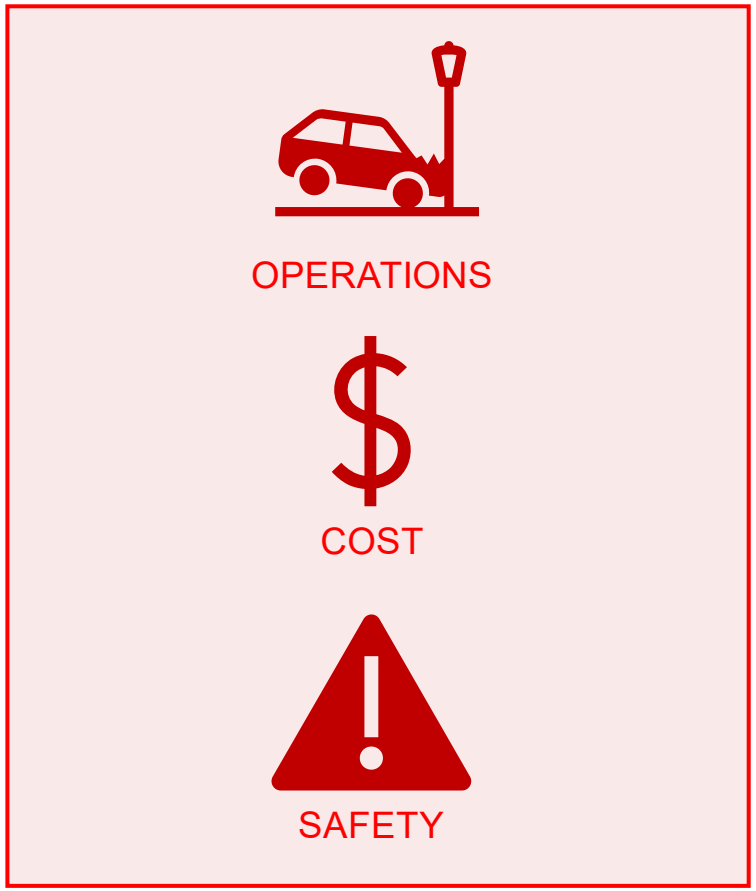
Impacts of Microbial Growth in Fuel Tanks & Systems

- Fuel supply failures
- Infrastructure integrity compromised
- Aborted flights
- Delayed asset deployment
- Unscheduled down time
- High cost for remediation
- Operational Safety



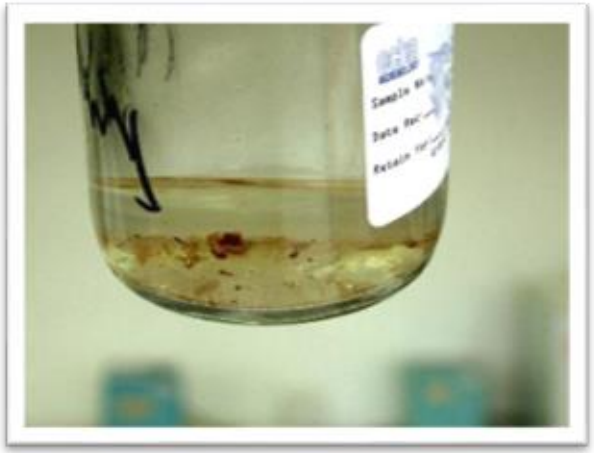
Control of Microbial Growth

PREVENT

Keep it clean (as far as practicable!)
Prevent ingress and accumulation of free water

MONITOR

Test at routine intervals to identify risk before it becomes a problem

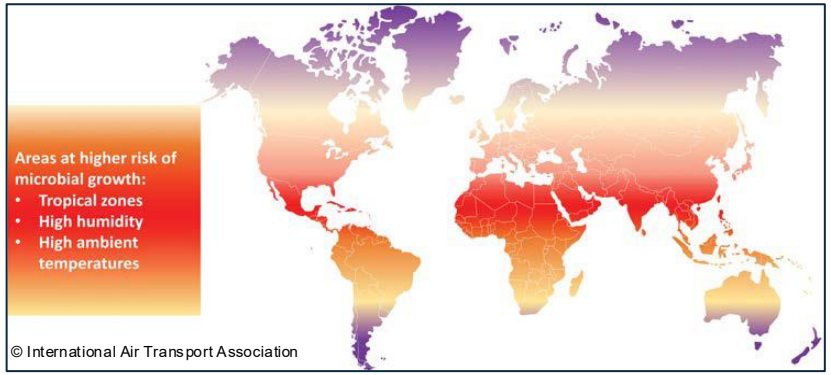


REMEDIATE

When monitoring indicates control is lost, or if problems are experienced

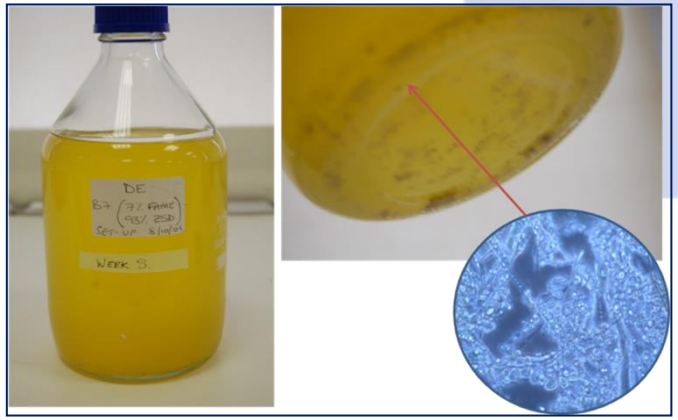
Prevention of MBG – Operational Risk

- Is there a risk of water ingress and accumulation?
  - Consider in-house QA / husbandry procedures, system design & condition.
  - Only very little water is needed for microbial growth; if you were a microbe, a 1 mm water film would look like a 300 m deep lake!
- Are environmental factors conducive to microbial growth?
  - Microbes prefer warm, humid conditions; 20 – 35°C (68 - 95°F).
  - Specialist microbes grow outside this temperature range.
  - Temperature fluctuations promote water condensation.
- Is fuel supplied always of good quality?
  - Consider supply QA procedures & infrastructure.
  - Don’t assume that if supply is good there is no MBG risk!
- Is fuel particularly susceptible to MBG?
  - FAME stimulates MBG.
  - Fuel System Icing Inhibitor (FSII) inhibits MBG.



Susceptibility of Biofuels (FAME) to MBG

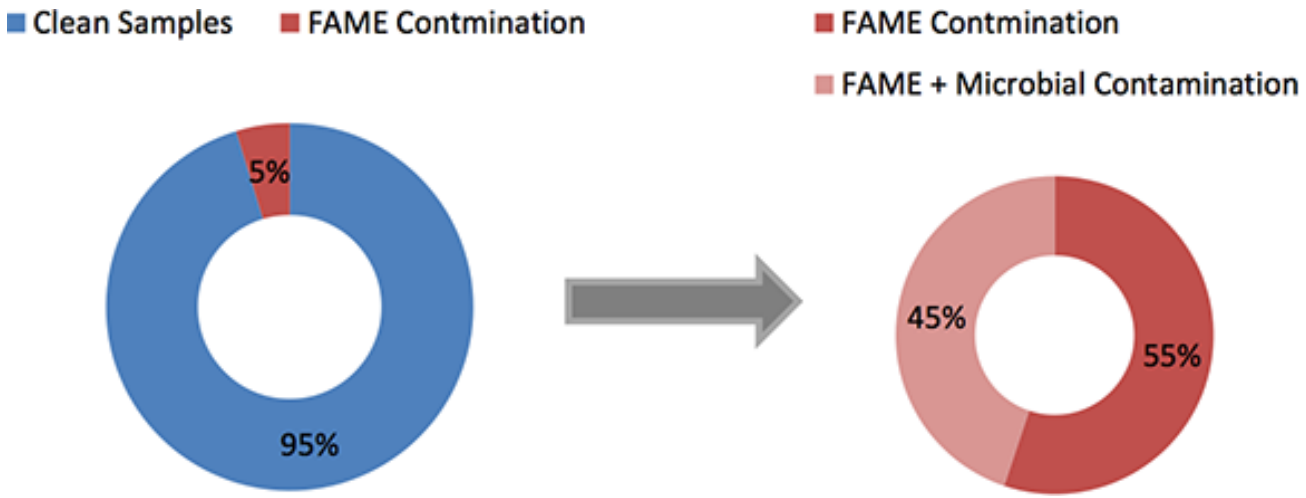
- Biodiesels containing, Fatty Acid Methyl Esters (FAME) are very susceptible to MBG.
  - rapidly degraded by microbes,
  - poor water separation.
- EI Study[1] indicated blends of 2 – 20% FAME are most susceptible in practice.
- Significant upsurge in operational problems for supply chain and end-users when road transport biodiesels first introduced.



1. EI Research Report: *Investigation of microbiological susceptibility of biodiesel and biodiesel blends*, EI 3241, Energy Institute, London, 2014

Susceptibility of Biofuels (FAME) to MBG

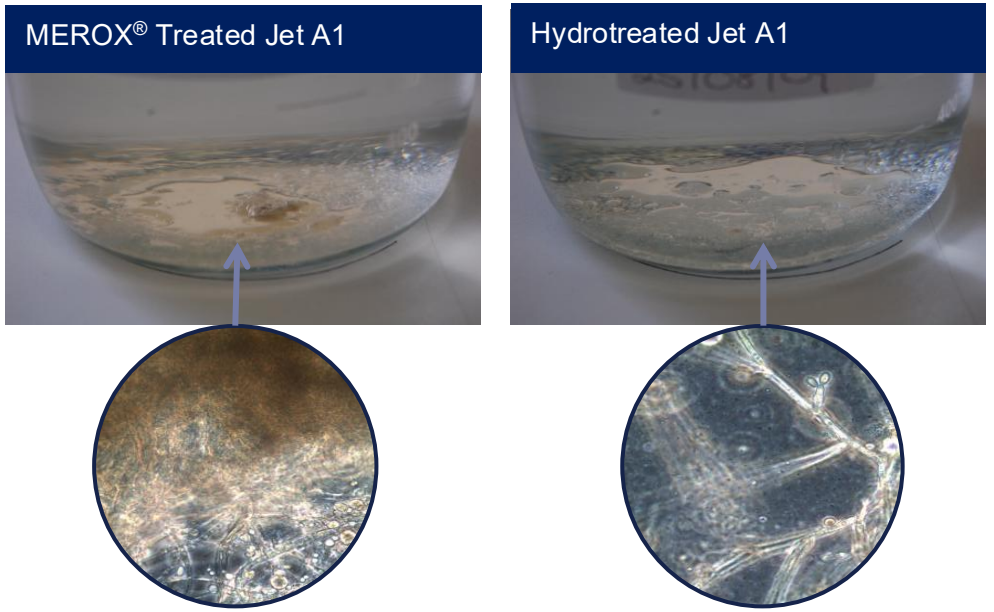
- A 2014 survey[2] of 2346 marine distillate bunker samples marine fuels derived from a wide range of ports, suppliers & barges found;
  - 5% of samples showed >0.5% FAME (even though nominally FAME was not permitted in specification at the time!).
  - 45% of samples showing FAME contamination showed significant levels of microbial contamination.
  - Levels of microbial contamination were higher in samples with FAME contamination.
- The study highlights implications for handling & storage of FAME containing fuel on-board.
- Quality challenges for defence fuel supply when purchasing commercial grades on the spot market.



2. A Global Survey of the Incidence of FAME and Microbial Contamination in Marine Distillate Fuels, Hill et al. (ECHA Microbiology, Guardian Marine Testing, Lloyd's FOBAS), IASH, 2015.

Susceptibility of Semi-Synthetic & Synthetic Blend Components to MBG

- Conventional jet fuels can show considerable variability in susceptibility to MBG;
  - e.g. hydrotreated fuels generally less susceptible than MEROX® treated fuel[1].
- Susceptibility of synthetic blend components (SBC) and semi-synthetic fuel blends is still not fully understood.



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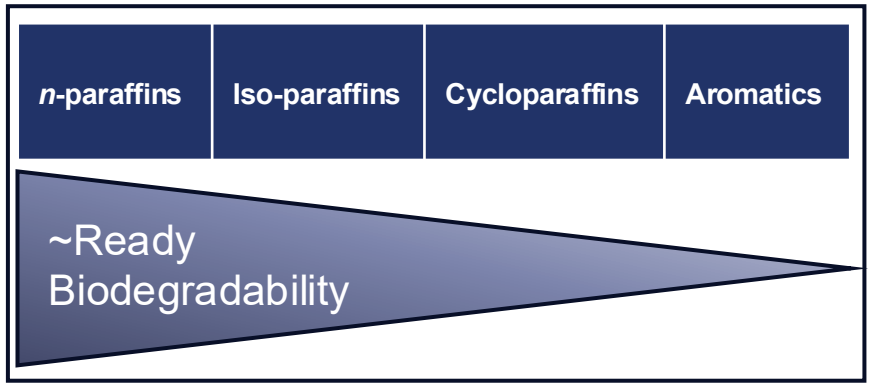
Susceptibility of Semi-Synthetic & Synthetic Blend Components to MBG

- Energy Institute 2024 study[3] considered;
  - existing microbiological research,
  - comparative data on synthetic & conventional jet fuel properties,
  - field test data.
- Chemical and physical properties of SBCs and semi-synthetic jet fuels suggest they are generally unlikely to impart significantly greater susceptibility to MBG than conventional fuels.
- Of the 8 currently approved pathways, FT-SPKs will probably be the most susceptible SBCs due to high proportion of *n*-paraffins.
- HEFA-SPK and others probably either similar or less susceptible.
- SBCs generally showed similar or lower susceptibility to MBG in laboratory studies. Some evidence that iso-paraffinic SBCs are less susceptible than those containing *n*-paraffins.
- Further research on-going.



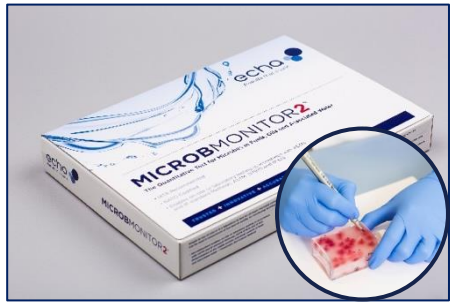
3. EI Research Report: *Assessment of the susceptibility of sustainable aviation fuel (SAF) to microbial spoilage (Phase 1 of 2)*, Project T2303, Energy Institute, London, (in press).

Prevention of MBG – Keep it Clean & Dry

- Implement appropriate routine prevention procedures at a frequency dependent on risk.
  - Water draining,
  - Product settling after receipts
  - Filtration
- From Refinery to End user….
  - KEEP IT CLEAN!
  - KEEP IT DRY!

Monitoring for MBG

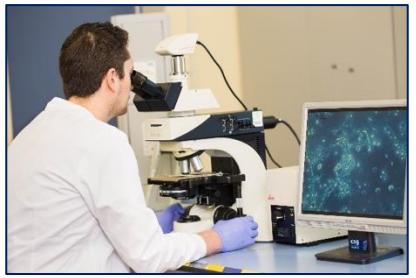
- Monitor for microbial growth if operational risk is significant.
- Visual inspection of tank drain samples and coalescer filters is a simple key indicator!
- Perform a MBG test on tank low point samples at a frequency based on risk.
- Use an appropriate test method properly validated for fuels testing.
  - CRC-AV-31-22 Microbial Test Kit Evaluation[4] (https://crcao.org/crc-project-no-av-31-22/)
- On-site testing:
  - Enables a good assessment and avoids errors and delays due to transit of samples, e.g.:
    - CFU tests – MicrobMonitor2 (IP 613/ ASTM D7978) / MicrobMonitor GMF
    - ATP tests – HY-LiTE Jet A1 (ASTM D7463)
  - Tests specific for problem causing microbes (e.g. SRB) can also be used e.g.:
    - Sig Sulphide SM

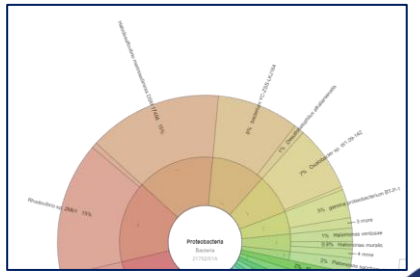


3. CRC Research Report CRC-AV31-22 *Microbial Test Kit Evaluation*. Coordinating Research Council, Atlanta, January 2026

Monitoring for MBG

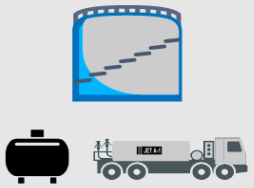
- **Laboratory testing:**
  - Enables more comprehensive diagnostic assessment:
    - Incident investigation, tracing contamination sources, risk assessment.
  - Light & electron microscopy can be important in assessing characteristics and relative extent of contamination.
  - Molecular Microbiological Methods (MMM) (e.g. qPCR and Next Generation Sequencing) are increasingly being developed and adopted for fuel and oil testing.
  - What is REALLY there?
    - MMM can provide a better understanding of the fuel / oil system microbiome.
  - What is REALLY happening?
    - Metagenomics, transcriptomics, epigenetics enable insight into metabolic processes, community interactions, identifying key microbial risks and highlight possible control mechanisms (e.g. prevent biofilm formation at fuel:water interface).
  - What is REALLY causing a problem?
    - MMM can look for key biomarkers linked to specific issues (biofilm formation, corrosion).
  - MMM are not quite field ready yet - with further development and simplification, they could be used as routine on-site monitoring tools.





Monitoring for MBG

JIG Guidance for Monitoring MBG of Aviation Fuel Facilities

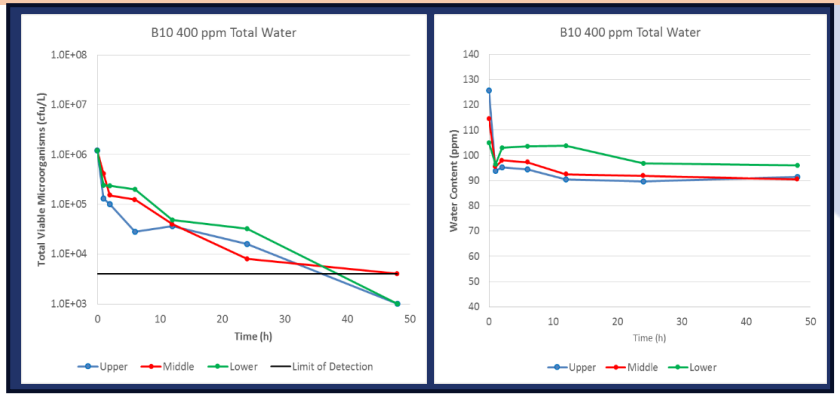
ITEM 	SAMPLING LOCATION 	SAMPLING FREQUENCY 		
		HIGH RISK FACILITY (>1 Action level microbe event in previous 2 years)	MODERATE RISK FACILITY (Single Action level microbe detected in previous 2 years, or cause - see above)	LOW RISK FACILITY
Fixed Storage tanks	Storage tank sump drain line or dead bottom sample	Monthly	Quarterly to 6-monthly adiviseable	ANNUAL monitoring after initial (at least) quarterly screening for 1 year to determine background contamination levels
Product Recovery tanks	Storage Tank sump drain line or dead bottom sample	Monthly	Quarterly	QUARTERLY where visual inspection is not possible
Defuelling Vehicle	Vehicle Tank sump drain line	Monthly	Quarterly	6-MONTHLY for vehicle routinely used for defuelling in the absence of cause

Source: JIG TID#1 – Microbial Monitoring Strategies (© Joint Inspection Group 2023)

Remediation of MBG

Options include;

- Settling of tank contents, then separating off water bottoms / contaminated product,
- Tank & system cleaning,
- Biocidal wash / flushing,
- Fuel biocide treatment,
- Filtration,
- Centrifugation / purifiers,
- Heat treatment,
- Changing the environment (e.g. water activity, salinity, nutrient levels, pH).



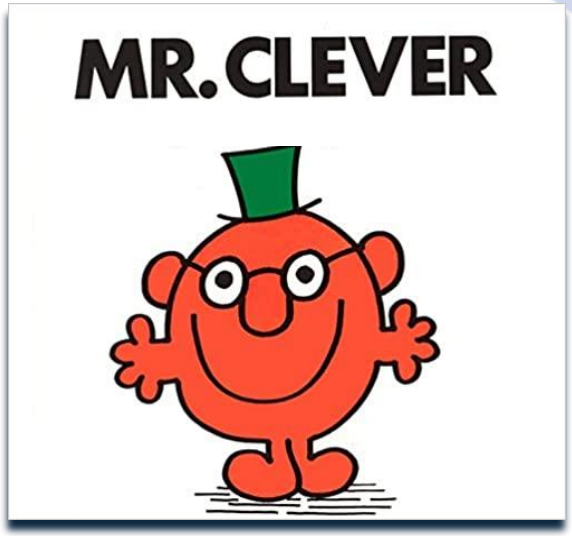
Remediation of MBG

Fuel Biocides;

- Biocides are traditionally seen as the most effective way to prevent and treat fuel and oil systems.
- Generally, more effective than “physical” treatment methods.
- Can be added directly to fuel for long lasting protection.
- Biocide use may be restricted by:
  - Approvals – currently only Biobor JF has widespread OEM approval for Aviation Fuel and only at point of uplift to aircraft,
  - Regulation – some approved in USA but not Europe and *vice versa,*
  - Compatibility with fuel and system components,
  - Health & safety issues,
  - Environmental impact.
- Increasingly stringent regulation of biocides has resulted in;
  - Reduced availability of existing anti-microbial chemicals,
  - Tighter controls over biocide use,
  - Higher costs and barriers for developing new anti-microbial actives.
- Underdosing of biocides can lead to microbes adapting and becoming tolerant or resistant to them.
- Overdosing of biocides can lead to serious engine failures!!!!

We need to get clever……..

- With fewer prevention and treatment options moving forward, we should focus on;
  - Good system design,
  - Understanding how operational parameters can minimise microbiological risks,
  - Effective maintenance,
  - Routine monitoring.
- Optimise use of existing anti-microbial chemistries,
- Consider specific inhibition targets rather than generic biocides,
- Non-biocidal approaches (filtration, water activity etc.),
- Optimise new testing technologies for intelligent risk assessment,
- Learn the lessons of the past.



THANK YOU !

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