Mineral oil hydrocarbons
MOSH/MOAH
A clear focus on analytics. For visionary development.

The world is constantly changing - and so are the numbers and types of legal provisions, ordinances, limit values and approval requirements. New allergies develop - and likewise new means of manipulation and contamination.

We offer our clients safety and certainty. As a responsible partner, we offer analytical and consulting services across the entire value chain. The Berlin-based ifp Institute for Product Quality GmbH is an accredited laboratory for the analysis of foodstuffs, animal feed, drinking water and pharmaceuticals.

Our experience and expertise is entirely at the service of our clients. We are proactive, and we think far ahead. We have developed and perfected many innovative diagnostics ourselves. This allows us to assist clients speedily, yet with diligence and care, frequently cutting through cumbersome red tape.

We pursue a clear vision from which everyone can benefit:

Working closely with our customers to make the food world safer for people is of paramount importance to us.

That is our responsibility.

By sharing our ever-increasing knowledge and by quickly and expertly deploying our skillset to our customers’ advantage, together we ensure lasting, shared success.

Our proven testing methods are used in many research and test labs. And we are well networked: the ifp is involved in numerous research projects. By working with us, users around the world (such as QIAGEN) can benefit from our expertise in the field of food analytics and kit development.

Corporate History

- 2020: Opening of Europe’s most modern laboratory centre for residues and contaminants at the Berlin headquarters
- 2015: Opening of the new headquarter in Berlin-Adlershof
- 2013: Launch of www.wasserschnelltest.de
- 2011: GMP certification as per Section 14 (4) No. 3 of the German Drug Law
- 2010: EnzymeFast® launch, InterLabTec AWARD 2011
- 2009: DIN EN ISO 13485 certification for the production of medical devices
- 2006 - 2008: VitaFast®, ID-Vat®, PCRFast® and ImmunoFast® launch
- 2005: DIN EN ISO 9001 certification for the production of diagnostics
- 2004: Founding of ifp Privates Institut für Produktqualität GmbH
Residues of Mineral oil hydrocarbons in foodstuffs are a much-discussed topic in industry and retail. This brochure informs you about the mineral oil hydrocarbons MOSH and MOAH, their occurrence, analysis, as well as legal aspects. The following contents were created by a team of proven experts from the institute for product quality.

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**Introduction**

Mineral oil hydrocarbons (MOH) include mixtures of saturated hydrocarbon compounds from mineral oil (MOSH) and mixtures of unsaturated/aromatic hydrocarbon compounds (MOAH). Mineral hydrocarbon residues have been in the spotlight for consumers in recent years. The main concern has not been contamination from crude oil, but rather substances and substance groups distilled from crude oil and further processing. Typical examples include grease or inks containing mineral oil.

MOH can find their way into foodstuffs by various means. One way is migration from packaging materials containing MOH. As mineral oil hydrocarbons are ubiquitous, sources of contamination are very diverse. They can find their way into foodstuffs by various means. Starting with agriculture up to storing in retail, a contamination can take place in every stage of production.

Advanced analytical development with regard to sensitivity and automation means that it is now possible to detect MOSH and MOAH representing less than 0.5 to 1 mg/kg in routine examinations. Thanks to this progress, new sources of contamination are constantly being identified and addressed.

In routine analysis, mineral oil hydrocarbons are recorded as sum parameters (by HPLC-GC-FID coupling), as there are several million individual compounds. That is why the exact composition of the individual substances in a sample is rarely known and thus makes a toxicological assessment and the associated stipulation of limits or guidelines difficult. More in-depth analysis (using GCxGC-ToF-MS), which can determine the exact composition of a MOH sample, is a well-established procedure at ifp. Precise identification of individual substances or substance groups is essential, not least because of the carcinogenic potential of some aromatic hydrocarbon compounds.
MOSH (Mineral Oil Saturated Hydrocarbons)\textsuperscript{1, 2, 3}

MOSH generally refers to mixtures of saturated hydrocarbon compounds from mineral oil. These can consist of cyclic (e.g. naphthenes) or acyclic alkanes (e.g. paraffins) and are usually highly alkylated. They are either directly derived from crude oil or are formed by hydrogenation of aromatic hydrocarbons or other transformation processes during the refinement of crude oil.

Saturated hydrocarbon compounds have no double bonds between the carbon atoms and are, therefore, very stable and not very reactive. They can also be accumulated by the body.

In crude oil, MOSH make up approx. 80\% of the main component.

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**Figure 1:** Chemical structure of selected compounds of the MOSH fraction. On the left side three representatives of a theoretical 18 structural isomers are shown for the molecular sum formula \( \text{C}_8 \text{H}_{18} \).

**Acyclic alkanes**

- Octane
- Methylheptane
- Trimethylpentane

**Cyclic alkanes**

- Cyclohexane
- Decalin
- Decahydroazulene

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Source:


MOAH (Mineral Oil Aromatic Hydrocarbons)\(^1, 2, 3, 4\)

MOAH refers to mixtures of unsaturated/aromatic hydrocarbon compounds from mineral oil. Unlike saturated compounds, aromatic hydrocarbons do contain double bonds between the carbon atoms and form aromatic annular structures (benzene ring system).

MOAH compounds contain one or more aromatic rings and are usually highly alkylated. These molecular properties increase their chemical reactivity. Aromatic compounds can be metabolised in the human body.

Natural crude oil has a MOAH content of approx. 20 %.

**Good to know**

MOAH contain potentially carcinogenic components. Therefore, there should be no traceable transfer of MOAH to foodstuffs.

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\(^3\) Questions and answers about mineral oil components in chocolate from Advent calendars and other foodstuffs (as at: 26 November 2015 based on BfR reports from March 2010 and November 2012).

MOSH Analogues

MOSH analogues\textsuperscript{1, 2}, due to their chemical similarity, are very difficult to separate MOSH analogues from the MOSH fraction using conventional HPLC-GC-FID methods, which can result in a higher MOSH content. The following substance groups are particularly relevant:

- **POSH** (Polyolefin oligomeric saturated hydrocarbons)
  POSH are saturated oligomers, which can be detected along with MOSH. These oligomers are formed in the production of polyethylene and polypropylene, which make up the main component of most plastic packaging.

- **PAO** (Poly Alpha Olefine)
  PAO are synthetic polymers. These are processed to various lubricants or hotmelt adhesives. Most poly-alphaolefin-based lubricants are permitted for use in food-processing plants.

- **MORE** (Mineral oil refined products)
  These include all other mineral oil raffinates approved and used as additives and processing aids such as paraffinic waxes.

\textsuperscript{1} “Toolbox zur Vermeidung von Einträgen unerwünschter Mineralölkohlenwasserstoffe in Lebensmittel” (Toolbox for preventing unwanted mineral oil hydrocarbons from entering foodstuffs) Lebensmittelverband Deutschland e.V. (BLL) 2017

\textsuperscript{2} German Federal Institute for Risk Assessment (BfR), Berlin, and Kantonales Labor, Zürich (2012) Measurement of mineral oil hydrocarbons in foodstuffs and packaging materials

\textbf{Good to know}

These MOSH analogues can be identified and quantified at ifp by GCxGC-ToF.
Please note
The sources of contamination are numerous and versatile!

MOSH/MOAH Pathways

Natural sources and contamination

- exhaust fumes from combustion engines
- emissions from energy supply systems and industrial plants
- pesticides
- packaging materials
- grease from harvesters or production machines

Contamination from specific applications

- batching oil in jute and sisal sacks
- harvesting tools
- cosmetics
Which Foodstuffs are Affected?

Basic ally, all foodstuffs can be affected. Because of their lipophilic properties, fatty foodstuffs tend to be most susceptible to MOSH/MOAH contamination.

**Cereals, flour and rice**, on the other hand, are susceptible to contamination because of their large surface area.

**Jute and sisal sacks** are often used to transport and store cocoa beans, coffee and spices. The batching oils used to process these natural fibres can migrate uncontrolled to the raw foodstuff.

A systematic list can be found in the leaflet published by the **Bund für Lebensmittelrecht und Lebensmittelkunde e.V. (BLL)** (BLL Toolbox)

1. “Toolbox zur Vermeidung von Einträgen unerwünschter Mineralöl Kohlenwasserstoffe in Lebensmittel” (Toolbox for preventing unwanted mineral oil hydrocarbons from entering foodstuffs) Lebensmittelverband Deutschland e.V. (BLL) 2017
Legal Situation

Safe foodstuffs

According to the latest scientific research, a health risk from aromatic mineral oil components, especially PAH-like 3-7 ring MOAH, cannot be ruled out.

Regulation (EC) No 178/2002, article 14 stipulates that foodstuffs that are not safe must not be put into circulation. Furthermore, foodstuffs are not considered to be safe if it is assumed that they are harmful or are not fit for human consumption.

The content of unwanted substances in foodstuffs must be reduced as far as possible following good manufacturing practice (ALARA principle). According to the contaminant control regulation (EEC) No 315/93, foodstuffs containing contaminants at unacceptable levels with regard to health, and in particular toxicologically, must not be put into circulation. Furthermore, contaminants should be limited to the minimal values that can be reasonably achieved by manufacturing at all of the stages stated in Article 1.

Safe food contact materials (FCM)

According to Article 3 of framework agreement (EC) No 1935/2004, materials and objects must be safe for food contact and must not release any components into foodstuffs in amounts that could put the health of the consumer at risk and unacceptably change the composition of the foodstuff.

The current fourth draft of the “Mineral oil regulation” stipulates an obligation to use functional barriers to prevent a migration of MOAH from packaging made from recycled materials.

Any migration of MOAH from packaging made from recycled materials should not be detectable in accordance with consumer protection. The legal limit of detection limit is 0.5 mg/kg foodstuff or food simulant.
In early 2019, the Joint Research Centre of the European Commission published guidance on sampling, analysis and data reporting for the monitoring of mineral oil hydrocarbons in food and food contact materials.

As indicated by the title, certain issues were standardised. Successful, meaningful EU monitoring depends above all on the uniform, standardised representation of results. In the past, it was frequently impossible to directly compare the measured results of different laboratories as the fraction distribution differed or was measured with differing sensitivities, for example. The following uniform structure for the analysis and presentation of results has now been introduced:

**Structure of the MOSH & MAOH according to hydrocarbon chain length**

<table>
<thead>
<tr>
<th>MOSH</th>
<th>MOAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total MOSH</td>
<td>Total MOAH</td>
</tr>
<tr>
<td>≥ C\textsubscript{10} \text{ bis } ≤ C\textsubscript{16}</td>
<td>≥ C\textsubscript{10} \text{ bis } ≤ C\textsubscript{16}</td>
</tr>
<tr>
<td>&gt; C\textsubscript{16} \text{ bis } ≤ C\textsubscript{20}</td>
<td>&gt; C\textsubscript{16} \text{ bis } ≤ C\textsubscript{25}</td>
</tr>
<tr>
<td>&gt; C\textsubscript{20} \text{ bis } ≤ C\textsubscript{25}</td>
<td>&gt; C\textsubscript{25} \text{ bis } ≤ C\textsubscript{35}</td>
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<td>&gt; C\textsubscript{35} \text{ bis } ≤ C\textsubscript{50}</td>
</tr>
<tr>
<td>&gt; C\textsubscript{35} \text{ bis } ≤ C\textsubscript{40}</td>
<td>&gt; C\textsubscript{40} \text{ bis } ≤ C\textsubscript{50}</td>
</tr>
</tbody>
</table>

Furthermore, the guidance regulates how the measured contents are to be stated:

- Unit in mg/kg
- With two significant digits (e.g. 150, 15, 1.5 or 0.15 mg/kg)
- Results rounded according to ISO 80000-1:2009

Source:
In the frame of Commission Recommendation (EU) 2017/84 - JRC Technical Report
In addition to the aforementioned new aspects and standardisations, minimum requirements were established for the quantification limits with which each laboratory must comply. The table lists the following recommendations/requirements, sorted by product group:

- **LOQ (max)** – maximum limit of quantification, which should not be analytically exceeded
- **LOQ (target)** – limit of quantification for the product group that is to be analytically addressed in each case
- **acc. R** - analytically acceptable and defensible recovery

Recommended maximum limit of quantification, target limit of quantification and acceptable recovery, sorted by product group.

<table>
<thead>
<tr>
<th>Category</th>
<th>Food examples</th>
<th>LOQ (max) in mg/kg</th>
<th>LOQ (target) in mg/kg</th>
<th>acc. R in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry, low fat content (&lt; 4 %)</td>
<td>Bread and bread rolls, breakfast cereals, cereals for human consumption; pasta, other cereal products</td>
<td>0.5</td>
<td>0.1</td>
<td>80 - 110</td>
</tr>
<tr>
<td>Higher fat content (&gt; 4 %)</td>
<td>Fine pastries, confectionery (including chocolate) &amp; cocoa, fish, meat, fish products (e.g. canned fish), oil seeds, pulses, sausages, nuts</td>
<td>1.0</td>
<td>0.2</td>
<td>70 - 120</td>
</tr>
<tr>
<td>Fats &amp; oils</td>
<td>Animal fats (e.g. butter), edible vegetable oils</td>
<td>2.0</td>
<td>0.5</td>
<td>70 - 120</td>
</tr>
<tr>
<td>Paper &amp; cardboard</td>
<td>Reporting only up to C&lt;sub&gt;35&lt;/sub&gt;</td>
<td>10.0</td>
<td>5.0</td>
<td>80 - 110</td>
</tr>
</tbody>
</table>

Most of the requirements described in the publication have already been established practice at the Institute for Product Quality (Ifp Institut für Produktqualität GmbH) for some time. As of July 2019, all outstanding issues will be integrated into the routine analysis system.
State Working Group on Consumer (LAV) and Food Federation Germany (BLL)

Following an analysis of more than 10,000 data sets, it was possible to establish orientation values for certain groups of food, which are generally achievable as part of good manufacturing practice (GMP). These orientation values can serve as a starting point for minimisation efforts (see BLL toolbox).

<table>
<thead>
<tr>
<th>Product group food category</th>
<th>MOSH and analogues (mg/kg)</th>
<th>MOAH (mg/kg)</th>
<th>Application notes (Notes on the food groups included/products not included and delimitations/potentially on reasons, database or other particular features)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable oils such as rape seed oil, sunflower oil, linseed oil, olive oil (except oils/fats from tropical plants and soybean oil)</td>
<td>13 n. q.²</td>
<td>2 n. q.²</td>
<td>these orientation values are not intended to be applied to oils/fats derived from tropical plants (e.g. coconut oil) due to insufficient statistical database (in December 2018)</td>
</tr>
<tr>
<td>Bread and cookies, fine pastries, cereal products and cereal-based products, cereals, rice, pasta</td>
<td>6 n. q.³</td>
<td>3 n. q.³</td>
<td>only applicable to end products for consumers; not for raw goods or raw dough</td>
</tr>
<tr>
<td>Confectionery (sweets, except chewing gum), chocolate and cocoa-based confectionery</td>
<td>9 n. q.³</td>
<td>3 n. q.³</td>
<td>only applicable to end products for consumers</td>
</tr>
</tbody>
</table>

n. q. - not quantifiable, i.e. contents < limit of quantification  
² LOQmax for each fraction for fats/oils corresponds to 2 mg/kg (cf. JRC Technical Report)  
³ LOQmax for each fraction for low-fat foods < 4% fat corresponds 0.5 mg/kg; > 4% fat corresponds to 1 mg/kg (cf. JRC Technical Report)

Source:
Information of the Lebensmittelverband Deutschland e. V. (Food Federation Germany), last updated: April 2019
MOSH: mineral oil saturated hydrocarbons
- paraffin-type (open-chain, usually branched) and naphthene-type (cyclic) saturated hydrocarbons

MOAH: mineral oil aromatic hydrocarbons
- aromatic hydrocarbons highly alkylated, primarily 1 - 5 ring systems
- highly complex mixtures
**POSH: Polyolefin oligomeric saturated hydrocarbons**
- Synthetic oligomers
- Chemically similar to MOSH
- When they occur alongside MOSH, they cannot be quantitatively separated by LC-GC-FID

**PAO: Poly Alpha Olefine**
- Synthetic hydrocarbons with short main and long side chains
- Typically main component of lubricants used in the food industry
DIPN: Diisopropynaphthalene
- Indicator for recycled cardboard
- Origin: Non-carbon paper, not separable through recycling process

Please note
Since DIPN is hardly used in the recycled process can be separated, DIPN is a indicator for recycled cardboard.

Good to know
The use of recycled cardboard can lead to high levels of contamination, both in direct contact and by gas phase migration.
GCxGC-ToF

Two-dimensional gas chromatography together with a mass-selective time-of-flight detector (GCxGC-ToF) can separate mineral oil hydrocarbons (MOSH/MOAH) in complex compounds from other types of hydrocarbon (synthetic oligomers such as POSH or naturally occurring terpenes). It is also possible to obtain more detailed structural information, e.g. about the number of aromatic nuclei, existing isomers and the level of alkylation, and thereby identify and quantify the source of the contamination (polyolefins, adhesives, ink formulations or grease).

Online HPLC-GC-FID, a long-established method which is now routinely used, cannot chromatographically separate the substance classes MOSH (mineral oil saturated hydrocarbons) and POSH (polyolefin oligomeric saturated hydrocarbons) from each other. It can also be difficult to determine the content of aromatic mineral oil components if resin oligomers or other aromatic compounds are present.
Determining the Barrier Properties of Packaging Films

Many potentially harmful compounds (e.g. mineral oils, softeners, ink components) can be migrate to foodstuffs from packaging materials. A **functional barrier layer** offers protection against these substances.

The **SVI guideline** is a simple simulation test for investigating the barrier function and any possible adsorption effects in the packaging material.

The basic setup is illustrated below. The plastic film to be examined is stored between a donor paper (containing representative marker substances) and an acceptor paper (free from contamination) under defined conditions. The marker substances can then diffuse from the donor paper through the plastic film into the acceptor paper.

### Basic structure of the barrier test in accordance with the SVI guideline

The assessment then takes the form of a comparative measurement between the donor paper and acceptor paper. The following representative substances are used for the analysis:

- Undecane
- Pentylbenzene
- Tridecane
- 2-Methylnapthalene
- Bicyclohexyl
- 1-Methylnaphthalin
- Tri-tert-Butylbenzene
- Diisopropyl phthalate
- Heptadecane
- 4-Methylbenzophenone
- 5-alpha-Cholesterol
- Tri-tert-Butylbenzene
- Diisopropyl phthalate
- Heptadecane
- 4-Methylbenzophenone
- 5-alpha-Cholesterol

**Assessment**

The barrier effectiveness is considered to be adequate if less than 1% of any investigated substance is transferred from the donor paper through the barrier (plastic film) to the acceptor paper by the product's best-before date.

The use of recycled board in outer packaging is in this case considered safe.

**The barrier test is suitable for:**

- Plastic films (single layer, multilayer)
- Long-term storage at room temperature
- Dry foodstuffs

Source:
Sampling and Shipping of Samples

Things to keep in mind when taking samples and shipping them to the ifp:

**Sampling:**
- representative sample and sufficient material (for food samples, at least 50 – 100 g are required for analysis)
- wash hands before sampling and avoid direct contact with the sample as best as possible
- use only suitable sample containers
- clean glass and PET containers are very well suited
- metal containers and aluminium foil are generally very well suited as primary packaging (caution: in rare cases, lubricants may be used during production)
- we will gladly check your packaging in advance for possible contamination sources
- caution when handling lids: the sealing in the sealing caps of some containers or the sealing caps themselves may also contaminate the sample; we recommend that you place a piece of suitable aluminium foil between the sample container and the sealing cap
- please do not use recycled cardboard as primary packaging!

**Shipping samples:**
- when shipping sample containers made of glass, they must be protected against breaking.
- in case of doubt, an additional layer of a suitable aluminium foil is helpful.

**Duration of analysis:**
- depending on sample and arrangement
- between 6 and 10 days
- express between 8 hours and 5 days
Our Services at a Glance

Analytics
- comprehensive offer
- accredited to ISO 17025
- immediate service on request
- 24-hour emergency service
- HPLC-GC-FID
- GCxGC-ToF

Packaging
- Migration tests to DIN SPEC 5010 and DIN 13130
- Barrier tests

Advice
- comprehensive advice on analyses and scope of inspections
- advice on food regulatory evaluation of analysis results
- planning of stage-by-stage monitoring
- advice on minimisation measures
- Training on-site or at ifp
Do you have questions about MOSH/MOAH or consumer goods? Would you like a quote? Are you looking for advice on migration testing? We’ll be delighted to help!

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We stand ready to help - and that goes for all concerns relating to food, water and pharmaceuticals.

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This brochure reflects the state of research current at the time of issue and makes no claim to be exhaustive.