

# Industrial Experience in Control and Elimination of Microbial Contamination of Petroleum Fuels

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## Summary

In this paper, problems concerning microbial contamination of diesel fuel, discovered in the system of fuel production and distribution in Poland, have been discussed. The actions undertaken to establish the size and scope of the contamination and to determine its origins have been reported. The procedure for the total decontamination of the whole distribution system has been described and the results of investigation of the microbial purity of the fuels after completing the biocidal actions have also been described.

## 1. INTRODUCTION

Operating problems, connected with the microbial contamination of engine fuels, were first noticed in Poland in 1995. After the rainy spring season, an exceptionally hot summer began. During that time, the fuel manufacturers were receiving signals from the users about frequent plugging of fuel filters in the vehicles and the need for their replacement. This information concerned mostly the diesel fuel, and problems were mainly reported by bus and large truck users, whose fuel consumption is very high. In addition, excessive plugging of filter grids, installed in the nozzles of pipelines used to pump fuel from the manufacturers to the distributor terminals, was discovered.

To everybody's surprise, the investigation of the causes of excessive amounts of sludge and sediment formation showed that it was microorganisms that were responsible for such a situation. These microbes felt themselves at home practically in the whole system of diesel fuel production and distribution in Poland. Therefore, a thorough diagnosis of the problem, and the undertaking of action to eliminate the contamination proved essential.

## 2. EVALUATION OF THE NATURE AND ORIGINS OF THE MICROBIAL CONTAMINATION OF DIESEL FUEL IN POLAND

In Poland, about 5.3 million tonnes of diesel fuel are produced each year, and its import equals about 1.2 million tonnes. The greater part of the fuel is distributed by one distribution network, which covers about 80% of the Polish market.

The distribution network includes both large terminals - primary ones, supplied mostly by domestic producers, local ones, supplied mostly by the main terminals, and

a considerable number of filling stations. Fuel is delivered to terminals and stations by pipelines, road tankers and railroad tankers. In such a centralised system, contamination in one of the elements of the distribution chain very easily leads to contamination of the whole system, particularly when the contaminated batch of fuel is introduced into the distributor main storage tanks.

The flow-sheet of the distribution system (an example of one of the largest refineries in Poland) is shown in [Figure 1](#). The additional directions of the distributor fuel supplies that are introduced to the same tanks, are also shown in the scheme.

The presence of the microbial contaminants in diesel fuels used by the end-users for vehicle engine propulsion started an extensive research activity, directed first of all to evaluate the level of contamination of the fuel distribution system and to explain its causes. A control of microbial purity of the fuels was started at the producer seats, in the fuel storage tanks of distributor terminals, and an examination of the imported fuels and fuel components was carried out. The presence of aerobic bacteria, moulds and yeasts was found in practically all of the fuel samples and in the bottom-water layer of the controlled tanks. In many of the fuel tanks, the anaerobic SRB bacteria were also found.

The results of analyses of the microbial contamination level in fuel samples taken at chosen points of the distribution system ([Fig. 1](#)) are shown in [Table 1](#).

The reported results showed that in the producer tanks the level of microbial contamination of fuels and of the water layers was medium or high. The presence of SRB bacteria in the water phase of large tanks was particularly disturbing. As expected, the contamination level in the end-user tanks and in the tanks of larger terminals was higher than in the producer tanks.

The analysis of the imported fuels revealed a large diversity of the contamination level of different supplies. An especially high content of mould in these products could have been the direct cause of the problems encountered while operating the vehicles.

The inspections and investigations allowed a detailed analysis of the causes of the contamination and of its origins. The results indicated that the contamination was introduced into the production and distribution system of diesel fuels in Poland with the imported products, particularly those from beyond the east border.

The results of the analysis of microbial contamination of imported fuel are shown in [Table 2](#). Microbiologically contaminated components of the fuels, imported by the refineries, caused the contamination of the bottom water layer in the producer's tanks, from which microorganisms were distributed with fuel to the whole system of distribution. Additionally, the contamination was introduced to the system by the purchase of imported fuels, stored in the distributor terminals.

### 3. ACTIONS UNDERTAKEN TO ELIMINATE THE MICROBIAL CONTAMINATION OF FUELS.

The confirmation of a high microbial contamination level in the whole system of diesel fuels production and distribution in Poland made it necessary to undertake further radical steps leading to elimination of microorganisms in fuels.

First of all, the complete dehydration of fuel tanks and removal of the contaminated water layer to a possible minimum were taken care of. The next step was choosing an appropriate biocidal agent. Based on comparative research of the efficiency of available biocides, Schulke & Mayr's biocide MAR-71 was chosen. This agent was highly efficient in biocidal actions. In a relatively short time after usage it ensured attaining a high degree of purity in the bottom water phase in tanks and in the fuels themselves, and also, what was very important, the producer guaranteed the possibility of its disposal in waste water.

The agent in quantity of about 200-250 mg per 1 kg of fuel was dosed during a three-week period to the stream of components of diesel fuel or directly to the base fuel in the refinery processing line. Fuel with the biocide was introduced consecutively into all the tanks in the refinery, and was held there for a period of about 50-70 hours, necessary for the appropriate course of biocidal actions in fuel and water phases. After this period, the fuel with the remaining part of the biocide was directed by a pipeline or by tankers to the distributor's tanks, where the decontamination operation was carried out as it had been in the refinery. In this way, the biocidal agent dosed in excess to the diesel fuel at the producer seat, was distributed with the fuel across the whole system of distribution. It remained for a long time in the water layers accumulated on the bottoms of

the tanks that compose the subsequent links of the system.

The decontamination process was carried out under strict control. During the whole operation, both the microbial contamination level and the concentration of the biocide itself in the fuel and in the water layer in subsequent tanks of the distribution chain were examined.

The changes of the biocide MAR-71 concentration in the fuel after passing subsequent contaminated tanks are shown in [Figure 2](#). Those changes depended on the level of fuel and water contamination level and on the amount of water accumulated on the tank bottom.

Simultaneously, the introduction of the biocide to imported products and components was ensured by dosing it directly to the tankers on the state border.

After an eight-week period, samples of water and fuel were taken for examination from chosen tanks, included in the operation. The results of microbiological examinations of these samples are shown in [Table 3](#).

These results show that the efficiency of the biocidal action in the whole diesel fuel distribution system, from the producer to the end-user, was very good. There was a dramatic reduction in the numbers of aerobic bacteria, yeasts and moulds in both fuel and water phases and SRB were completely eliminated. Both the choice of the biocide and the way of carrying out the decontamination operation were appropriate. Introduction of the biocidal agent into diesel fuel already at the stage of fuel production, and its high concentration ensured its delivery to all the elements of the distribution system, and guaranteed the success of the operation. As a result of a favourable distribution coefficient, MAR-71 biocide in a high concentration accumulated in the water layer of each of the tanks for some additional time, until the tanks were dehydrated, and so it additionally protected the system from another possible contamination.

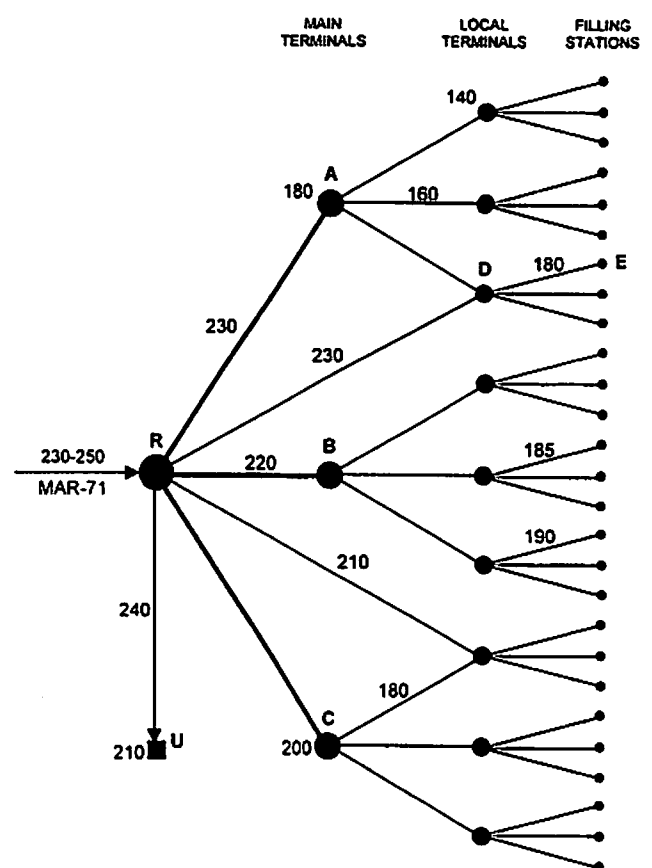
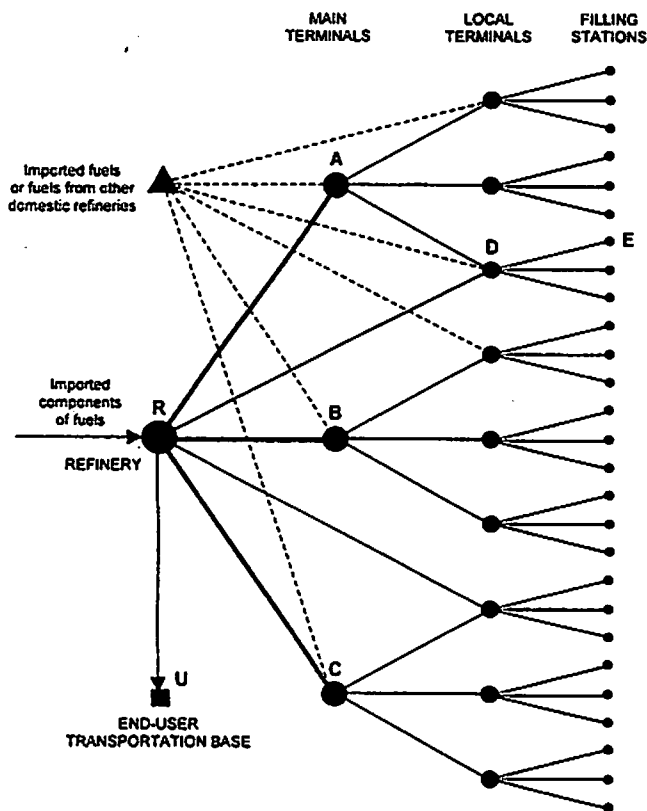
### 4. ECOLOGICAL ASPECTS OF BIOCIDAL USAGE

While choosing the biocide intended for such a wide biocidal action, a safe concentration in water drainage containing the chosen chemical, is very important. In the case of MAR-71 biocide, Schulke & Mayr provided a simple way of chemical destruction of the biocide in waste water, and this company also determined the maximum allowable concentration of the chemical, which was safe for biological sewage plants, and in waste water poured directly into waste systems. Because of that, by an appropriate dilution of the waters containing MAR-71, a safe utilisation of the waste created during the biocidal action was possible.

A low content of biocide in fuels was not a direct problem for the end-users of the decontaminated diesel fuel. MAR-71 is completely combustible and no toxic combustion products are produced.

## 5. SUMMARY

The Polish experience in discovering and combating microbial contamination of fuels shows that the success of the operation is determined mostly by an appropriate choice of the biocidal agent, and by a well-planned way of carrying out the whole operation. While carrying out the action, the discipline and co-operation of all the action participants are very important. Overlooking one of the elements of the action, e.g. insufficient decontamination of one of the elements of the distribution system, may ruin the whole effort and lead to another contamination of the system. The action undertaken in Poland was successful, and our further efforts have led to maintaining the level of microbiological purity in the whole system of fuel production and distribution. The most efficient protection possible prevented contamination both from the outside, e.g. by importing contaminated fuels, and from the inside, as a result of neglecting the cleanliness of tanks, pipelines or tankers. It requires a co-operation of Polish refineries, distributors and importers. An appropriate system of microbial purity control, allows actions which prevent the system from spreading any contamination originating in individual elements of the chain, and this is very important.



**Figure 1:** Flow-sheet of the fuel distribution system in Poland (producer - end-user), based on the example of one of the refineries

- transportation with road tankers or railroad tankers
- fuel pipeline
- - - transportation of the imported fuel

**Figure 2:** Changes of biocide MAR-71 concentration in fuel during pumping to subsequent tanks in the distribution system (mg per kg of fuel)

- transportation with road tankers or railroad tankers
- fuel pipeline

Fuel type	Sampling place	Analysed material	Microorganisms content in fuel (CFU per litre) in water (CFU per millilitre)			
			Aerobic bacteria	yeast	mould	Anaerobic bacteria
Diesel fuel 1	R-1 refinery	Fuel <sup>Δ</sup>	6400	300	800	-
		Water <sup>ΔΔ</sup>	$3 \times 10^3$	$2 \times 10^3$	$5 \times 10^2$	$10^3$
Diesel fuel 2	R-1 refinery	Fuel <sup>*</sup>	1000 - 50 000			-
		Water <sup>**</sup>	$10^6$	$< 10^{2*}$	none <sup>*</sup>	None <sup>*</sup>
Diesel fuel 1	A/Distributor terminal	Fuel <sup>Δ</sup>	8800	300	1200	-
		Water <sup>ΔΔ</sup>	$1 \times 10^9$	$2 \times 10^4$	$1 \times 10^3$	None <sup>*</sup>
Diesel fuel 1	B/Distributor terminal	Fuel <sup>*</sup>	$> 50\ 000$			-
		Water <sup>**</sup>	$10^7$	$< 10^{2*}$	none <sup>*</sup>	(+++)
Diesel fuel 1	D/Local distributor terminal	Fuel <sup>*</sup>	$> 50\ 000$			-
		Water <sup>**</sup>	$10^5$	$< 10^{2*}$	none <sup>*</sup>	(+++)
Diesel fuel 1	E/Filling station	Fuel <sup>*</sup>	$> 50\ 000$			-
		Water <sup>**</sup>	$10^7$	$10^3$	none <sup>*</sup>	(++)
Diesel fuel 2	U/End-user storage tank	Fuel <sup>Δ</sup>	5800	1300	900	-
		Water <sup>ΔΔ</sup>	$2 \times 10^6$	$8 \times 10^4$	$2 \times 10^4$	$10^5$
Diesel fuel 2	U/End-user vehicle tank	Fuel <sup>Δ</sup>	9200	2200	1000	-
		Water <sup>ΔΔ</sup>	$2 \times 10^7$	$4 \times 10^5$	$1 \times 10^3$	$10^4$

- \* The analysis was carried out using the Sig Fuel Test...
- \*\* The analysis for aerobic microorganisms was carried out using Easicult Combi Tests and for anaerobic SRB bacteria Easicult S Tests were used
- Δ The analysis was carried out according to IP 385/95 method
- ΔΔ The analysis for aerobic organisms was carried out using a dilution method, and for anaerobic SRB bacteria - the Sig Sulphide Test was used
- \* Lower determination limit of the method
- \*\* Below the detection limit

**Table 1:** The results of the analysis of microbial contamination of fuels in the distribution system of refinery R-1

	Analysed material	Microorganisms content in fuel [CFU per litre]			
		Aerobic bacteria <sup>1)</sup>	yeast	mould	Anaerobic bacteria <sup>2)</sup>
Delivery 1	fuel	10400	400	20	$< 1000$
Delivery 2	fuel	2000	200	1200	$< 1000$
Delivery 3	fuel	3000	100	400	$< 1000$

- <sup>1)</sup> The analysis for aerobic microorganisms was carried out using IP 385/95
- <sup>2)</sup> The analysis for anaerobic microorganisms was carried out using the Sig Sulphide Test

**Table 2:** The results of the analysis of microbial contamination of imported fuel

Fuel type	Sampling place	Analysed material	Microorganisms content in fuel (CFU per litre) in water (CFU per millilitre)			
			aerobic bacteria	Yeast	mould	Anaerobic bacteria
Diesel fuel 1	R-1 refinery	Fuel <sup>Δ</sup>	40	< 10	10	-
		Water <sup>ΔΔ</sup>	8 x 10 <sup>1</sup>	2 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	< 1 <sup>*</sup>
Diesel fuel 2	R-1 refinery	Fuel <sup>Δ</sup>	100	30	10	-
		Water <sup>ΔΔ</sup>	6 x 10 <sup>1</sup>	3 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	< 1 <sup>*</sup>
Diesel fuel 1	A/Distributor terminal	Fuel <sup>Δ</sup>	100	20	10	-
		Water <sup>ΔΔ</sup>	3 x 10 <sup>2</sup>	3 x 10 <sup>1</sup>	2 x 10 <sup>1</sup>	< 1 <sup>*</sup>
Diesel fuel 1	B/Distributor terminal	Fuel <sup>Δ</sup>		<1000 <sup>*</sup>		-
		Water <sup>ΔΔ</sup>	< 10 <sup>3</sup> <sup>*</sup>	<10 <sup>2</sup> <sup>*</sup>	none <sup>**</sup>	none <sup>**</sup>
Diesel fuel 1	D/Local distributor terminal	Fuel <sup>Δ</sup>		< 1000 <sup>*</sup>		-
		Water <sup>ΔΔ</sup>	< 10 <sup>3</sup> <sup>*</sup>	< 10 <sup>2</sup> <sup>*</sup>	none <sup>**</sup>	none <sup>**</sup>
Diesel fuel 1	E/Filling station	Fuel <sup>Δ</sup>	160	50	20	-
		Water <sup>ΔΔ</sup>	2 x 10 <sup>2</sup>	5 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	< 1 <sup>*</sup>
		Water <sup>ΔΔ</sup>	2 x 10 <sup>2</sup>	1 x 10 <sup>1</sup>	< 10	< 1 <sup>*</sup>
Diesel fuel 2	U/End-user vehicle tank	Fuel <sup>Δ</sup>	80	10	10	-
		Water <sup>ΔΔ</sup>	1 x 10 <sup>2</sup>	1 x 10 <sup>1</sup>	1 x 10 <sup>1</sup>	< 1 <sup>*</sup>

- \* The analysis was carried out using the Sig Fuel Test....
- \*\* The analysis for aerobic microorganisms was carried out using Easicult Combi Tests and for anaerobic SRB bacteria Easicult S Tests were used
- Δ The analysis was carried out according to IP 385/95 method
- ΔΔ The analysis for aerobic organisms was carried out using a dilution method, and for anaerobic SRB bacteria the Sig Sulphide Test was used
- ◆ Lower determination limit of the method
- ◆◆ Below the detection limit

**Table 3:** The results of the examination of the microbial contamination level of fuels in the distribution system of refinery R-1 after having completed the decontamination operation.