

## **MICROBIAL CONTAMINATION IN DIESEL FUEL – ARE NEW PROBLEMS ARISING FROM BIODIESEL BLENDS?**

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### **Abstract**

Standard diesel fuel is allowed to contain only 0.2 cm<sup>3</sup> water per litre of fuel from which a third of this is dissolved. The rest of the water settles at the tank bottom and is sufficient to serve as a biosphere for the microorganisms. Microbial products of decomposition form an emulsion of water and fuel and make separation of the water more difficult. Microbes are the cause for operational problems like fouling of tanks, pipes, filters and tank corrosion. These microbial problems in mineral diesel have been known for over 70 years. But nowadays the diesel fuel is a blend with biodiesel such as fatty acid methyl esters (FAME). Since the widespread of biodiesel blends an increase of operational problems is observed. Does the addition of FAME increase the risk of microbial contamination? Is it enhancing microbial growth?

The fatty acid esters, such as FAME, produce an environment in mineral diesel in which microbial growth is encouraged due to the ability of microorganisms to degrade natural fat and oil to yield energy for growth. The microbial growth can be enhanced at every stage in production, storage, distribution and in end users vehicles. Good housekeeping, monitoring and proper usage of an effective biocide are crucial measures for an anti-microbial strategy. A tailor-made fuel biocide for mineral diesel / FAME blends is introduced.

### **Introduction**

The fact that hydrocarbons from petroleum products can be used as a source of carbon by various microorganisms is widely known. H. Kaserer<sup>1</sup>, N.L. Söhngen<sup>2</sup> and K. Störmer<sup>3</sup> reported on the utilization of hydrocarbons by microorganisms. However, these reports do not indicate the relationship between occurrence or damage in practice and microorganisms' activities.

The discoveries of microbiological phenomenon on direct or indirect effects in practice gradually increased. C.E. Zobell<sup>4</sup> described the practical problems occurring as a consequence of microbiological attack on lubricating oils, diesel oil, natural gas, cooling oils, asphalt and rubber. According to A.R. Lansdown<sup>5</sup>, airplane accidents were attributable to the blockage of filters due to the growth of bacteria and fungi in propellants. D.G. Parbery<sup>6</sup> reported similar observation. E.C. Hill<sup>7</sup> and other authors found that anhydrous oils contain some organisms and active growth took place as soon as water was present.

Although it has been known in principle for more than twenty years that microorganisms are disruption factors, often there is no information on this whatsoever in the service laboratories of the oil and gas industry.

A typical scenario was the frequent breakdown of the fire engines at an airport. Analyses often show filter blockage in the fuel system. Based on this result, firstly the fire-engine tanks, followed by the storage tanks, were cleaned. The material causing the filter blockage was also analyzed further, and it was shown that the blocking was caused by fibres of organic material. Therefore, the use of paper towels was prohibited, since it was suspected that the fibres of these paper towels somehow got into the fuel system and thereby blocked the filters. However, when the problems did not cease, a microbiological control was carried out, which revealed the actual problem - massive microbiological contamination.

The above example showed that the knowledge of microbiological attack is not been widespread. It is suspected that knowledge concerning microbial problems is intentionally not passed on, so as to avoid claims for compensation. Nobody wants to accept the responsibility for ensuring microbiological perfect quality products.

At present, microbiological purity is not a criterion of quality in mineral oil standards. Microbiological tests should become a standard in the event of blocked filters and unexplained sludge deposits in land vehicle engines, ship engines or airplane engines. The same applies to mineral oil storage, irrespective of where these come in the sales route, whether refinery or end-user filling station.



**Fig. 1 - Microscopic picture of a microbe in fuel**

### **How is this possible?**

Microorganisms are ubiquitous. They colonize the earth; exist in human, animals and plants. They exist in a variety of forms: fungi, moulds, viruses, bacteria and yeasts. They are useful in the food and medicine industry; they work specifically in sewage treatment plants; and also pose an ecological significance. Their presence, however, with their uncontrolled multiplication often create problems.

Microbial activity and growth are only possible in the presence of free water. Without water, microbes become dormant or die. Therefore, in order for microorganisms to grow and

develop in or on a material, the material must be infected and contain adequate quantity of water.

In general, as little as 100 ppm of water is sufficient for microorganisms' multiplication. Standard fuel contains up to 0.2 ml water per litre. A third of this is dissolved and the rest settles at the bottom of the tank. Thus, microorganisms can live and multiply in diesel fuel easily. This is particularly true in the condensation water deposits at the bottom of the storage tank or which is finely distributed in the fuels.

In ventilated oil tanks that are exposed to temperature fluctuations, free water is formed as a result of condensation. Water vapours are breathed in with air, condense on tank walls and drop down onto the bottom at some points. Leaking fill caps are another prime source. Holes in underground tank walls allow ground water to enter.

Water can also come from other sources. Fresh or seawater may be put in oil-storage tanks intentionally, especially during washing of difficult accessible parts of the systems, or as ballast in tankers. Such additions of water also bring in inorganic salts, end up as nutrient salts, with other biological impurities.

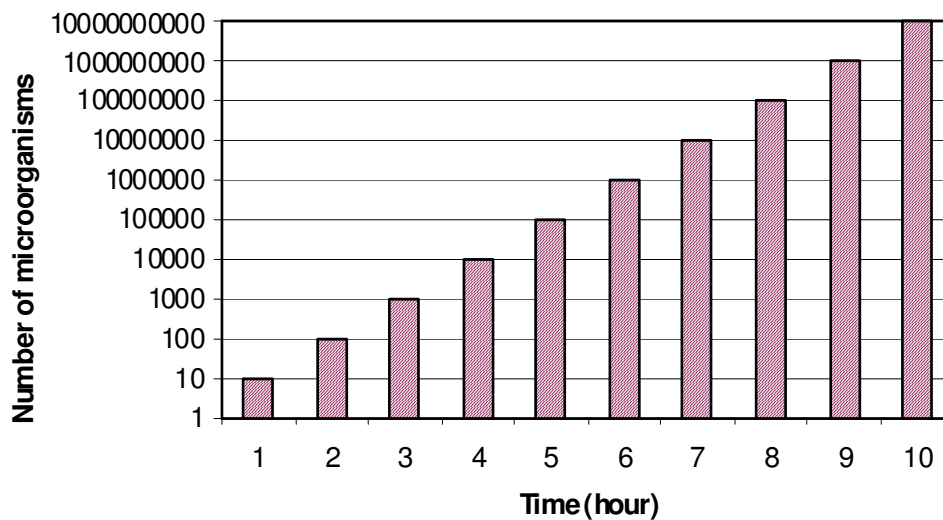
Foreign impurities such as soil, sawdust, leaves and many others, in the storage tanks may also constitute a dangerous source of infection and good culture media for microorganisms.

Water may dissolve some water-soluble components out of the oil phase. Both phases usually contain air, which is of importance for the development of aerobic microorganisms. Naturally, spores and bacteria always contaminate the fuel oil itself because they are present everywhere. They are too small to be removed or filtered practically.

The growth usually takes place in the zone between water and oil. The phase boundary is the ideal nutrient medium for organisms. Depending on types of microorganisms and the micro ecological conditions, the growth can expand in the oil or the aqueous phase. The contamination of the diesel fuel can be passed on from the refinery to the storage tanks via the intermediate tanks, to the customer's tanks or the filling station, and from there into the vehicle tanks. The transmission of bacteria/fungi into the supply chain is easily done.

Under optimum conditions after 20 minutes, as a result of division, one microorganism becomes two, after a further 20 minutes four, then 8, 16, 32, 64 etc. (Figure 2). After 10 hours, there would be already 1,073,741,824 microorganisms.

The consequences of microbial growth are the formation of sludge in contaminated tanks. On the tank walls, slimy, slippery, dark colour coatings of microorganisms may develop. This leads to dark and cloudy diesel fuel that was originally light and clear. As a result of the biomass, filter blockages occur, which in some cases make daily filter changes in the vehicle necessary. In addition, aluminium and sheet-steel tanks will also be damaged by pitting corrosion due to the acidic metabolic products of microbial growth (bio-corrosion).



**Fig. 2 - Rapid multiplication of microorganisms.**

Both problems i.e. filter blockage and corrosion are no doubt due to microorganisms. This connection is well understood among experts and has been discussed for many years. In order to solve this problem, the use of biocide has been proven effective in many cases in practice.

### **How Does One Recognize Microorganisms?**

Of course, not every blocked fuel filter is attributable to microbial impurities. It is not visible to the naked eye whether sludge deposits in diesel tanks or filters are microorganisms, or simply just precipitations or ageing products from the diesel.

Only microbial examination with determination of bacterial count provides a reliable answer. [schülke](#) has over hundred years of experience in preservatives and industrial hygiene. We have adopted and implemented in-house experimental and laboratory analysis methods to examine problematic samples of fuel, water or sludge.

Since oils are not soluble in water or culture media, the bacterial counts, or the colony-forming units (cfu), cannot be determined by the usual dilution procedure using culture plates. For this reason, membrane filtration was applied, as described by M.A. Rogers and A.M. Kaplan<sup>8</sup>. This required 100 ml of fuel oil to be poured into a sterile diaphragm with  $0.45 \pm 0.02 \mu\text{m}$  pore width and filtered under vacuum. The cfu contained in the oil, both of bacteria and fungal spores are retained on the filter due to their larger diameters. The residue from the filtration was rinsed with 100 ml of sterilized 0.1% aqueous solution of a wetting agent (alkyl-aryl polyether alcohol) that is harmless to microorganisms, and then rewashed with 30 ml of sodium chloride solution. Each filter with germs was then laid on a nutrient agar plate that contained 0.1% meat extract, 0.2% yeast extract, 0.5% peptone and 0.5% cooking salt, and then incubated for 5 days at 25 °C. The number of growing colonies gives the cfu per 100 ml of oil.

Microbiological monitoring is also possible with the on-site test kit MicrobMonitor2 (ECHA Microbiology Limited). The test uses a small glass bottle containing a thixotropic nutritive gel formulated specifically to grow microbes associated with fuel and oil spoilage.

## What Must Be Done?

M.A. Rogers and A.M. Kaplan<sup>9</sup> have suggested various biocides to prevent the growth of microorganisms in petroleum products.

As early as 1971, the Naval Research Laboratory in Washington investigated the effectiveness of various biocides for the treatment of navy distillate. With the IP Code of Practice for examination of light distillate fuel for variable microorganisms (IP 386/88), the testing of diesel fuel samples was standardized.

In addition, a standard for sampling was also drawn up by a working group in the Institute of Petroleum. A guideline for the investigation of microbial content in fuel boiling below 390 °C and associated water was outlined in November 1996. This describes the sampling process in detail and includes a revised version for microbiological testing.

The SGS (Societe Generale de Surveillance) limit values are used for microbial load in trade agreements. The total viable organisms are limited to  $<3 \times 10^3$  cfu/l, that is, less than the limit for drinking water, which in Germany, for example, is  $<100$  cfu/ml =  $<10^5$  cfu/l. However, it is important to note that even at this low level, it is possible to lead to severe problems in practice. Hence suitable biocide and preventive measures are necessary.

Good housekeeping and/or continuous use of a chemical preservative (biocide) can solve the microbial problems occurring in clean systems.

If an infection is already well established, the microbes must be killed and removed as soon as possible. Physical or chemical decontamination or both should be employed. The chemical biocide selected must be rapidly effective against large numbers of microbes in the presence of substantial organic fouling.

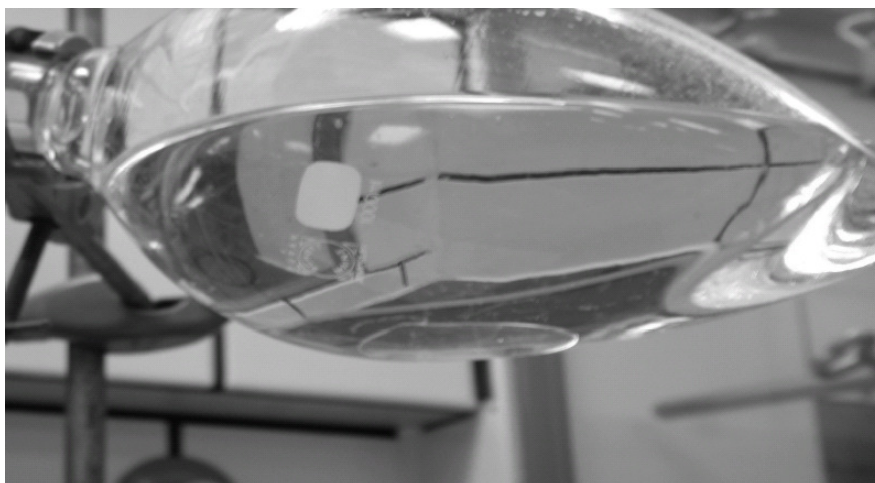
Although the details of antimicrobial strategies differ from system to system, one of the key decisions is the choice of biocide. The biocide selected should be able to kill microbes in oil and water phase, safe to use, and with acceptable environmental impact.

[schülke](#), together with the affected operators of oil depot, refinery, tanker lorry, fleet, and etc. have developed a biocide that fulfils the basic criteria; and formed appropriate strategies in order to kill microorganisms, to avoid microbial growth and to prevent recolonisation by means of preventive measures. We have developed an effective biocide, which is based on the chemistry of methylene-bis-oxazolidine (MBO), especially for the application in diesel fuel. This compound contains no heavy metals or halogens and combusts completely without ash. It can be added directly to the diesel fuel and has been tested and approved by leading engine and vehicle manufacturers<sup>10,11,12</sup>, the oil industry<sup>13,14</sup> and the NATO<sup>15</sup>. It is reported that the substance has no negative effects on injectors or combustion processes in engines.

MBO is characterized by its broad spectrum of effect against both aerobic organisms (bacteria, yeasts, mould fungi) and anaerobic organisms. In particular, the growth of sulphate-reducing bacteria that lead to severe corrosion damage is reliably inhibited. Due to its excellent anti-corrosion properties, it also prevents corrosion caused by microbial breakdown products and neutralizes any acids formed. Furthermore, it shows a good immediate effect.

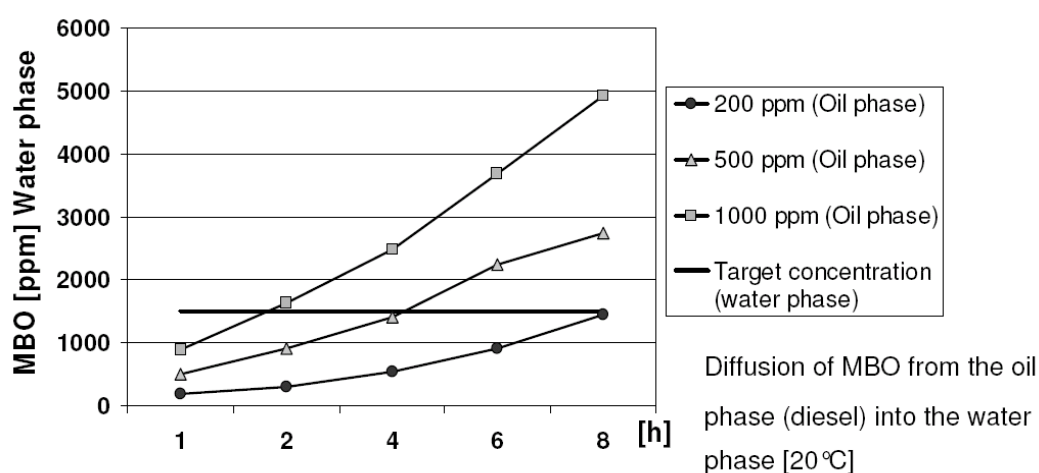
MBO is readily soluble in water and organic solvents. Only low concentrations are soluble in non-polar solvents. Its water/diesel oil distribution coefficient is determined as 28 (FAME 35 - 42); hence it is present in greater amounts in the particularly susceptible water phase.

MBO shows a good diffusion from the fuel into the water phase. The tests were performed in a separatory funnel (Figure 3).



**Fig. 3 – Testing of the diffusion (1000 ml diesel fuel, 10 ml water)**

Already at a use concentration of 200 ppm in the fuel and a contact time of 8 hours the target concentration of 0.15 % MBO in the water phase is achieved (Figure 4).



**Fig. 4 – Diffusion of MBO into the water phase**

The quick, partly diffusion of MBO into the water phase combined with the good solubility in the fuel phase, allows sanitizing of a complete distribution chain from the refinery through the storage tanks up to the end-users car tank.

MBO forms no corrosive combustion products and is halogen and sulphur free (approved according to the “Bundes Immissionsschutz Gesetz” Germany).

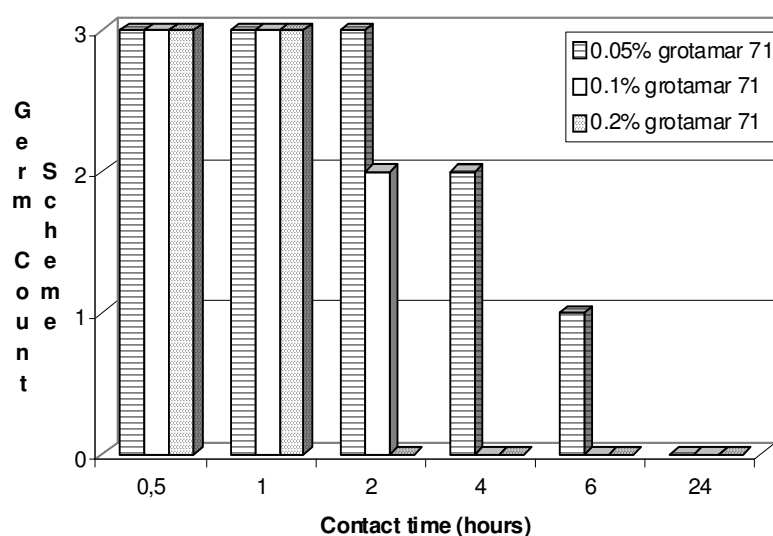
MBO shows excellent stability in diesel oil and other fuel. This permits economical long-term protection.

In the „Harmonized Offshore Chemical Notification Scheme List of Notified Chemicals“ (HOCNS) of *Cefas* (Centre for Environment, Fisheries & Aquaculture Science [grotamar®](#) 71

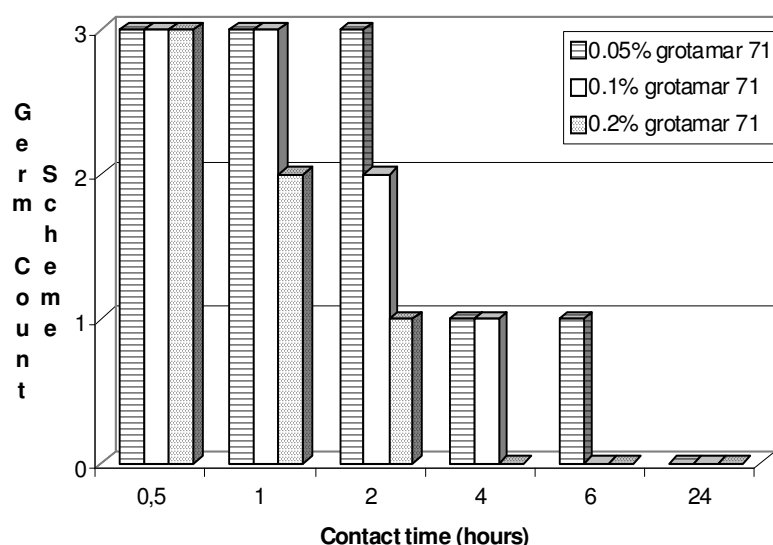
is classified with „Gold Banner“, *Cefas* is an internationally renowned aquatic scientific research and consultancy centre. *Cefas* aims to be the prime source of high quality science used to conserve and enhance the aquatic environment, promote sustainable management of its natural resources, and protect the public from aquatic contaminants.

The tests conducted have shown that MBO is a good biocidal compound. Different decontamination concepts and recommendations are very much depending on the degree of microbiological contamination. Test results in water presented a reduction in the number of microorganisms by >5 log steps within a few hours (Figures 5,6,7,8,9,10). Treated product can usually be sold. The number of residual microorganisms is evaluated semi-quantitatively as a function of time in accordance with the scheme:

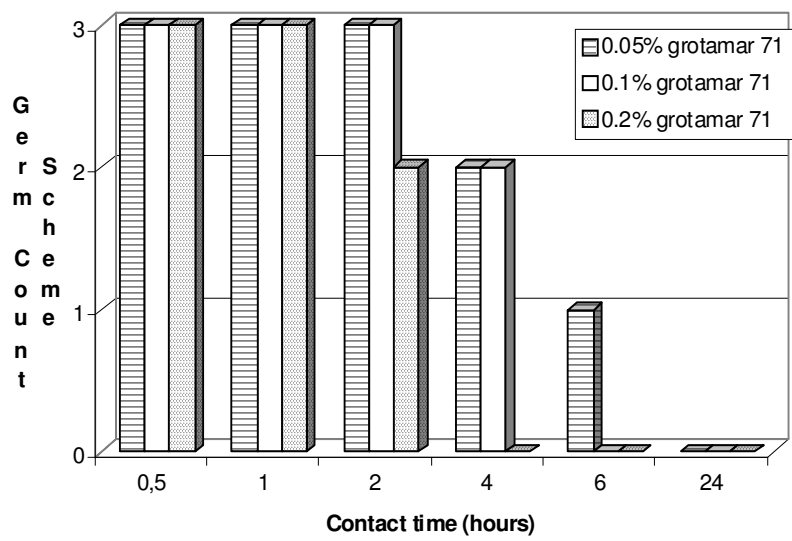
- 0 = no growth (<10<sup>2</sup> germ count/ml)
- 1 = slight growth (~10<sup>2</sup>-10<sup>3</sup> germ count/ml)
- 2 = moderate growth (~10<sup>3</sup>-10<sup>5</sup> germ count/ml)
- 3 = massive growth (>10<sup>6</sup> germ count/ml)



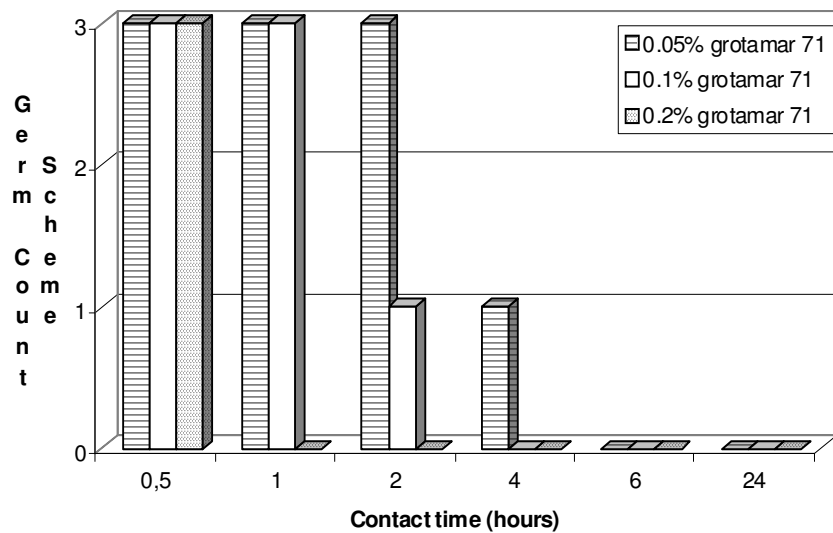
**Fig. 5 - Germ count reduction test: *Pseudomonas aeruginosa***



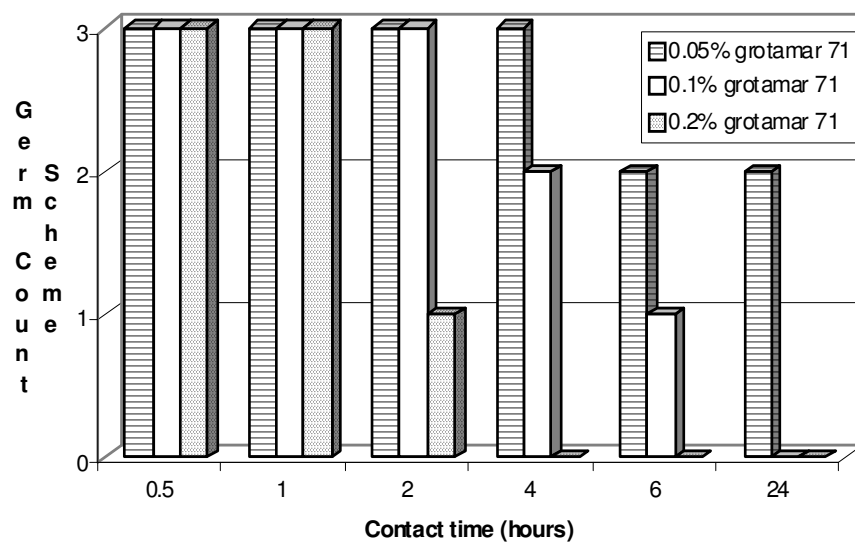
**Fig. 6 - Germ count reduction test: *Pseudomonas putida***



**Fig. 7 - Germ count reduction test: *Candida albicans***

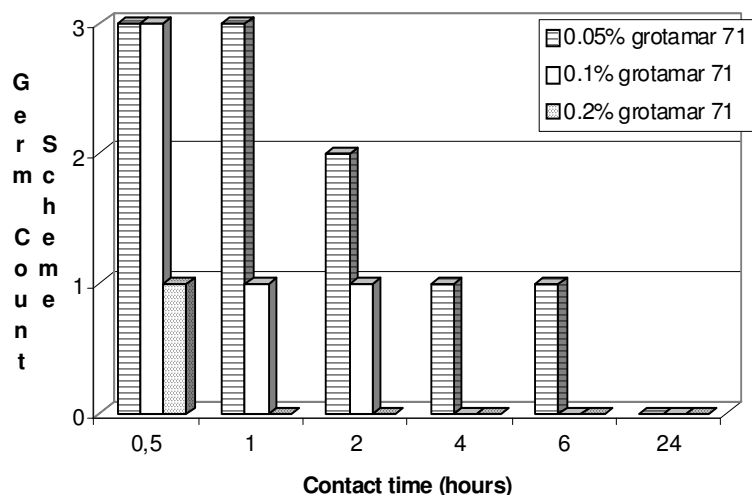


**Fig. 8 - Germ count reduction test: *Rhodotorula***



**Fig. 9 - Germ count reduction test: *Aspergillus niger*.**





**Fig. 10 - Germ count reduction test: Fusaria.**

### Environmental Concern

Worldwide, strict demands are made for a modern fuel biocide. The addition of halogen compounds is generally prohibited, as in accordance with the Federal Decree on Protection from Emissions. The efforts to use fuel with the lowest possible sulphur content have resulted in the demand for biocides that contain no sulphur. Due to technical demands, the biocide must dissolve both in the diesel fuel and in the condensed water phase. Biodegradability and the absence of heavy metals are also demanded.

An MBO based biocide is a good choice in terms of environmental acceptability. When it is used correctly, the substance basically passes via the sales route to the vehicle fuel tank, together with the fuel. Here it is converted with the diesel fuel into normal combustion products. There is no additional environmental contamination through exhaust emissions. The combustion products are not hazardous, hence in Germany, it is not restricted by the law to protect against emissions (decree on chlorine and bromine compounds as fuel additives) 19<sup>th</sup>. BimSchV 1992.

If the substance passes into the environment via a biological sewage-treatment plant, it can be broken down biologically. According to the results of tests of biodegradability MBO is considered as being readily biodegradable (Method: OECD 301D / EEC 84/449 C6). If higher concentrations are passed directly into a biological clarifying plant, they can be inactivated by sodium bisulphate. An MBO based biocide is rapidly and completely biodegradable. Safe disposal of waste biocides or biocide spillages can be achieved by substantial dilution with water.

### Preventive Measures

A fuel oil could be kept free of microorganisms only by complete aseptic handling. This is usually not possible in practice. Hence, even anhydrous fuel oil always contains a limited number of microorganisms as a consequence of infection from air, container walls, or by impurities.

It is understood that active propagation of the organisms only occurs in the presence of water. In addition, the presence of a free-water phase under the fuel also causes rust in the iron storage tanks. If the storage has no free water, neither problem will exist.

There is only one sure way to keep a fuel system dry: "Check for the presence of water on a regular basis, and remove it when it is found". The water checking should be a direct visual observation of a sample from the lowest point in the tank. Detergents in the fuel can deactivate the thieving compounds used as water indicator. Therefore, it is not a reliable compound for water contents determination. Water checking and removal from underground storage can be accomplished by using a hand pump and a long suction pipe.

When buying fuel on the spot market, care must be taken to ensure that one's own storage systems are not contaminated with specially adapted organisms. Sampling systems must ensure that the microbiological findings are already available when the fuel is received. Contaminated material must never be brought into the tanks without treatment. When taking fuel from a tanker into the tanks, homogeneous distribution of the biocide can be ensured. Dosing can take place either via an injector or via dosing pumps. Of course, care must also be taken to ensure careful draining.

It should be mentioned here that modern filter/water separating systems could easily achieve the necessary draining to <60 ppm water in order to go below the growth limit for microorganisms. Experience has shown that with <60 ppm water in diesel fuel, further multiplication of organisms can be prevented. This is because water is mostly present in dissolved form and the  $a_w$  (active water) value necessary for microorganisms growth is not reached.

However, these filters are not meant for replacing the use of biocides since microorganisms can easily inactivate the filters by means of rapid growing and blocking.

Further to avoid recontamination, planning principles for the new design of tanks are useful and necessary. The possibility of convenient, economical and regular drainage is one of the key factors for consideration.

The tank design must permit complete drainage. Drainage pipes must really be fitted at the lowest point in the system. Water pockets in the piping system and in slanting filters must be avoided. The additional incorporation of filter water separating systems has proven to be useful, for example in the German navy.

Unnecessary contamination, such as occurs as a result of ballast water during transport by river shipping, must be avoided. In transport via pipelines, care must also be taken to ensure that there are drainage facilities at the lowest points.

When designing tanks and transport systems, maintenance of the microbiological quality of the fuel must be included as a planning principle.

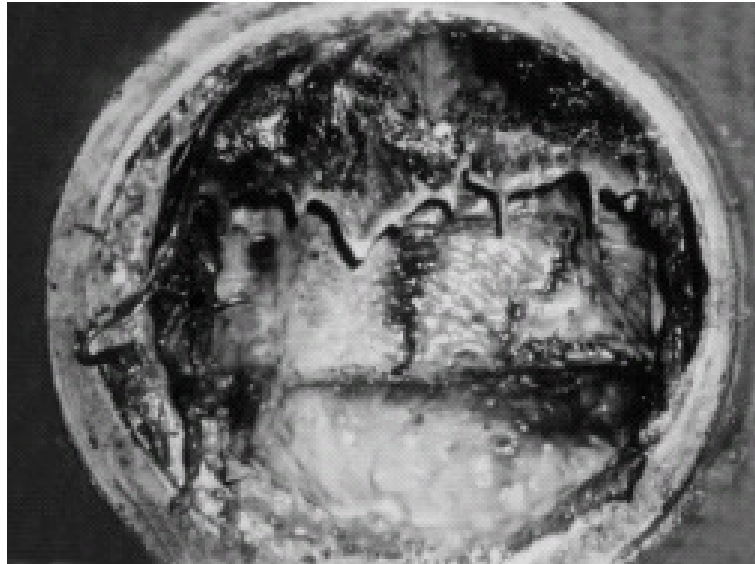
In practice, the following decision tree has proven to be useful when determining the measures to be taken:

1. Base sample from the water phase is sludge and heavily contaminated.
2. Empty the storage tank and clean with a suitable disinfectant system cleaner. A biocide should be added when the tank is refilled. Shock treatment with biocides is

often necessary. Filtering to remove particles of dirt should be an automatic part of the process. The contaminated fuel is sometimes returned to the refinery for redistillation.

3. Base sample from the water phase are heavily contaminated, but no striking sludge formation.

Clean the tank system by means of careful drainage and subsequent dosing of biocide. Mechanical treatment is unavoidable in case of the formation of biofilms (Figure 11)



**Fig. 11 - Biofilm in a pipe**

The steps of a system cleaning can be described as follows:

1. Emptying the tank
2. Removing the biofilms mechanically
3. Cleaning the tank walls and piping system with a biocidal system-cleaner like [grotanol® SR 2](#) → Figure 12 (ideal is circulation in the piping system)
4. First refilling only with fuel containing a minimum amount of biocide (e.g. 50 ppm [grotamar® 71](#))
5. Shock dosing in case of refilling with the former fuel quality (after filtration)

#### **Microbiocidal system cleaner for circulation systems and production plants**

- **High concentrated and free of water**
- **Effective even in very low use-concentrations**
- **Excellent cleaning and microbiocidal effect**
- **Broad, balanced spectrum of effect against bacteria, yeasts and moulds**
- **Good immediate effect**
- **Good anticorrosion properties**
- **Low foaming**
- **Usable for all steel-, copper and aluminium alloys**
- **Fulfills the requirements of the EN 1275**
- **Contains no organically bound chlorine (has no effect on the AOX value)**
- **Use concentration 0.25 – 0.75 % in water**

**Fig. 12 – Benefits of *grotanol*<sup>®</sup> SR 2**

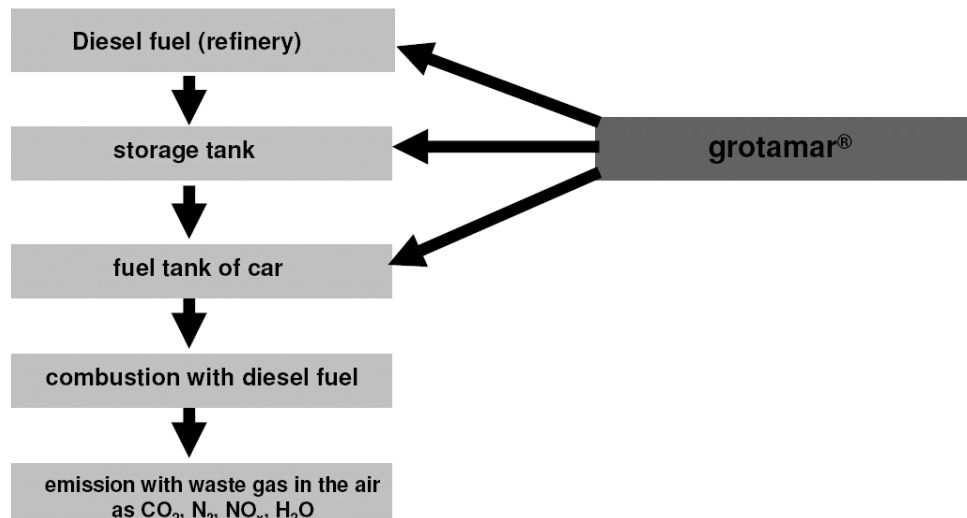
If necessary, adequate mixing can be achieved by recirculating the fuel. In the first week after adding the biocide, the filters must be carefully checked because increased sludge formation can occur as a result of the microorganisms being killed.

With regard to the economic factors, the costs of biocide dosing, compared with the cleaning costs, are of lesser significance, so that in borderline cases a “killing dose” of biocide can often be used, even though there is the risk that cleaning must be carried out later if the dirt load is too heavy.

If fuel and water phases are only moderately contaminated, a careful draining of the fuel systems and subsequent dosing of biocide might be successful.

Examples in practice have shown that an MBO-based biocide can be added at the beginning of the sales route, e.g. in the refinery, so that it goes through all the trade stages until the end user’s tank, e.g. the vehicle tank. A loss of biocide via the sales route happened due to the consumption by killing microorganisms and of migration into the water phase of inadequately drained storage tanks. Hence, correct additional use-concentrations of the biocide have to be determined.

In general different steps in the supply chain might need biocide dosage (Figure 13). The biocide will remain in the fuel until combustion in the engine.



**Fig. 13 – Dosage possibilities of a fuel biocide**

### **Changes in 2007**

Since 2007 the situation regarding microbiological contamination changed severely:

#### Situation before 2007

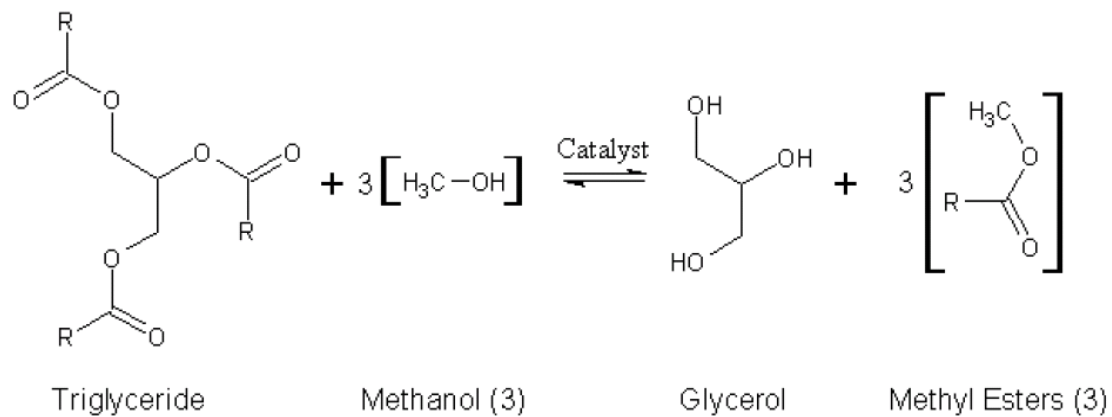
- no blends with FAME
- FAME only traded as neat product
- spot business
- bacterial contamination in the water phase (near to water oil phase)
- rare cases of biofilm formation
- limited problems in the fuel phase

#### Situation since 2007

- introduction of B5 (B7) fuel qualities
- increasing N° of contamination
- change of the germ spectrum (bacteria + fungi)
- problems even in the oil phase
- no sufficient sedimentation
- increasing number of biofilm formation in storage tanks and filtration units
- problems even in tanks without a free water phase

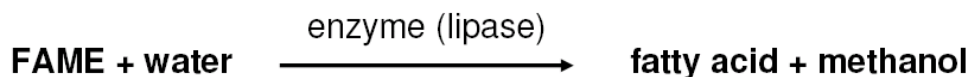
The addition of FAME to the mineral diesel leads to additional challenges for storage and handling of fuel.

Looking at the generic biodiesel reaction (Figure 14),



**Fig 14 – Generic biodiesel reaction**

we can expect also hydrolyses of the ester in the free acid and methanol. This reaction is catalysed by lipase (Figure 15).



**Fig. 15 - Hydrolyses of FAME**

A lipase is a water-soluble enzyme that catalyzes the hydrolysis of ester bonds in water-insoluble, lipid substrates. Lipase is produced by microbial growth. The activity of lipase is industrially used for fat splitting, patented e.g. under US5677160, HENKEL CORP mentioning “Another preferred lipase is the lipase derived from *Pseudomonas* sp. ATCC #21808...”. This indicates that normal waterborne contamination forms lipase. Practical experience has shown a complete hydrolysis of methyl stearate in a spin finishing emulsion at a pH 7 within 24 h. A proper biocidal system cleaning gets more important. Residual biofilm will contain enzymes, which are also active when the microbes are killed.

The FAME itself and especially the fatty acids are well known dispersing agents. The water droplet size will be reduced. Additionally, agglomerates of microorganisms will be dispersed and the particle size reduced. The particle size will reduce the settling speed dramatically (Figure 16 Stokes’ Law).

$$v_p = \frac{2r^2g(\rho_p - \rho_f)}{9\eta}$$

$v_p$  = settling speed  
 $\rho_p$  = density of solid particle  
 $\rho_f$  = density of the liquid  
 $\eta$  = viscosity of the liquid  
 $r$  = diameter of particles

**Fig. 16 - Stokes’ Law**

The reduced particle size can be assumed to be the reason for the increased microbial problem in the fuel phase and the insufficient sedimentation.

### **Additional Requirements on a biocide for B5 – B10 fuel**

The circumstance that microbiological contamination didn't settle and the germs are present in the fuel phase leads to additional requirements for a fuel biocide. The uniform spreading of the biocide in the fuel phase gets mandatory. Self dispersing biocides are needed if stirring or injection during pumping is not possible.

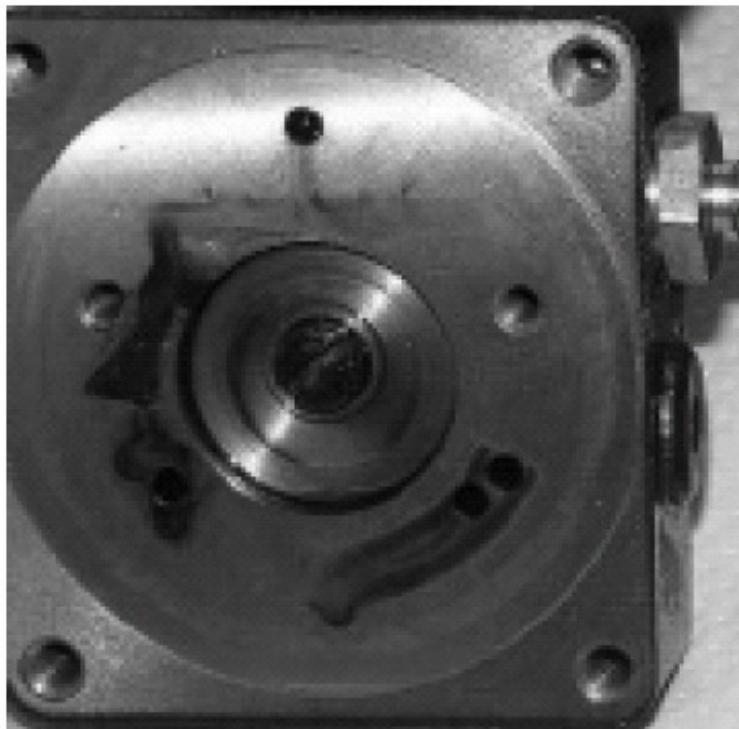
FAME blends are more sensitive to deterioration. A biocidal additive should have anti-oxidising properties.

Copper carry-over in FAME blends are more likely; a biocidal additive should have anticorrosive properties

A tailor-made biocide for B5 – B10 fuel is reasonable.

### **Experience with heating oil**

The main difference between heating oil compared to mineral diesel is the use of copper and copper alloys in oil burning installation. Copper may have a severe impact to the stability of heating oil. It leads to an adulteration of the heating oil. Polymerisation products lead to soiling of filters and nozzles and blockage of fuel pumps (Figure 17).

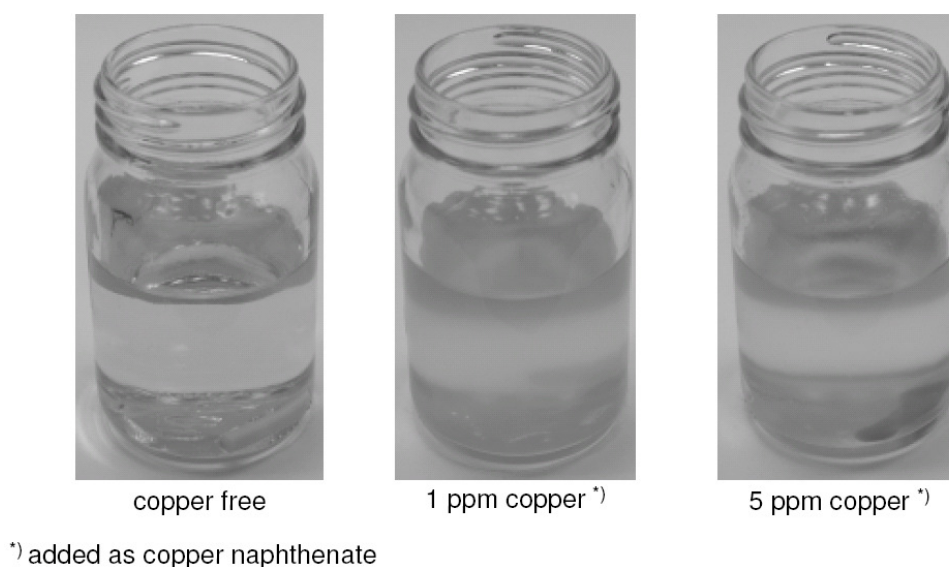


**Fig. 17 – Residues in a heating oil pump leading to blockage**

Hints from the market indicate increased problems with pump blockage in MBO treated heating oil. To evaluate the influence of copper in oil burning installations in a laboratory test we put electrolytic copper plates (100x20x1 mm) in 200 ml heating oil and stirred it for 4 months at room temperature. The test series includes an untreated heating oil, a sample with 500 ppm MBO and a sample with 2500 ppm of the new developed corrosion inhibited, self

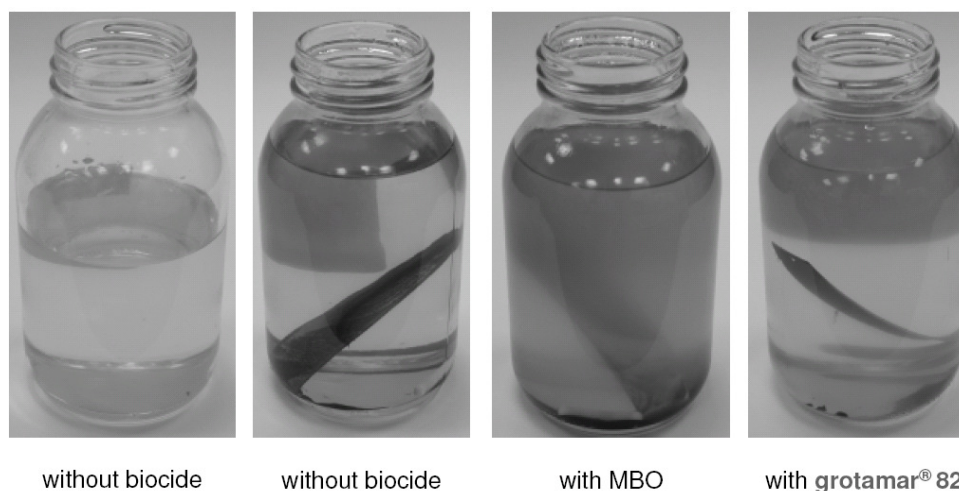
dispersing fuel biocide [grotamar<sup>®</sup> 82](#). 2 months all samples were still clear. After 3 months the sample with MBO gets turbid and a deposit was formed. The samples without biocide and with [grotamar<sup>®</sup> 82](#) remained unchanged.

In a second test series we added copper naphthenate into B5 diesel fuel to introduce 1 and 5 ppm copper. The samples were stirred for 4 month at room temperature. Already after 14 days the samples with 1 and 5 ppm copper showed a dark high viscose deposit and got turbid (Figure 18)



**Fig. 18 – B5, compatibility with copper (4 months stirred at room temperature)**

In a third series we tested B5 diesel fuel with copper plates and stirred them for 6 months at room temperature. The test series includes an untreated B5, a sample with 500 ppm MBO and a sample with 2500 ppm [grotamar<sup>®</sup> 82](#), as well as a sample without copper plate as reference. Already the neat B5 quality leads to severe corrosion at the copper plate and a deposit formation within 2 months. The effect is increased in the sample with MBO. The sample with [grotamar<sup>®</sup> 82](#) showed a better stability compared to the untreated fuel (Figure 19).

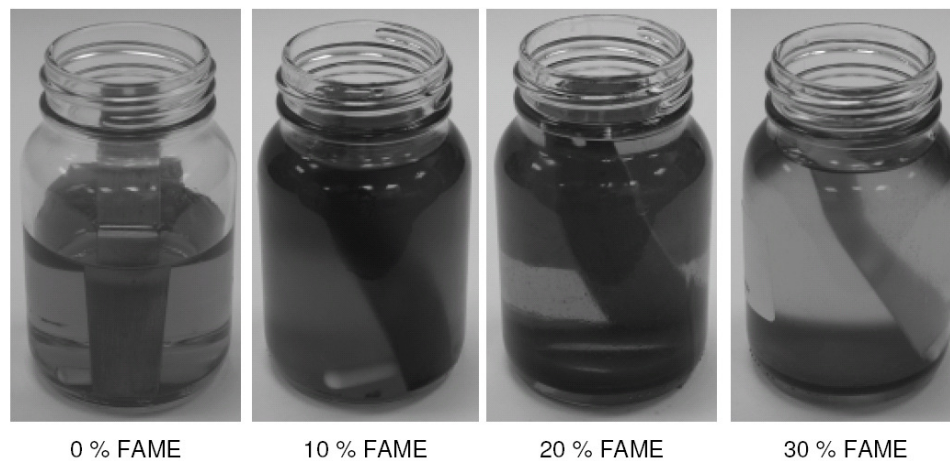


**Fig. 19 – B5, compatibility with copper plates (6 months stirred at room temperature)**



Parallel tested samples without copper plates remained unchanged with and without biocide over the test period of 6 months.

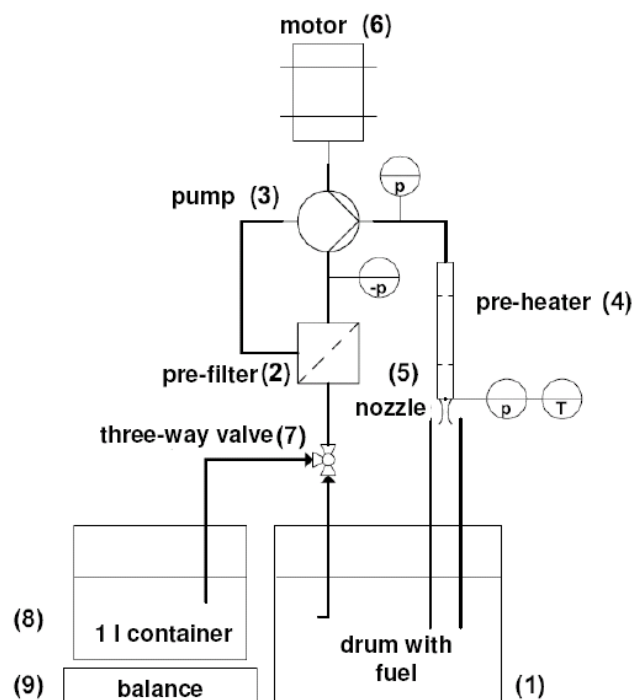
In a fourth series we tested the influence on copper corrosion of the FAME addition to heating oil. Samples with 0 % - 10 % - 20 % and 30 % FAME were stirred with copper plates for 4 months. The FAME addition leads to turbidity within one month, later to a dark high viscose deposit (Figure 20)



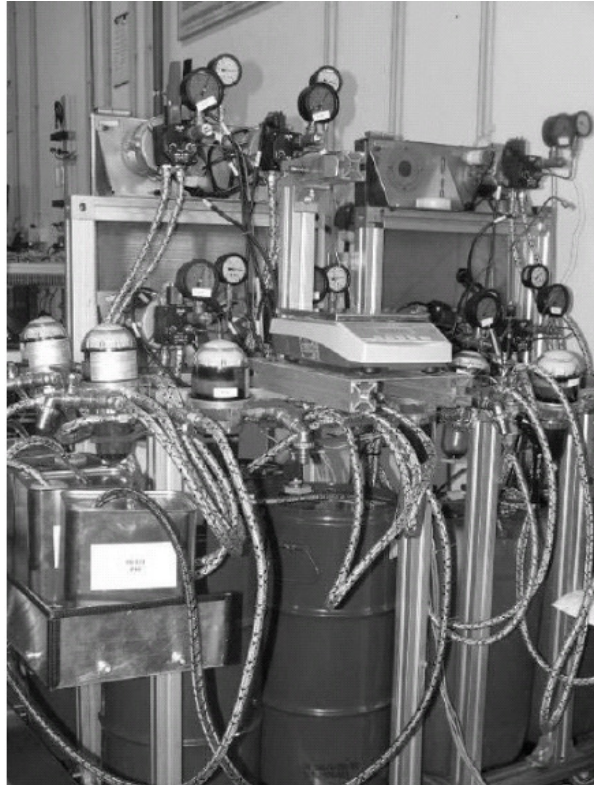
**Fig. 20- Heating oil with FAME addition, compatibility with copper**

### Testing of the performance reliability of fuel oil burner pumps

The OWI Oel-Waerme-Institut developed a “Hardware-in-the-Loop test bench” build up with original parts used for oil burning installations (Figure 21 and 22).



**Fig. 21 - Hardware-in-the-Loop test bench, OWI Oel-Waerme-Institut (schematic)**



**Fig. 22 - Hardware-in-the-Loop test bench, OWI Oel-Waerme-Institut (schematic)**

Summarised results from OWI Oel-Waerme-Institut<sup>17</sup>

1. Standard heating oil can be circulated for 2000 h in the test bench without filter plugging and pump blockage
2. The addition of 500 ppm MBO leads to an increased carry-over copper in the heating oil
3. The copper catalyses the oil deterioration and leads to pump blockage during the test period
4. **grotamar<sup>®</sup> 82** prevents the carry-over of copper and protects the fuel against oil adulteration
5. The addition of FAME to heating oil leads to a dramatic decrease of the performance reliability of the fuel oil burner pumps - it should be avoided without special additivation

**Benefits of the new tailor-made fuel biocide**

Figure 23 shows the benefits of **grotamar<sup>®</sup> 82** in comparison to the classical MBO (**grotamar<sup>®</sup> 71**)

	grotamar <sup>®</sup> 71	grotamar <sup>®</sup> 82
Broad, balanced spectrum of effect (incl. sulphate-reducing bacteria)	✓	✓
Immediate effect and long term efficacy	✓	✓
Good anticorrosion properties (steel corrosion)	✓	✓
Good anticorrosion properties (copper and copper alloys)		✓
Density adapted to fuel		✓
Self dispersing		✓
Good solubility of the biocidal active in diesel fuel and in water	✓	✓
Free of halogens (demanded by the German law on the prevention of emissions)	✓	✓
Free of sulphur	✓	✓
Recommended for the use in heating oil		✓
Good anti-oxidising properties		✓
Tailor-made for modern diesel fuel qualities with FAME content (>B5)		✓
MBO content	> 99 %	20 %

Fig. 23 – Comparison grotamar<sup>®</sup> 71 - grotamar<sup>®</sup> 82

## Conclusion

A few examples are illustrated how microorganisms in fuel oil grow in the presence of water (e.g. condensed water in tanks) and the degradation of hydrocarbons by microorganisms can cause failures in the form of corrosion clogging of oil burner pipes, filters, engines, fuel distribution systems, etc.

Diesel fuel produced needs to be kept free of microorganisms by carefully kept free of water during transportation and storage. When necessary, contaminated diesel fuel must be treated with a biocide.

The problem has changed with introduction of the B5-B10 diesel qualities.

A tailor-made biocide for FAME blends is available (BPD supported).

For a successful disinfection of a fuel tank a complete removal of biofilms is necessary. The use of a biocidal system cleaner is recommended.

Adding FAME to heating oil needs an adaption of the additive package.

Heating oil needs special corrosion inhibited biocides.

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