Mineral oil hydrocarbons in food

Fact Sheet: The situation with folding cartons and paper packaging
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Note: Version 3 contains amendments in chapters 2, 3, 6 and 8 compared with version 2 (30Jan19)

Content

1. Management Summary

The “mineral oils” discussed here are MOSH (Mineral Oil Saturated Hydrocarbons) and MOAH (Mineral Oil Aromatic Hydrocarbons). Both MOSH and MOAH are complex combinations of very similar chemical compounds with different chain lengths, molecule sizes and branch patterns.

Sources in food are contamination via the food manufacturing process itself, the environment and migration from packaging materials. The level of migration from the packaging to the food depends in particular on the shelf life of the food, the original content in the packaging, the packaging design and the physical and chemical properties of the food.

Information from Toolbox projects indicate ways to minimise the entry routes. They provide summaries in table form of the potential entry routes for mineral oil hydrocarbons that are known at the present time.

Various national and European monitoring programmes aim to give an overview of food exposure and pinpoint possible connections to packaging materials. As awareness of contamination has increased, so the measurable concentration levels of mineral oil hydrocarbons in many foods have been reduced substantially.

In close co-operation with paper manufacturers and processors, the folding carton industry supplies a variety of solutions for protecting packaged products against mineral oil hydrocarbons. The objective is to find the optimum solution for the food in question via close liaison between all the market players.

Identification and quantification of MOSH and MOAH in food and packaging are demanding analytical assignments. In order to obtain comparable results, a number of conventions and specifications therefore need to be observed. With the standard processes, it is possible to reach MOSH and MOAH detection limits of 0.5 mg/kg reliably in most foods.

At the current time, there are no conclusive toxicological and health analyses of MOSH and MOAH in food.

The European Food Safety Authority (EFSA) has expressed its concern about both MOSH (e.g. with reference to accumulation) and MOAH (suspected to be potentially carcinogenic). Between 2011 and 2017, the German Ministry of Food and Agriculture (BMEL) compiled a number of draft regulations about food contact materials based on recovered paper and board. In spite of the efforts made by the BMEL over a period of many years, a legal regulation has not been issued.

The current legal and scientific situation requires distributors of food and packaging manufacturers to minimise MOSH and MOAH.

2. Chemistry and the Presence of Mineral Oil Hydrocarbons

Mineral oils made from highly purified, refined and processed crude oil have been used for specific purposes in cosmetics, pharmaceuticals and food for many decades now. Some examples are Vaseline, microcrystalline waxes and liquid paraffins.

Food can, however, also be contaminated by lower-quality mineral oils, which migrate into the food, for example via contamination in the food manufacturing process, from recycled fibres in paper packaging or from the environment. In the latter case, the mineral oils come from printing inks based on mineral oils that are used for such purposes as newspaper printing [1-4].

The combinations detected in food consist of saturated and/or aromatic hydrocarbons. Chemically speaking, the saturated hydrocarbons (**MOSH** = **M**ineral **O**il **S**aturated **H**ydrocarbons) are linear and ring-shaped hydrocarbons with single C-C bonds. **MOAH** (= **M**ineral **O**il **A**romatic **H**ydrocarbons) consist of a complex combination of mainly highly alkylated hydrocarbons with one or more aromatic rings. Both MOSH and MOAH are complex combinations of very similar chemical compounds with different chain lengths, molecule sizes and branch patterns. The ratio of MOSH to MOAH varies according to the crude oil refining process. In mineral oil hydrocarbons from newspaper printing inks currently in use, the ratio is typically about 75-80% MOSH and 25-20% MOAH.

Since 03/2019, a definition of mineral oil hydrocarbons (MOH) can also be found in the guideline issued by the European Reference Laboratory for Food Contact Materials [46]. In this guideline, MOH are defined as being obtained originally from crude mineral oils or from coal, gas or biomass by Fischer-Tropsch synthesis. A distinction is made in that hydrocarbons which occur naturally, such as odd n-alkanes, natural olefins of terpenic origin (squalene, steroids, carotenoids) and hydrocarbons from PE/PP plastic oligomers (POSH) or synthetic isoparaffins with side chains (POA), e.g. from adhesives or lubricants, are not covered by the definition of mineral oil-based hydrocarbons (MOH).

3. Mineral Oil Hydrocarbons in Food

There have already been frequent reports about mineral oil contamination of food in the past. Hazel nuts, cocoa beans or rice that were transported in jute sacks and were contaminated by the batching oil used in treatment of the jute fibre were a prominent example in 1991. Hydrocarbons from release agents or waxes were also found in bakery products and sweets (1991). Ukrainian sunflower oil with high levels of MOSH and MOAH contamination caused a stir in 2008 [4, lecture by M. Biedermann].

Attention was drawn to mineral oil hydrocarbons in connection with food and the packaging used for it after the German Institute for Risk Assessment (BfR) reported in 2009 [2] that these hydrocarbons can in some cases be present in amounts of up to > 1,000 mg/kg MOSH and > 250 mg/kg MOAH in packaging made out of recycled board or paper [5]. At the beginning of the debate, printing inks containing mineral oil that were used for food packaging purposes were a possible source of hydrocarbons. Parts of them can migrate to food, as studies commissioned by the German Ministry of Food, Agriculture and Consumer Protection also demonstrated in 2012 [5-7]. Printing inks containing mineral oil that are used primarily in newspaper printing and contain solvents based on mineral oil were identified as the main source of mineral oil hydrocarbons in recycled board and paper.

Folding carton board based on virgin fibres can also contain Mineral Oil Saturated Hydrocarbons (MOSH). Certain aromatic-free hydrocarbons are approved for use as formulation resources for paper applications, e.g. for food contact in accordance with BfR Recommendation XXXVI. These hydrocarbon solvents (paraffinic, naphthenic, with a carbon number between C10 and C20) may be used, provided that they satisfy the purity requirements for liquid paraffins (cf. official notice 155 in the "Bundesgesundheitsblatt" 25 (1982) 192). Migration of substances with a carbon number between C10 and C16 into food may not exceed the temporarily specified level of 12 mg/kg in this context. In the case of substances with a carbon number between C16 and C20, migration into food may not exceed the temporarily specified level of 4 mg/kg. It is therefore possible to determine MOSH content in virgin fibre board too; aromatic hydrocarbons (MOAH) should not, on the other hand, be detectable as originating from virgin fibre board.

Mineral oil hydrocarbons are, however, also detected in food very frequently when contamination from board or paper retail packaging is out of the question.

A review study of existing data in the Netherlands [39] carried out in 2018 revealed that dry foods like rice, pasta, breakfast cereals and chocolate coatings that are packaged in board account for only a small amount of overall mineral oil exposure due to food in the Netherlands. Measures aimed at reducing exposure attributable to the use of board packaging would therefore have only a limited impact in the Netherlands.

What can in general be said is that a variety of different sources of contamination have been identified. In order to reduce the contamination of food by undesirable mineral oil hydrocarbons, industry (Association of the German Confectionery Industry, BDSI [8], German Federation for Food Law and Food Science, BLL [10]), FoodDrink Europe [47] has developed "Toolbox"© concepts. They provide summaries in table form of the potential entry routes for mineral oil hydrocarbons

that are known at the present time (state of the art in 2017). On the basis of such information, every company can investigate and implement measures to reduce contamination that are customised individually to meet the requirements of its own particular processes and products.
The entry routes can be divided up into unintentional sources, such as contamination from packaging materials based on recovered paper or transport materials like jute sacks for raw materials, work in progress and final products, improper use of machine lubricants, compressed air that contains oil and the necessary and targeted use of substances, such as food grade lubricants, liquid paraffins, waxes and other paraffin products as food additives, dust binders for pesticides etc. Natural food components, such as wax layers on fruit and certain oligomers from polyolefin plastics, are closely related to some mineral oil hydrocarbons at the chemical level too [9].
To a minor extent, contamination of food by mineral oil hydrocarbons has, finally, been detected via the environment too, attributable particularly to exhaust gases from internal combustion engines, heating systems and power plants.
In order to obtain an overview of food exposure and pinpoint possible connections to packaging materials, the EU recommended that the member states carry out a monitoring programme in 2017 and 2018 to measure MOSH and MOAH levels in food and the packaging materials used for them [11]. Consumer exposure to MOSH and MOAH in ready-to-eat food is also being investigated in the seven-year MEAL study carried out by BfR [12]. Various consumer organisations like Stiftung Warentest, Ökotest or Foodwatch have different food groups tested regularly by laboratories in specific campaigns to determine any mineral oil content, the most recent example being Ökotest with its investigation again of advent calendar chocolate in December 2018 [Ökotest 12-2018, "Oh du Fröhliche – nicht nur Schoki im Kalender"]. Information about the underlying sources of the mineral oil hydrocarbons in the food is not normally provided in this context. In addition to this, the standards for evaluating the level of MOSH/POSH and MOAH content determined tend to be both arbitrary and variable. As awareness of contamination has increased, so the measurable concentration levels of mineral oil hydrocarbons in very many foods have been reduced substantially.

4. Migration of Mineral Oil Hydrocarbons

Migration of MOSH and MOAH from packaging to dry food at room temperature occurs mainly by evaporation of the more volatile hydrocarbons with carbon numbers up to about C24 [5-7]. The mineral oil hydrocarbons are transported via the gas phase and either condense on the food or are adsorbed by the food. This means that MOSH and MOAH can also migrate when there is no contact between the food and the packaging. Inner packaging made of paper and many plastics like polyethylene (PE) or polypropylene (PP) can only delay but not prevent the migration of mineral oil hydrocarbons from the outer packaging to food too. The non-polar, volatile compounds migrate through these non-polar plastics or diffusion-open papers.

In contrast to this, contact with such fatty food as take-away pizza in transport boxes can lead to MOSH and MOAH migration up to higher carbon numbers of C35 and higher [5, 13].

The level of migration depends not only on the concentration of the mineral oil hydrocarbons in the packaging and/or the surface/mass ratio of the packaging and food; it is also determined to a large extent by the type of food, the contact period, the temperature, the concentration gradient and thus the distribution balance. The air exchange under the storage conditions plays a role too. Food stored in packaging that contains mineral oil in the middle of a pallet had higher MOSH and MOAH concentration levels than identical samples that came from the edge zones of the pallet. In the latter case, a large proportion of the hydrocarbons can evaporate outwards into the ambient air and does not therefore condense on the food.

Low storage temperatures of the kind to which frozen food is exposed slow evaporation and thus migration of mineral oil hydrocarbons substantially and thus reduce the risk of food contamination considerably [3, 5].

In storage tests, hydrocarbons based on mineral oil that migrated from board packaging reached concentration levels of up to 52 mg/kg MOSH ≤C24 and 9 mg/kg MOAH ≤C24 in food at room temperature [5, 7].

5. Comprehensive Evaluation of Packaging Solutions

At the beginning of the public debate about mineral oil hydrocarbons in food, folding cartons and paper packaging made from recycled material were considered to be the main sources of contamination. As a result of the ongoing debate about mineral oil over a period of several years within the entire food chain, including the packaging and raw material industries, private and public testing facilities, authorities and non-governmental organisations, extensive information is available today about foreseeable contamination sources as well as about avoidable and unavoidable ubiquitous contamination.

Numerous influencing factors, such as the kind of food (fatty, dry, moist etc.), the shelf life and thus the duration of contact with the packaging material, the processing, transport and storage conditions and the way the food is handled by the consumer, need to be taken into consideration when configuring an appropriate packaging system. Mineral oil is an issue that is being debated not only in the food industry but also in the cosmetics, pharmaceuticals and pharmacy fields, in order to avoid contamination by aromatic hydrocarbons, among other things [4].

In close co-operation with paper manufacturers and processors, the folding carton industry provides various solutions to protect packaged products from mineral oil hydrocarbon contamination from recycled papers and mineral oil hydrocarbons that are present everywhere. They include in particular:

1) Use of carefully selected recovered paper grades with reduced mineral oil hydrocarbon content to manufacture sustainable paper and board based on recycled materials;
2) Use of paper and board made from virgin fibres to manufacture food contact materials;
3) Use of paper and board based on virgin or recycled fibres with a functional barrier (coating, adsorber or other measures);
4) Use of suitable inner packaging with functional migration barrier properties.

The manufacturers of fibre-based paper and board with functional barrier properties are familiar with the individual processing conditions for their materials and recommend them to their customers, e.g. in brochures and personal consultations. Assessment of the risk in each individual case and quantification of the migration level from the finished food contact material are carried out on the basis of the migration levels determined (see the analysis section).

The design of the folding carton is particularly important in this context. Internal edges, flaps, windows or pouring aids as well as correct creasing are taken into account. The packaging material should also be stored in a contamination-free environment that is as dry as possible.

Where fibre-based packaging solutions with integrated barrier properties are concerned, attention is always paid to sustainability and subsequent recyclability via the paper recovery system as well. Folding carton manufacturing guarantees good printability, good processability, process stability during packaging and filling as well as a wide range of basis weights.

Since folding cartons are not as a rule closed with a gas-tight seal, contamination of the food by mineral oil hydrocarbons from external sources cannot be ruled out completely.

Gas-tight plastic packaging generally demonstrates permeability to mineral oils after a certain amount of time in storage too. Films made from certain materials like polyethylene terephthalate (PET) or polyamide (PA) are hardly penetrated by mineral oil hydrocarbons at all and can therefore be considered to be a *functional* barrier in packaging. In order to facilitate examination of the suitability of plastic barrier films for inner bags, findings of the Swiss packaging institute SVI have been summarised in a guideline for users [14].

The characteristics of all the parts of the packaging need to be taken into consideration in a comprehensive concept. It is particularly important that products which contain no mineral oils are used in all packaging components, such as printing inks, lacquers or adhesives. Close co-operation and the exchange of information throughout the supply chain are essential to make this possible.

The objective is to find the optimum solution for the food in question in view of the requirements on the packaging (e.g. gas exchange), the physical properties of the food (fatty, moist, dry, …), the shelf life, the storage temperature and the conditions during transport and storage up to the end of the shelf life – through close co-operation between all the market players.

6. Analysis of Mineral Oil Hydrocarbons in Food and Packaging Materials

The hydrocarbons that come from mineral oil are thousands and thousands of different but nevertheless very similar substances. They cannot be separated into individual signals by standard analytical procedures. On the contrary; what are produced are wide humps of substance signals. It is therefore a difficult analytical process to identify and quantify MOSH and MOAH in food and packaging. The consequence of this is that the analytical procedures used only have very low specificity by comparison with detection methods for such individual substances as pesticide residue. In order to obtain comparable results, a number of conventions and specifications therefore need to be observed.

In co-operation with the canton laboratory in Zurich, BfR has developed a method and a compendium for the development and establishment of analytical methods for determining mineral oil hydrocarbons. [16, 17]. Acceptable to good result comparability has been achieved in various round robin tests for such matrices as rice, cereals and board [18].

In March 2019, a technical report about sampling and analytics was published in implementation of the EU Commission Recommendation 2017/84 on the monitoring of mineral oil hydrocarbons in food and food contact materials. This report was compiled by a mineral oil task force headed by the European Reference Laboratory for Food Contact Materials (EURL-FCM) [45]. In addition to a definition of MOSH/MOAH, this report contains sampling specifications as well as the subsequently outlined analytical procedures. The necessary validation parameters, such as limits of quantification for certain analytical procedures, C-fractions and matrices are also defined. The limits of quantification that are at least required (LOQ-max) vary in this context according to the fat content of the food; the desirable limits of quantification with the method (target LOQ, LOQ-t) are further below them (see Table).

Table II Performance requirements for MOSH and MOAH analysis: maximum LOQ for each C-fraction (LOQ-max), target LOQ for each C-fraction (LOQ-t), acceptable ranges for recovery (R_{rec}) of mineral oil from samples, and intermediate precision

Categories	Associated foods #	LOQ - max [mg/kg]	LOQ -t [mg/kg]	R_{rec} [%]	interme-diate precision [%]
Dry, low-fat content (< 4% fat/oil)	bread and rolls; breakfast cereals; grains for human consumption; pasta, products derived from cereals	0.5	0.1	80 - 110	15
Higher fat/oil content (> 4% fat/oil)	fine bakery ware; confectionery (incl. chocolate) and cocoa; fish meat, fish products (canned fish); oilseeds; pulses; sausages; tree nuts	1	0.2	70 - 120	20
Fat/oils	animal fat (e.g. butter); vegetable oils	2	0.5	70 - 120	20
Paper and Board	Reporting only up to C_{35} (extraction optimised up to C_{35})	10	5	80 - 110	10

Source: [46]

A process in which the samples are extracted with an organic solvent is generally used to determine MOSH and MOAH in food and packaging. These extracts are purified if necessary and are separated into saturated (MOSH) and aromatic (MOAH) hydrocarbons with the help of a precisely specified column chromatography process.

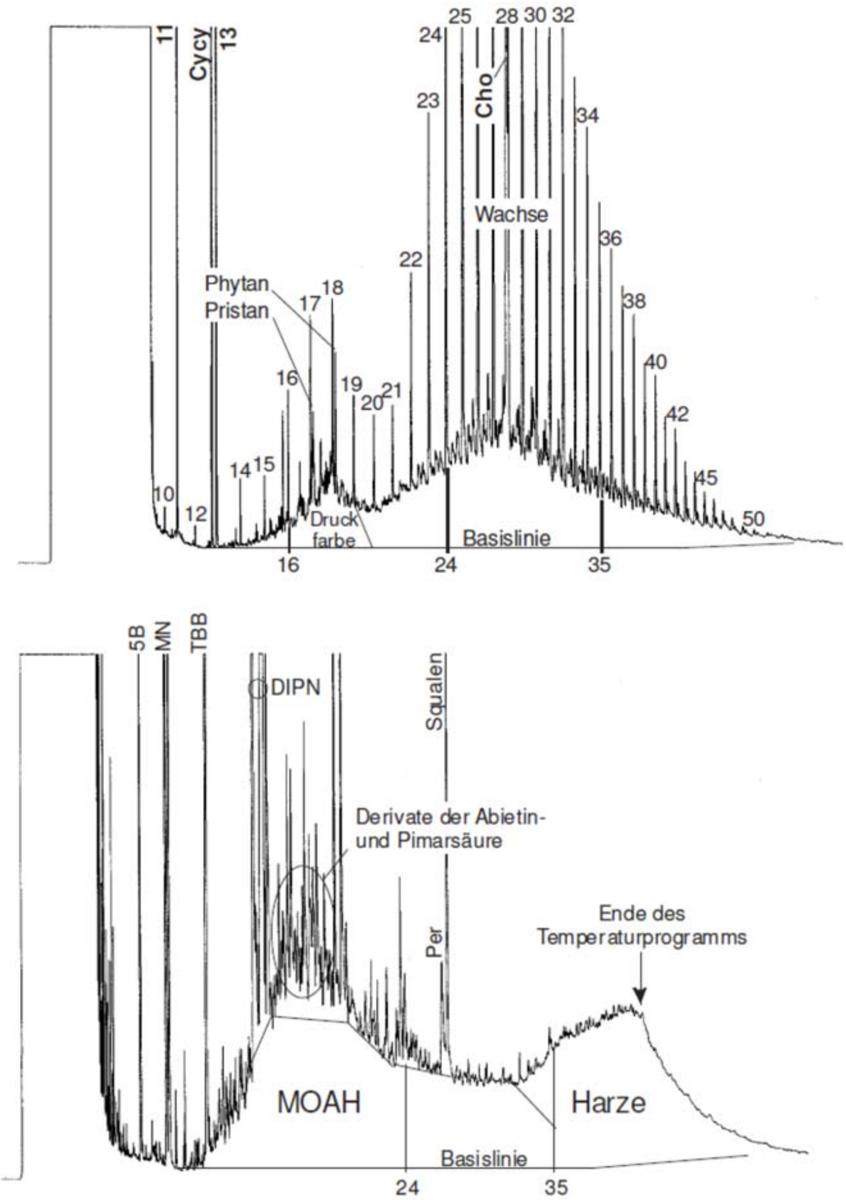

Illustration: HPLC-GC/FID chromatograms of mineral oil hydrocarbons from recycled board
MOSH (top) and **MOAH** (bottom) [17]

A manual silica gel process or a combination of liquid chromatography, gas chromatography and a flame ionisation detector (HPLC-GC/FID) can be used for separation purposes. The detection and determination limits of the process vary according to the sample matrix. In most foods, determination limits of 0.5 mg/kg MOSH and MOAH can be reached reliably with the standard processes; in the case of fatty foods, this determination limit is also possible dependably following special processing [19]. In 2017, a European standard was approved for the determination of mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH) with online HPLC-GC-FID in vegetable oils [20]. This process has proved to be suitable in round robin testing in the very demanding vegetable oil and fats matrix with mass MOSH and MOAH concentrations of more than 10 mg/kg in each case. A DIN SPEC compiled by the PAS process for determination of the migration of mineral oil hydrocarbons from food contact materials that contain a proportion of recovered paper is currently at the final approval stage [21]. This means that a standardised process is available to measure Tenax® migration, in order to assess the functional barrier quality of finished papers and board.

Two-dimensional gas chromatography is used for improving the characterisation of hydrocarbon combinations and for distinguishing hydrocarbons from mineral oils from hydrocarbons from other sources, e.g. from polyolefin plastics (**P**oly**o**lefin **S**aturated **H**ydrocarbons, POSH) as well as for the targeted detection of the multi-core aromatics that are considered to be particularly critical from the toxicological point of view. Additional information is obtained with the help of mass selective detectors. State-of-the-art procedure involves the combination of a time-of-flight mass spectrometer and two-dimensional GC, which is known as GCxGC-MS(TOF). Higher signal specificity is achieved as a result. Classic FID technology, on the other hand, continues to be considered universally suitable for the determination of mineral oil component quantities [4, 22]. At the present time, a very controversial debate is in progress among experts about whether MS detection is essential or even appropriate for the reliable determination of mineral oil contamination in food [37, 38].

Work is currently being carried out on projects for modelling and forecasting mineral oil migration into food; the reliability of these concepts for different applications still has to be proved [23].

7. Toxicological Assessment of Mineral Oil Hydrocarbons

It is difficult to assess the health risk of mineral oils in different products, because combinations of different substances have to be evaluated rather than individual substances and there are numerous data gaps [3, 4]. A conclusive assessment of the health impact of MOSH and MOAH is not available at the present time and is not expected in the foreseeable future either.
Saturated hydrocarbons (MOSH) with molecular weights of C16-C35 are absorbed by the human body. They are stored in a number of organs, such as the lymph nodes, the spleen and the liver, and form microgranulomas there [26]. It has in addition been determined in animal experimental studies [25] that mineral oil combinations can lead to inflammatory reactions in the liver of one of the rat strains used. The relevance of the accumulation of MOSH in tissue that has been observed in human beings as well is unclear, however, and doubts are regularly voiced in the business community and among experts about the applicability of the results of animal experiments [40].
The EFSA considers exposure to MOSH from food to be a cause for concern [26]. The aromatic components (MOAH) from mainly alkylated aromatic hydrocarbons are another cause for concern [24]. According to EFSA, MOAH with three or more aromatic rings that are not alkylated or display single alkylation may be mutagenic and carcinogenic [26]. There is less concern about single- and double-core aromatics as far as potential carcinogenicity is concerned, but no information is available about further toxicological endpoints and effects here either [26]. This information is, however, also necessary for a comprehensive toxicological assessment. The demand made by the German Institute for Risk Assessment (BfR) is therefore that there should be no detectable migration of MOAH of any kind into food [3].

8. Legal Requirements

According to the contaminants regulation [29], a contaminant is any substance not intentionally added to food which is, however, present in such food as a result of the production, […], processing, […], packaging […] or holding of such food or as a result of environmental contamination. Depending on their origin, mineral oil hydrocarbons in food can therefore be considered as contaminants attributable to food production, packaging or the environment. Regulation (EU) 1935/2004 [28] applies to packaging. According to Article 3, migration of substances from packaging into food may not endanger human health or bring about an unacceptable change in the composition of the food. Article 14 of Regulation 178/2002 [30] enables food to be classified as no longer fit for human consumption because of contamination by, for example, mineral oil hydrocarbons.

In the spring of 2017, the German Consumer Protection Ministers‘ Conference asked the German government to initiate and co-ordinate a national minimisation strategy to reduce mineral oil contamination of food, taking all sources of contamination into consideration [31].

So far, there are no specific legal requirements in Germany for assessing the migration of mineral oil hydrocarbons from packaging into food.

Between 2011 and 2017, the German Ministry of Food and Agriculture (BMEL) compiled a number of draft regulations about food contact materials based on recovered paper and board. In the past six years, limits for MOSH and MOAH migration into food have been formulated (2011), provisions focussing exclusively on MOAH migration into food have been proposed (2013), maximum MOSH and MOAH content in material has been defined, combined with maximum permissible migration levels (2014), and, finally, the concept of a functional barrier to migrating aromatic hydrocarbons combined with a defined “non-migration limit” of max. 0.5 mg/kg for the migration of MOAH (C16 to C35) into food has been presented in the form of a regulation text (2017) [32] – as contributions to a 22^{nd} regulation to amend the German food contact regulation (“mineral oil regulation”). In this context, food contact materials made from paper or board containing recovered materials may only be manufactured and marketed if they incorporate a functional barrier. The obligation to provide a barrier does not, however, apply if other action is taken or other conditions exist which make sure that MOAH migration is below the above-mentioned detection limit. Above and beyond the application area outlined in the regulation, the detection limit of 0.5 mg/kg in food does not, however, represent a generally tolerated maximum MOAH level in food. In spite of the efforts made by the BMEL over a period of many years, a legal regulation has not been issued. It cannot be said with any certainty at the present time whether such a national regulation would be confirmed or will be rejected by the European Commission during the notification process that is required there. Other countries are studying the problems involved in regulation of mineral oil migration too. Austria requires suitable measures for food in recycled board, such as barriers or additional inner packaging which guarantees that substance migration from recycled board meets the requirements of Article 3 of Regulation (EC) No. 1935/2004 [33].

The Swiss food contact material regulation specifies in Article 27 a ban on recycled paper and board in direct contact with food, unless it is separated from the food by a functional barrier layer [34].

In the CEPI guideline about the food contact compliance of paper and board (paper production and processing) that was revised in 2019, the mineral oil problem is only referred to in a footnote [48]. Attention is drawn here to possible contamination via (cold offset) printing inks due to direct printing or the recovered paper system. The guideline also mentions the CEPI/CITPA agreement about the elimination of mineral oil-based printing inks from packaging, which is being observed in Europe to a very large extent for food applications.

In 2017, Belgium formulated action limits for saturated hydrocarbons (MOSH) in different food categories [35]. Due to the potentially carcinogenic impact of components of MOAH, it is recommended that exposure is kept as low as possible. As a possible action limit, reference is made to the 4^{th} BMEL draft [32] and the “analytical detection limit” for MOAH C16-C35 of 0.5 mg/kg in food that is mentioned there.

The Dutch study carried out by RIVM [39] also considers potentially carcinogenic MOAH in food to be critical and recommends identification and, as far as is possible, reduction of the sources of MOAH contamination. Where MOSH are concerned, on the other hand, the Dutch Institute for Public Health and the Environment does not think there is any danger to the Dutch population. Nevertheless, neither the MOSH levels recommended by the Belgians nor the qualifications made for the Netherlands are finding acceptance in specifications made by major retailers to suppliers and for own brands. The requirements made on mineral oil hydrocarbon content in food for MOAH (requirement “not determinable”) and MOSH (requirement < 2 mg/kg) [41, 42] are considerably stricter here and are difficult to reach for individual product groups.

MOSH and MOAH benchmarks that can be achieved in best practice are being compiled and determined for certain food groups in a project carried out jointly by the German Federation for Food Law and Food Science (BLL, renamed the German Food Association in 2019) and the study group for food contact materials, wine and cosmetics of the German State Consumer Protection Task Force (ALB) [43]. Initial results were published in April 2019 [44]. Since what is involved here is an agreement between the food industry and representatives of the state food monitoring authorities, a certain amount of acceptance of these benchmarks by both the monitoring authorities and the market in the form of the retail trade or NGO is expected. The Conference of German State Consumer Protection Ministers also welcomed this project as a key element of a national minimisation strategy at its conference in May 2019 and recommended its continuation [46].

By analysing more than 10,000 MOSH/MOAH data records from industry and monitoring authorities, benchmarks irrespective of source were in particular specified for vegetable oils, bread and small baked goods, pastries, grain products and grain-based products, cereals, confectionery, chocolate and cocoa-based confectionery (see Table; source: [44]).

LAV-BLL: MOH Benchmark levels (April 2019)				
No.	**Product group Food category**	**MOSH and analogues [mg/kg] C_{10}-C_{50}**	**MOAH [mg/kg] C_{10}-C_{50}**	**Notes on use** (Notes on the food groups recorded / on non-recorded products and limitations / if appropriate on reasons, basis of the data or other special features)
1	Vegetable oils, (such as rapeseed oil, sunflower oil, linseed oil, olive oil) (excluding oils/fats of tropical plants and soya oil)	13	n.q.[2]	these benchmark levels are not intended for application to oils/fats that have been extracted from tropical plants (e.g. coconut oil) due to an insufficient base of statistical data (in Dec. 2018)
2	Bread and biscuits, fine pastries, cereal products and cereal-based products, cereals, rice, pasta	6	n.q.[3]	only applicable to end products for consumers, not to raw commodities or raw doughs
3	Confectionery (sugar confectionery except chewing gum), chocolate and cocoa-based confectionery	9	n.q.[3]	only applicable to end products for consumers

n.q. not quantifiable, i.e. contents < limit of quantification (here: LOQ_{max} in mg/kg in accordance with the JRC Guidance on sampling, analysis and data reporting for monitoring of mineral oil hydrocarbons in food and food contact materials, Valid as of 2019)

[2] LOQ_{max} for every fraction (cf. JRC Technical Report[1]) for fats/oils is equivalent to 2 mg/kg
[3] LOQ_{max} for every fraction (cf. JRC Technical Report[1]) for low-fat foods < 4% fat is equivalent to 0.5 mg/kg; > 4% fat is equivalent to 1 mg/kg

The figures given indicate what content levels of mineral oil-like hydrocarbons (MOSH, MOSH analogs like POSH, PAO, MORE and MOAH) – irrespective of source – can be expected in foods of a specific group with high statistical probability if good manufacturing practice is applied. If these levels are exceeded, the reasons should be identified in order to eliminate the source(s) of the contamination. The Toolbox can again be a help here in avoiding mineral oil hydrocarbon contamination of food [8, 47].

Regulations introduced below legal level can be found in Germany in the appendix to BfR Recommendation XXXVI "Paper and board for food contact" [27]. Hydrocarbon solvents (paraffinic, naphthenic, with a carbon number between C10 and C20) are permitted here as formulation resources for paper/board. The purity requirements for liquid paraffins that are specified there must, however, be satisfied. In this context, the following limits have been stipulated temporarily for maximum permissible migration into food: 12 mg/kg for C10 – C16 and

4 mg/kg for C16 – C20. Due to the risk of accumulation in the human body, migration of MOSH with higher chain lengths should be minimised to "as low as reasonably achievable" (= ALARA). Where MOAH are concerned, BfR requires that migration into food should "not be detectable" [3]. The following requirement in Recommendation XXXVI continues to apply as conditions for the use of recovered fibres as raw materials for paper production:
"… In the case of dry, non-fatty foods with a large surface area, such as flour, semolina, rice, breakfast cereals, breadcrumbs, sugar and salt, the migration of volatile, hydrophobic substances via the gas phase needs to be taken into special account. This can be done, for example, by the additional use of suitable intermediate packaging."
This can be understood to be an indirect encouragement to include the migration of mineral oil hydrocarbons into food in development of the overall packaging solution.
In the 2017 national food contact material monitoring exercise in accordance with § 51 of the German Food and Animal Feed Act, Germany specified investigation of mineral oil in and mineral oil migration into food contact materials made from paper/board and textile packaging [36]. The report by the German Consumer Protection and Food Safety Agency (BVL) summarising the results produced by the inspection authorities has not been published yet.

The quintessence of the current legal and scientific situation for distributors of food and packaging manufacturers is therefore the minimisation requirement. The technical measures that are reasonably achievable must be taken, in order to reduce the content in food, for example by reducing migration of mineral oil hydrocarbons from such packaging materials as folding cartons. Some retail chains are demanding from their suppliers the "absence" of MOSH and MOAH in food. At the present time, it must be said that this demand cannot be satisfied.
The MOSH and MOAH levels in food that can be considered technically achievable can only be determined by analysing a large enough number of measurements made with specific products. These levels must also be considered variable in the context of a dynamic minimisation process. Intensive discussions are currently being held about appropriate approaches, that will definitely be

driving the future of the mineral oil debate.

9. References

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10. About FFI

Since 1948, FFI - Fachverband Faltschachtel-Industrie e.V. has been representing the interests of more than 60 companies with over 80 production locations that manufacture about 840,000 tonnes of folding cartons per year, amounting to a production value of about EUR 1.9 billion. The members of the FFI account for roughly 75% of the industry's sales. The folding carton industry has about 9,500 employees from numerous professions, including such industry-specific ones as packaging engineers, printers, packaging technicians, packaging developers or media designers as well as commercial, technical and logistic professions. The industry is currently training about 700 apprentices and has a tradition of being a future-oriented and responsible employer.

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