

WHITE PAPER:

Protecting Equipment from Microbial Contamination when changing Fuel Chemistry

Increases in bio-content in fuels have the potential to increase Microbial Growth (MBG) in fuel systems. This paper discusses the reasons why and equipment protection via fuel testing.

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Background

The various transport sectors (aviation, ground and marine) are being challenged to produce “green” fuels in order to reduce greenhouse gas emissions. In the full cycle of greenhouse gas emissions, 74% comes from end user combustion. So how can fuel chemistry contribute in minimizing climate change without impacting equipment negatively?

Most petroleum products such as aviation fuels, diesel and marine fuels are manufactured using product specifications detailing particular characteristics. These product specifications detail the physico-chemical properties of the various fuels and are used to control its quality throughout the fuel supply chain. Traditionally, product specifications such as ASTM D1655[1] for aviation fuel, EN 590[2] or ASTM D975[3] for diesel fuel and ISO 8217[4] for marine fuels were developed to describe fossil-fuel based finished product. These product specifications are currently being changed to accommodate the use of renewable fuel components i.e. biofuels.

[1] ASTM D1655 - Standard Specification for Aviation Turbine Fuels
[2] EN 590 - Standard for Diesel Fuel
[3] ASTM D975 - Standard Specification for Diesel Fuel
[4] ISO 8217 - Petroleum products - Fuels (class F) - Specifications of marine fuels

Change in Fuel Chemistry

In order to contribute to the global reduction of gas emissions, a great effort over the last two decades have been placed in changing the chemistry of fuels. It is proven via recognized life cycle impact assessment models that the production and use of biofuels do contribute positively to various “clean air acts and emission regulations”.

To accomplish such objective, the main changes seen so far in this industry is the substitution of fossil fuel and crude oil with various biomass materials and transformation processes. As an example, the aviation sector has recognized and approved several biomass transformation pathways to produce sustainable aviation fuel via the ASTM D7566[5] product specification that can be used as a substitute to ASTM D1655 jet fuel. Products meeting ASTM D7566 specification are considered drop-in replacement for commercial Jet A/A-1 fuels.

Similarly, the EN590 and ASTM D975 diesel standards for diesel fuel are being met by the production of renewable fuels using new refining processes such as the Hydro processing of Vegetable Oils (HVO) known as “Green Diesel” along with the co-processing of waste product (oils, plastics) and other raw material to substitute conventional crude oil.

The ultimate objective is to produce a finished product that have equivalent characteristics, properties such energy content and ultimately equivalent or superior performance than conventional diesel fuel.

However, some of these renewable fuels such as conventional biodiesel product meeting EN 14214[6] and ASTM D6571[7] product specifications have different chemistry and properties. Despite these, they are widely used as a blend with conventional diesel fuel or as pure product (B100).

With recent stringent environmental regulations, we foresee a greater use of these materials in the years to come. They will be more prevalent in the fuel supply distribution support as substitute for both diesel fuel and marine fuel-grades.

As for any change in life, it comes with pros and cons. As stated earlier, the chemistry of some these new bio-components has different characteristics and can react differently in presence of environmental element such as water. Biodiesel molecules are more polar, hence have greater affinity with water rendering the fuel more susceptible to water retention.

[5] ASTM D7566 - Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
[6] EN 14214 - Liquid petroleum products - Fatty acid methyl esters (FAME) for use in diesel engines and heating applications - Requirements and test methods
[7] ASTM D6571 - Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels

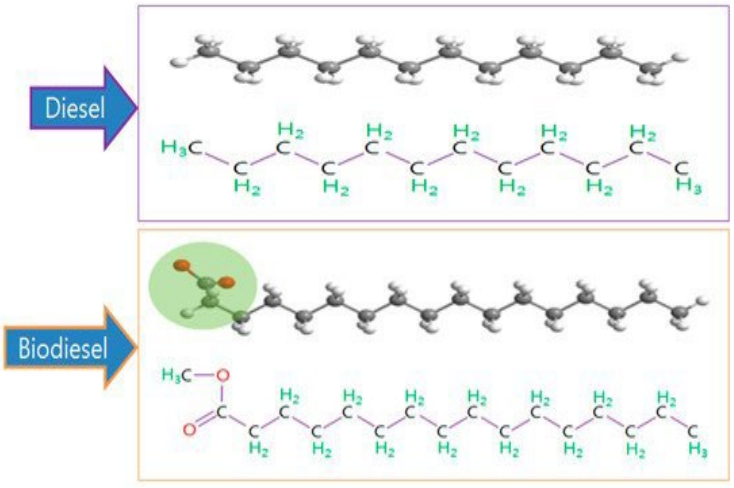
The nature of its chemistry can provide a challenge in keeping emulsified water at bay. The picture below shows clean diesel fuel with and without free and emulsified water.



Studies have shown that diesel fuels containing biodiesel content may be more susceptible to premature degradation when not properly maintained due to the chemical properties of biodiesel.

We know from the research paper "Moisture Absorption in Biodiesel and its Petro-Diesel Blends[8]" that 100% biodiesel fuel can hold 15 to 25 times more water compared to 100% diesel fuel. It also states that the biodiesel hits saturation quickly. This is because both water and biodiesel molecules are polar, so the water molecules are attracted to, and bond quickly to, the biodiesel molecules.

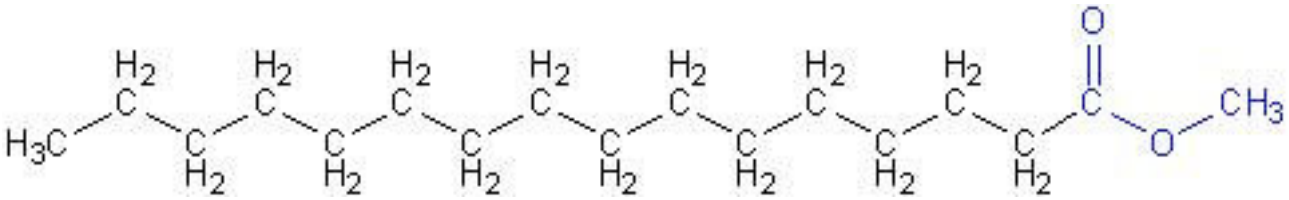
The actual bonding mechanism of water to biodiesel is through a hydrogen bond. While weaker than a covalent or ionic bond, it still attaches multiple water molecules to a biodiesel molecule. The hydrogen atoms (positive charge) in the biodiesel bonds to the oxygen atom of water (negative charge). As seen in the biodiesel molecule pictured below, there are many hydrogen attachment points. This is why pure biodiesel can hold 15 to 25 times more water than pure diesel. In addition, additional water molecules continue to bond to the already attached water molecules, so the number of water molecules attached to the biodiesel will continue to grow.



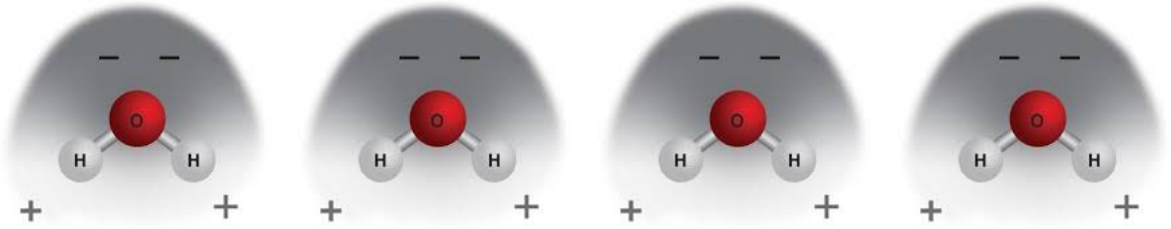
[8] Moisture Absorption in Biodiesel and its Petro-Diesel Blends - Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org

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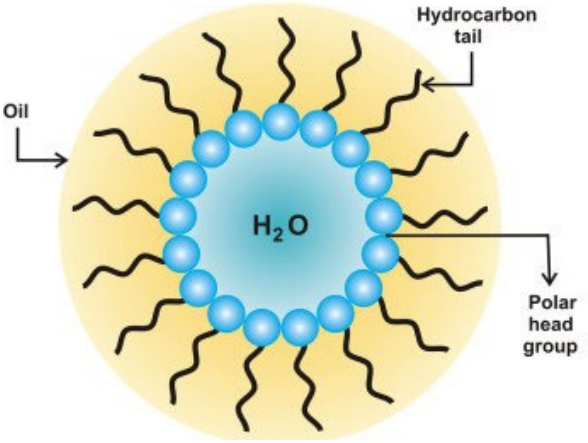
Biodiesel molecule



Water molecules



When present, biodiesel material creates inverted or reverse micelles in presence of water via hydrogen bonds, i.e. the FAME molecule organize the polar part to the inner side to solubilize water and the non-polar part in contact with the hydrocarbon matrix.



The presence of entrained/emulsified water provides the required oxygen for aerobic microorganisms to grow in fuel systems.

Microorganisms and Fuel Systems

In these pandemic days, we understand better those microorganisms are everywhere, and some can be very harmful. They are in the air, the ground and in your fuel systems. There are two commonly found organisms in fuel, bacteria and fungi.

Microbes work in consortia (communities working together) and biodeterioration (the detrimental change to materials due to bioorganic activity) results from microbes working together to degrade fuel and affect your fuelling equipment.

Many different types of microorganisms are able to use fuel as a food source. Aerobic microbes require a source of free oxygen to grow. In contrast, anaerobic microbes will grow only in the complete absence of free oxygen. Like all other life forms, all microbes require the presence of water. Water typically collects in low points of fuel systems and can become stagnant but nowadays it can stay finely dispersed in the fuel layer. Therefore, microorganisms are not homogeneously distributed in fuel storage tanks.

In addition, these microbial organisms do not require large amounts of water. They typically range from 0.5 to 3 microns in size and are therefore generally less than 1/1000 the size of a 3 mm thick film of water. This explains why small spots of condensation on the walls of a tank are sufficient to support growth. Viable organisms are found in the air, soil, and even in the fuel, so it is virtually impossible to keep a fuel system sterile. The effects of these organisms can vary by the type of organism and the volume or mass of organisms present in the system.

The vast majority of microbial contamination in fuel systems is within biofilms. Biofilms are complex structures of sticky, slimy polymeric substances that provide a protective habitat for microbes growing within them. Moreover, biofilms are typically in a state of dynamic stability in which masses of cells are sloughed off, forming biomass clusters as new biofilm is generated.

These microorganism clusters, or flocs, can plug filters or screens or other small orifices in the fuel system. Historically, the fungus Hormoconis resinae (H.res) was found to be an especially proficient filter/screen-plugging agent. Over the past decade it has been shown that diverse microbes can be as problematic as H.res.

Microbial plugged dispenser filter compared to a filter with no microbial contamination



The proficiency with which microbes plug screens can be seen in the following figure. Additionally, this fungus has a resinous coating while it is growing, which further blocks fuel flow through the

colony. Its generation can vary from systems to systems, being dependent of environmental conditions, fuel types, regeneration and turnover of fuel stocks etc.[9]

This why producing on-specification product is not enough to ensure fuel quality. It is equally important to minimize fuel system exposure to contaminants such as water and sediments. This can be accomplished by improved design of fuel storage tank, filtration system, water and particulate matter sensors etc.

Because of fuel biodeterioration, corrosion of storage tanks and of fuelling equipment is a major industry concern. It known and documented that damage can occur beyond repair and do cost the fuelling industry millions of dollars every year.[10] This why a quality management system is required to ensure fuel quality and to protect critical equipment such as vehicles, marine vessels, standby generators etc.

Tank Testing

Focusing on microorganisms and its potential effect on fuel itself and on fuel systems, it is highly recommended to test the environment in which the fuel is being stored. The concept of testing in the field and "testing at the tank" is not a new concept but should be re-enforced and implemented. It also supports the concept of "Detecting early".

ASTM D6469[11] is a guide that also suggests means for detection and control of microbial contamination in fuels and fuel systems. It helps in designing a strategy that considers system design, sampling and analysis, and preventive and remedial treatment.

It is essential and critical that representative samples are taken from fuel systems and tanks as the results will dictate the required maintenance. Regarding sampling, ASTM D6469 para 8.5 specifically state:

> Samples for microbiological testing should be kept on ice for transport to the laboratory. Tests should be performed within 4 h and no later than 24 h after sampling. Samples stored at higher temperatures, or for longer times, can show the presence of microbial contamination that does not represent actual fuel system conditions.

Since time is of essence for microbial testing, therefore we strongly advocate the testing fuel regularly and at the site for better results.

[9] CRC Report No. 667 - Diesel Fuel Storage and Handling Guide
[10] In situ Linkage of Fungal and Bacterial Proliferation to Microbiologically Influenced Corrosion in B20 Biodiesel Storage Tanks
[11] ASTM D6469 - Standard Guide for Microbial Contamination in Fuels and Fuel Systems

Perfect Storm

Fuel stored for prolonged period in storage tanks combined with certain environmental conditions such as hot and humid temperature or large temperature swing between seasons present the right condition for the generation of water via condensation, potential for the generation of microbiological growth, hence the “perfect storm”.

Red Dyed Diesel Fuel



We, therefore, advocate the conduct of a risk assessment approach as each region, fuel depots, operations will foster different conditions to set frequency of fuel testing regime. Remember, fuel quality should not be taken for granted.

In this context, it is not unusual to have operators to recirculate fuel monthly, take bottom-tank fuel samples quarterly to perform a visual check to ensure no free water accumulate in bottom of storage tanks. Often storage tank will have a sump/drain line to draw accumulated water and sediments in the bottom of tanks. These drain lines always contain latent fuel from previous drainage and somewhat present the worst-case scenario. In the context of verifying or investigating for presence of microorganism, we recommend taking the first few litres coming out of the drain line. Appropriate test should be conducted timely.

Most reported cases of fuel contamination have been with facilities where fuel is not tested with a poor or no water management program. Several case studies and scenario can be found in various literature and industry guidance document such as Energy Institute Guidelines on Detecting, Controlling, Mitigating Microbial Growth in Oils and Fuel Used at Power Generation Facilities.

Biofouling of Fuel in Storage Tank



Several publications have reported the negative effects of microbiological growth in fuel systems. The following is merely a short list of these consequences:

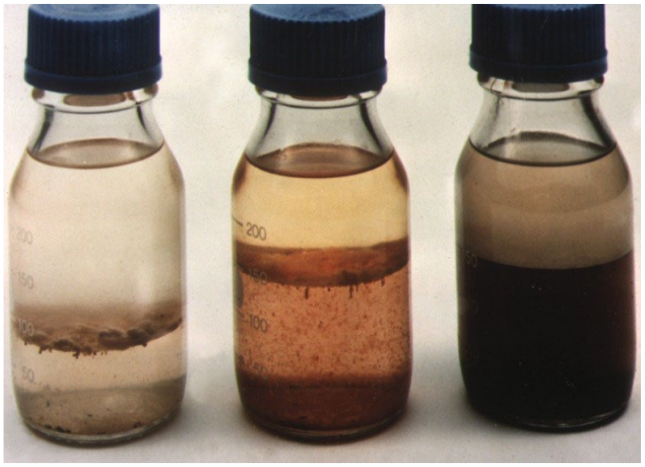
- Prolonged operation with fuels and oils containing over 500 ppm of water
- Filter plugging
- Pump failures
- Plugging of small orifices and lines
- Sluggish response of servo-valves and equipment having small orifices
- Nozzle fouling
- Engine stalling
- Sealant and elastomeric materials being deteriorated
- Epoxy material being deteriorated

- Corrosion of tank floors, sidewalls, and tubing
- Fiberglass material being deteriorated

These situations are combined with direct impact on fuel properties such as:

- Appearance, i.e., not being Clear & Bright
- Acidity number
- Oxidative stability
- Viscosity and viscosity index,
- Water separability

Fuel Displaying a water phase (bottom layer) with Microbiological Growth a fuel/water interface



Summary

In summary, microorganisms are invisibly small organisms that are everywhere in nature. They are present in your fuel system in the likes of spores and bacteria. They will grow and develop in mixed communities over time if proper environmental conditions are created. These conditions are not limited to the following but are aggravating factors: low turn-over of stock, tanks not being filled for prolonged period which will allow condensation and free water to accumulate at the bottom of the tanks, no regular drainage of water-bottoms and regular verification or testing of the fuel.

Regular maintenance of storage equipment and associated accessories such as filtration system combine with frequent fuel testing both at the tank and in laboratory using adapted test methods specifically designed to assess fuel quality is the key to prevent microbiological growth and keep the perfect storm at bay.

Testing for microbial contamination with results in minutes

Traditionally, fuel testing methods have depended on fuel samples being sent to laboratories, and in the case of marine applications, being sent onshore for analysis. Sending the fuel samples onshore or to other laboratory locations isn't simple. ASTM D6469 highlights that if a sample is to be tested for microbial contamination and cannot be tested on-site, it should be transported on ice and tested within 24hrs or the sample may no longer be a true representation of the environment from which it came. Delays cause varying results which may cause an increased risk to your asset.

Now with the innovative test at the tank technology that **FUELSTAT®** test kits offer you can get results on site within 15-30 minutes. The FUELSTAT® range includes FUELSTAT Plus and NEW FUELSTAT One, both are lateral flow test kits for accurate and rapid microbe detection, developed to find micro-organisms that do damage to fuel. The kits are self-contained, requiring no additional equipment. They are so easy to use that an individual can carry out the tests with only minimal training.



FUELSTAT®

For more information visit: www.conidia.com/fuelstat

Removal of water to prevent contamination



Aquafighter® filters actively remove bound, suspended and emulsified water out of diesel fuel directly in the tank and keeps it water-free at all times. This is accomplished through 3 indispensable actions that are necessary to achieve the desired fuel purity and consequently provide tank protection:

- Demulsifies water by physico-chemical adsorption of water molecules to less than 65ppm total fuel water content with maximum efficiency. (Aquafighter causes water to release naturally from fuel and it achieves this without adding to or altering the fuel, unlike certain fuel additives would do. After market additives can cause corrosion themselves)
- Attracts & Captures water immediately upon release from the fuel molecules
- Isolates water in its protective gel to permanently segregate it from the fuel & tank environment so your fuel & tank is protected at all times. (Aquafighter will encapsulate the water preventing corrosion, microbial growth & re-emulsification until it is removed from the tank)

AQUAFIGHTER

For more information visit: http://www.conidia.com/aquafighter

Who we are

Conidia Bioscience research, design, develop, manufacture and globally distribute innovative solutions for maintenance of fuel systems. Our products are designed to offer practical and easy to use, industry leading solutions to both maintain and monitor the stored fuel in your system, whether that be a fixed ground installed diesel fuel tank, or in an aircraft wing. Through simple steps of ensuring water doesn't develop within stored fuel, and instant testing at the tank, we keep fuel contamination free and ready to use, avoiding costly remedial action and fuel system failures.

FUELSTAT® fuel tests are developed, manufactured and marketed by Conidia Bioscience Limited. Based in UK, Conidia Bioscience Limited was founded in early 2000's by experts in immunoassay techniques and holds the internationally patented intellectual property for FUELSTAT®.

Conidia Bioscience manages the global distribution of Aquafighter® water removal filters for Diesel and middle distillate fuels.

Where to find us

FUELSTAT® and Aquafighter® are distributed globally by a network of specialist distributors covering the major sectors. Contact info@conidia.com who will arrange for a distributor to support you.

References

- ASTM D1655 - Standard Specification for Aviation Turbine Fuels
- EN 590 - Standard for Diesel Fuel
- ASTM D975 - Standard Specification for Diesel Fuel
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