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Discussion on microbial contamination of naval fuels

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ABSTRACT

Article Deals with problem of naval fuels' microbial contamination. This problem in Poland is not well known and described, but operational problems encountered very often prove that this is a very serious problem. Examples of laboratory tests performed on real samples are presented as well as possible effects of microbial contamination are discussed. Authors also suggest continuous monitoring of naval fuels as main preventive tool. Article covers following topics:
- *general information about microorganisms present in naval fuels*
- *conditions necessary for microbial growth, with special attention to conditions encountered on vessels*
- *operational problems resulting from microbial contamination*
- *methods of microorganisms detection and examples of preventive actions.*

Keywords: naval fuels; microbes on fuels; microbial growth; microorganisms; fungi; ulphate-reducing bacteria

INTRODUCTION

It has been known for over 100 years that some microorganisms can feed with hydrocarbons but only for about 40 years people have started to realise the adverse effect of microbes on fuels' cleanness as well as their corrosiveness to materials used in distribution systems (storage and operational tanks, pipelines etc.) and in fuel systems of vessels.

The core factor for microbial growth in fuels, not only the naval ones, is presence of water. Every case of fuel contaminated with water brings real and big risk of microbial growth. In fuel tanks ideal conditions for microbial growth exist on fuel-water surface. Fig. 1 presents, as a scheme, storage tank with layers that exist during fuel storage.

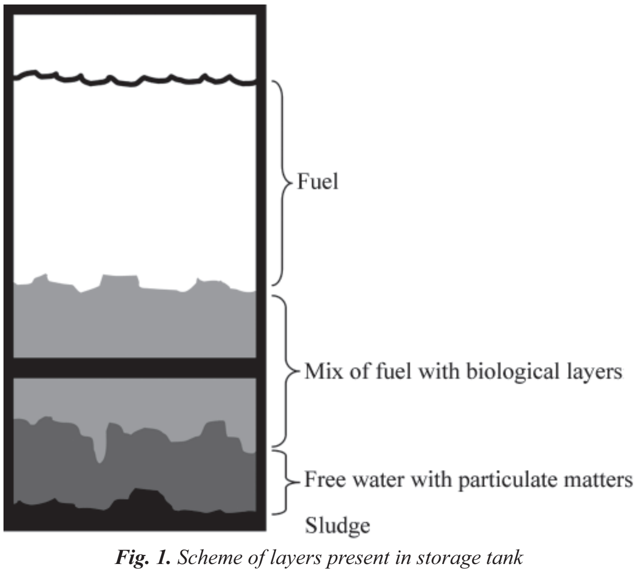

Fig. 1. *Scheme of layers present in storage tank*

Microbial growth is stimulated also by other factors, i.e. fuel composition (as naval fuels most vulnerable are heavy fuels, fuel distillates (diesel fuels) and light fuels), storage conditions (temperature between 15 and 40 °C) and amount of free water in storage tank.

Microbial contamination of naval fuels has posed some operational problems for many years. Such problems can be avoided by discarding of water, but practically it is impossible to discard all of the water. Water as separate phase in fuel tanks can origin from condensation of water dissolved in fuel as well as from water deliberately added to fuel tanks for ballast and to eliminate vapour space.

MICROORGANISMS ENCOUNTERED IN FUELS

Microorganisms having the biggest effect on fuels' performace can be differentiated into two main categories:
- fungi
- sulphate-reducing bacteria.

There are also yeast, but they are nor as important as fungi and bacteria.

Fungi can create coherent mats at the fuel - water interface. Fungi enter the fuel from soil as airborne spores.

Bacteria usually enter fuel tanks with water. They grow in water under the fuel layer, without oxygen presence [1].

Gloriah Hettige in her work [2] has isolated thirty one types of fungi and five types of bacteria. Neyhof and May have also described other types of fungi and bacteria [3].

The main types of fungi were the following:
- Cladosporium resinae
- Penicillium corylophilum

- Paecilomyces variotti
- Aspergillus
- Mucorales
- other, unidentified.

The bacteria were the following:
- Pseudomonas
- Desulfovibrio.

Among yeast there were the following types:
- Candida
- Rhodotorula.

MICROBIOLOGY OF FUELS

The first reports regarding microorganisms were in the early 1930's. The reports described problems connected with fuels and oils infected by bacteria [4, 5].

Most of work concerned aviation fuels, though probably there also were problems with naval fuels, but they were used in less sophisticated (compared to jet ones) engines.

Liggett [6] has performed comprehensive work on microbial contamination of marine, rail and road diesel fuels.

Hydrocarbons C_{10} - C_{18} are much readily assimilated by microorganisms than the C_5 - C_9 ones. Test results showed that microbial growth had taken place also in naval fuels, but effect of their activity was no as severe as for aviation fuels.

This was why some contamination and corrosion in naval fuel recognised as of no importance so it was not justified to take appropriate countermeasures similar to ones for aviation (water discarding, microbial monitoring).

As a result the problems regarding microbial growth at vessels became bigger.

Such unfavourable occurrences were linked mainly with chemical changes in fuel resulting from refinery processes [7] as well as from wider use of additives, which sometimes promote microbial growth.

Hill [8] has found severe microbial growth both in heavy fuel oils and lighter diesel oils.

The biggest problems were because of fungi *"Cladosporium resinae"* which were superseded by a lot of other types of fungi, bacteria and yeast.

Distillate fuels contain ample of oxygen sustaining aerobes growth, but in case of dormant tanks, content of oxygen decreases and anaerobes such as sulphate-reducing bacteria *Desulfovibrio* can grow. Such bacteria never exist alone, but also together with other organisms, creating big complexes living in water and feeding on fuel. Fuel with its additives is not the only nutrition source. It is permanently used and replenished, opposite to water and microorganisms contained there.

Conditions in naval fuel tanks, especially presence of large amounts of water, effect on variety of types of microorganisms as well as on their growth rate. It can be assumed that microbial growth in vessel's fuel systems is bigger and faster than in aviation ones.

The ratio of water to fuel in water-displaced tanks can be high. There is wide range of nutrients in such mixture, in addition to those already contained in water. The nature and quantity of such nutrients depend on type of water used to fill the tanks. It can be saline deep-seawater as well as estuarine one. Extent of colonisation can be affected by sewage content and trace metal contamination in the water.

The ratio of water to fuel in standard fuel tanks is low and there is less particulate organic matter when compared to water-displaced tanks. Amount of nutrients will be determined by the previous history of the fuel and such factors as condition of tank linings and seals.

RESULTS OF MICROBIAL ACTIVITY

Inconsiderable amount of water, even strongly infected, does not influence on significant fuel deterioration. Such water can result in severe corrosion. It is well known that more the water much bigger threat to cleanness of fuel in terms of microbiology. Activity of microorganisms can lead to:
- presence of slimes and clogging pipes, valves and filters
- coalescers malfunction due to fungi growth on filter cloth sleeve
- malfunction of volume measurement systems
- accelerated corrosion due to aggressive substances (acids, sulphides) and electro-chemical corrosion cells creating, corrosion inhibitors depletion and degradation, protective coatings degradation and preventing formation of stable oxide layers.

Symptoms of severe contamination of naval fuels are the following:
- filter clogging
- coalescers malfunction
- injector fouling
- fuel system components corrosion.

MICROORGANISMS DETECTION

Crucial matter is to obtain water bottom sample. For such sample it is possible to perform both qualitative and quantitative testing using a routine culture methods. But sometimes it is impossible to obtain such excellent sample, so in order to evaluate level of fuel contamination we can use different methods. Some of them are summarised below:

Microscopic method

It is used mostly to detect motile bacteria, fungal hyphae, protozoa, algae and unusual debris. It also allows identification of small particles such as non-motile bacteria and spores in the presence of large amounts of mineral particulate matter. Disadvantage of this method is the high cost of devices and necessity of highly qualified personnel, but major advantage is short time of analysis.

Centrifuge method

It bases on centrifuging sludge sample previously homogenised. The length of specific layers in test tube is read from calibration graph. Its disadvantage is, as in previous metod, high cost of equipment.

Chemical methods

- pH of water phase measurements
- acidity measurements
- metallic elements content
- sulphides presence
- burning at 500°C.

Membrane filters method

It is based on passing fuel being examined through defined membrane filter and evaluation of substances collected on filter's surface.

Dip-slide method

The nature of this method is to dip a small plastic paddle coated with nutrient into a sample. Next step is to return the paddle into its container and to incubate. One type of nutrient detects ant evaluates bacteria while the another detects yeast and fungi, and allows for quantitative assessment of contamination. Disadvantage of this method is long incubation time, up to 3 days, but major advantage is simplicity so it can be used my not qualified personnel. Examples of results obtained with this method are presented on Fig. 2.

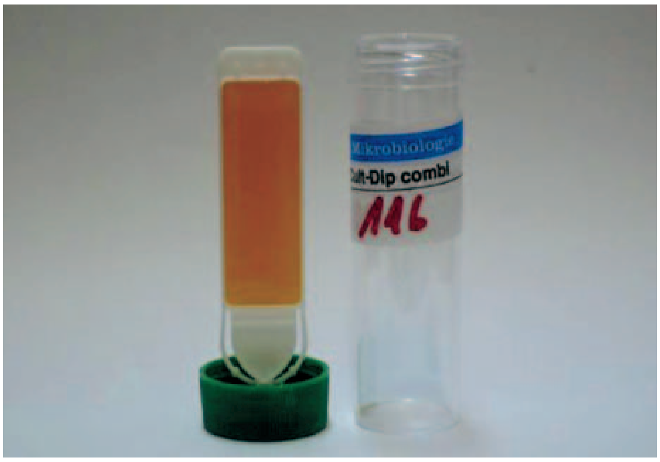

Fig. 2. *Plastic paddle coated with nutrient (prod. Merck) used in dip-slide method*

ATP method

This is a new method evaluated recently. It uses presence of ATP in microorganisms contained in fuels. Its main advantage, when compared with other methods, is short time of measurements that allows for reliable results within approx. 10 min. Example of test device used in this method is presented on Fig. 3.

Fig. 3. *Hy-Lite device (prod. Merck) used in ATP metod for microbial contamination assessment.*

EXAMPLES OF NAVAL FUELS MICROBIAL CONTAMINATION

Examples of naval fuel samples, where microbial contamination has been confirmed, are presented on Fig. 4. The samples were taken from operating vessels. Easily visible is fuel colour change and microbial layer on fuel-water interface.

Slides with cultures of fungi, bacteria and yeasts are presented on Fig. 5.

Fig. 4. *Naval fuels samples with confirmed microbial contamination*

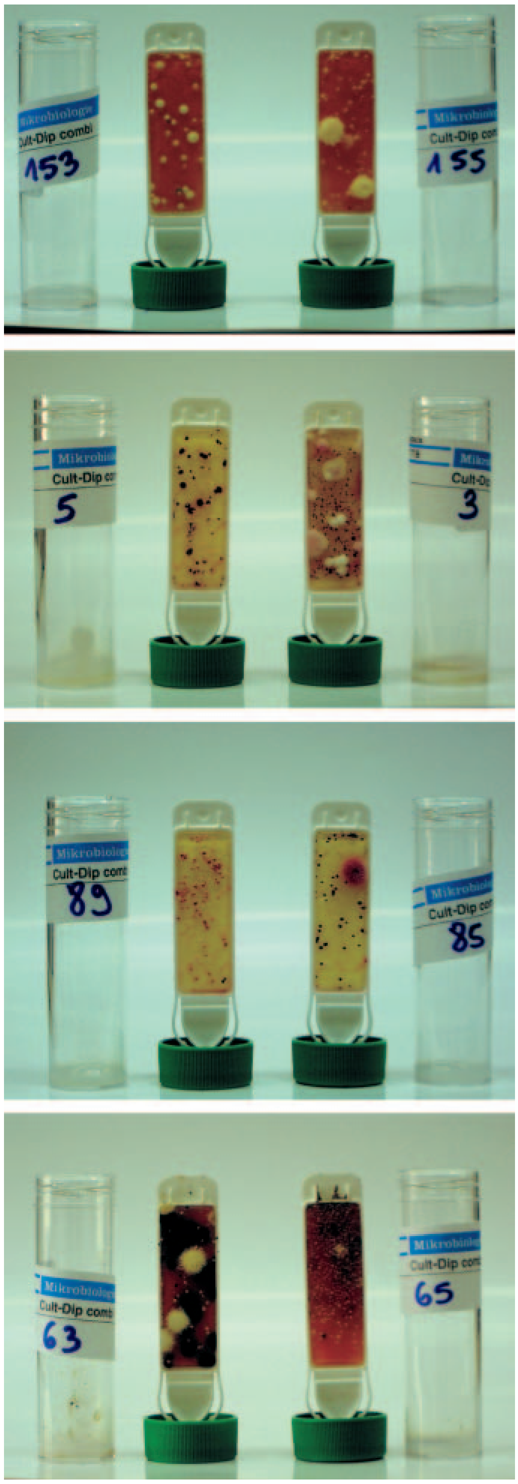

Fig. 5. *Slides after tests of microbial contamination*

COUNTER MEASURES AND PREVENTIVE ACTIONS

Fuel composition

Fuel should be formulated that it is no longer good nutrient for microbial growth. Straight hydrocarbon chains are more vulnerable than branched ones. Some additives promotes microbial growth and some prevents that. So far, there is no comprehensive study concerning fuel composition effect on microbial growth, and refineries are using established production processes, therefore changes in fuel composition are not currently feasible.

Good housekeeping

This mean includes:
- minimising water content
- rust and scale discarding
- high temperatures avoidance
- avoidance of fuel contact with contaminated surfaces
- active fight against microbial growth at the beginning of the process of growing.

Mechanical decontamination

This preventive action includes:
- filtration
- centrifugation.

Biocide treatment

Biocides are the chemicals used to destroying microbes. There are wide range of chemicals used as biocides. Some of them are the following:
- Biobor JF
- Kathon 886
- Grotan OX
- Bodoxin
- Omadine TBAO
- Bioban FP etc.
- Grota Mar.

Biocides should have the following properties:
- be combustible, without ash
- have no adverse effect on fuel properties or engine performance
- be soluble or very miscible in fuel, but preferably in water
- be not corrosive
- be able to total killing of all microbes at minimum dose.

CONCLUSIONS

- Microbial contamination of naval fuels pose problems and threat to proper use of vessels.

- Effect of microorganisms can be minimised by adhering to rules of good housekeeping, as well as by the use of relevant chemicals (biocides and biostats). Use of the chemicals should be based on relevant laboratory testing to check its influence on fuel system's components.

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