DR EHRENSTORFER™

FOOD CONTACT MINDFULNESS

lgcstandards.com/drehrenstorfer
dr.ehrenstorfer@lgcgroup.com

LGC Quality | ISO 17034/ISO Guide 34
ISO/IEC 17025 | ISO 9001

INTRODUCTION

The ever-increasing focus on the safe consumption of food has led to robust processes around the globe for the risk management of chemical contaminants in food production and supply.

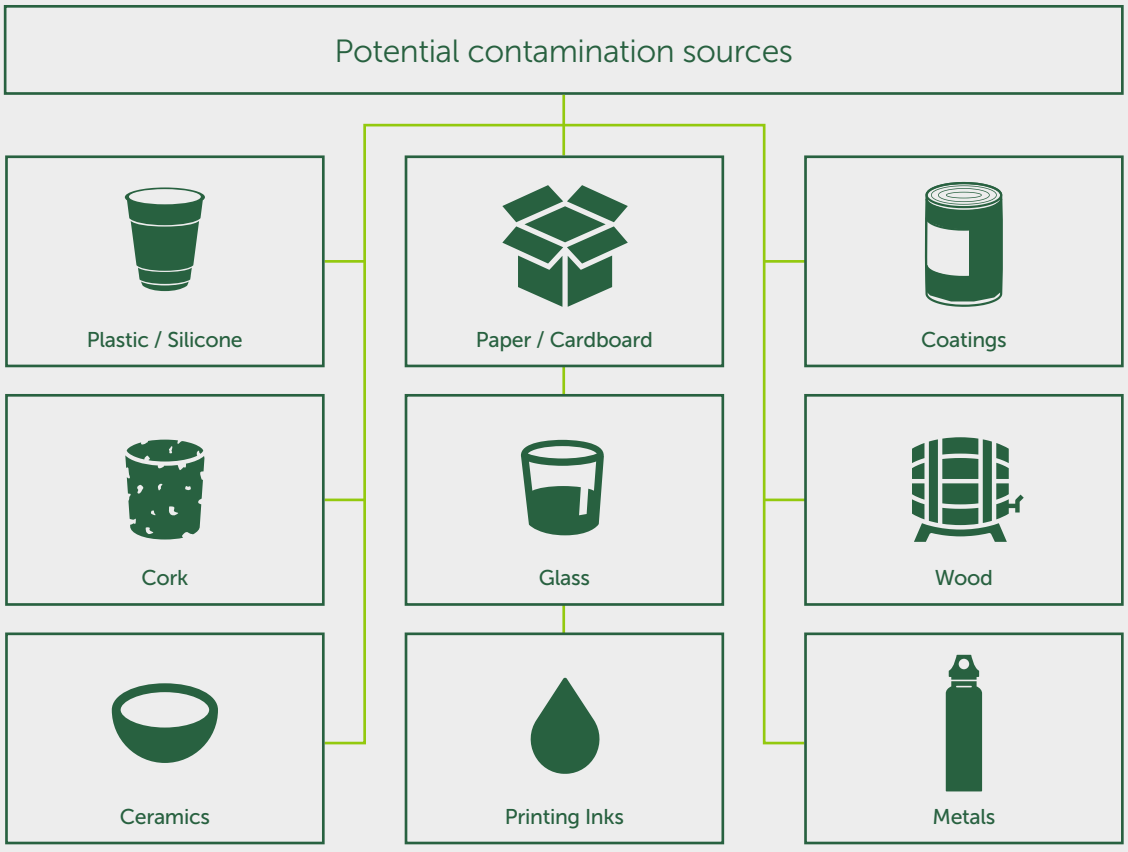
Food Contact Materials (FCM) is one significant potential source of contamination and one that is constantly evolving. Including food packaging and other articles that contact food from preparation to consumption, the sheer scope of this potential contamination source means that it is a particularly challenging area of control, regulation and risk management.

In this paper, we will provide an overview of the compliance testing and regulations of food contact materials, and examine the approach to safety risk management across this evolving and wide-ranging potential pool of contaminants.

We will illustrate five examples of high-profile FCM contaminants: bisphenol A (BPA); per- and polyfluoroalkyl substances (PFAS); phthalates; mineral oil hydrocarbons (MOHs); and photoinitiators.

Food contact materials go far beyond food packaging: FCMs can encompass anything from packaging to kitchen utensils and tableware, factory machinery, tote bins, preparation surfaces and food gifting sets. Some examples of FCMs that are potential sources of contamination are shown in **Figure 1**.

Figure 1: Examples of FCMs as potential contamination sources



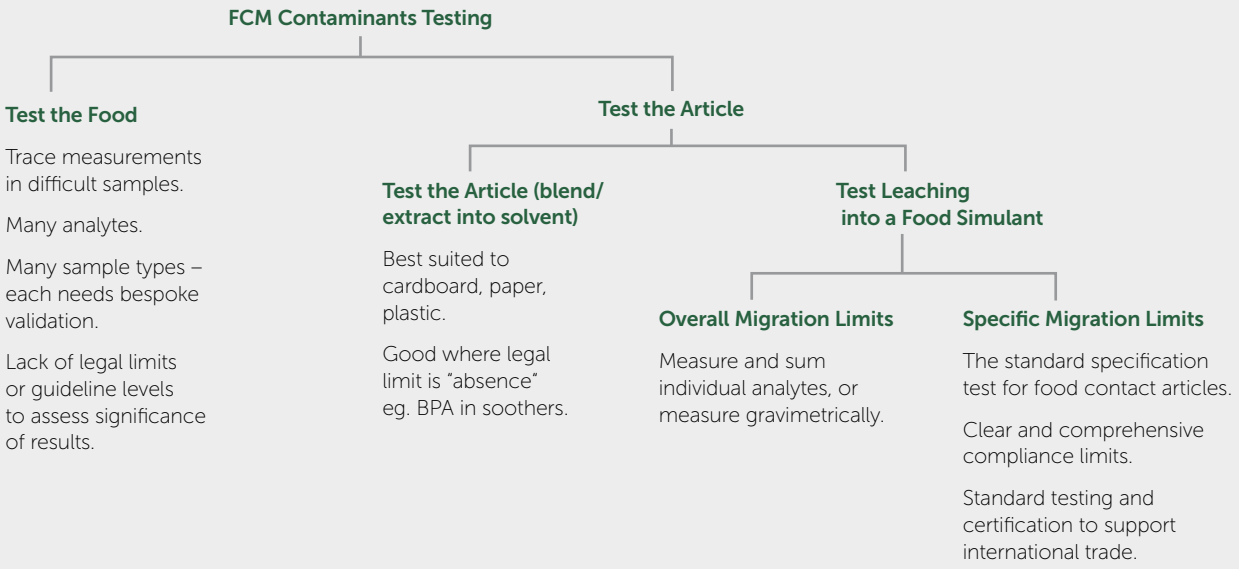
Historically, interest has focussed upon migration of intentionally added substances (IAS) such as residual monomers and functional additives from plastics, silicone and rubber. More recently, focus has also switched towards migration of non-intentionally added substances (NIAS), including contaminants from recycled packaging materials (cardboards and papers). Within the next few years it is likely that the use of cellulose and starch-based materials, as well as active packaging that extends food shelf-life, will increase exponentially. The balance of risk and benefit in using these materials needs to be assessed before use.

There is a consumer-driven agenda to reduce plastic packaging and to reduce food waste, resulting in industry efforts to redevelop food packaging, improve recycling, and use novel materials. In addition there is a comparatively high awareness of potential risks from certain packaging materials, such as bisphenol A (BPA), leading to a drive for alternatives. However, these novel materials and packaging alternatives may introduce new contaminant hazards, alongside issues in existing contact materials. It is essential that evidence-based assessments are made, but also that these risks are then viewed and managed in a holistic manner. Control of chemical contaminants in food is often based upon very conservative risk assessments that should be regularly re-evaluated.

TESTING AND REGULATIONS

There are two approaches to FCM contaminant testing (**Figure 2**). Food testing is needed to support toxicological risk assessments, while article testing is essential to underpin safety specifications, compliance certification, and to support international trade in FCMs.

Figure 2: Two different approaches to FCM contaminants testing



As it is impossible to measure leaching in all foodstuff, standardised simulants are used to represent different types of food. The time and temperature that the article is left in contact with the simulant are chosen to mimic a worst-case scenario. The amount of contaminant(s) that migrates into the simulant is then measured.

The choice of simulants varies slightly depending on the legislation, but those used under the EU plastics regulation 10/2011[1] are typical (**Figure 3**).

Figure 3: Choice of simulants under EU plastic regulations 10/2011

Food Type	Simulants
Representing aqueous foods	10% aqueous ethanol
Representing acidic foods	3% aqueous acetic acid
Representing alcoholic and more lipophilic foods	20% aqueous ethanol
Representing spirits and dairy products	50% aqueous ethanol
Representing fatty foods	Vegetable oil
Representing dry foods	Poly(2,6-diphenyl-p-phenylene oxide)

Specific Migration Limits (SMLs)

SMLs are the maximum concentration of contaminants permitted in the simulant (or in a food) under standardised test conditions. The EU legislative framework[2] has extensive lists of SMLs for plastics: they have been set for hundreds of substances, either individually or in groups of chemicals. SMLs are often based upon a toxicological assessment, extrapolating simulant concentrations using worst-case assumptions to provide assurance that the Acceptable Daily Intake (ADI) would not be exceeded if migration occurred into food.

SMLs are the industry-standard approach for specifying and certifying the acceptability of FCMs. Testing methods to determine specific migration and SMLs have been published in standards such as EN13130[3] (listed >25 compounds). Certification may be by testing, but may also be based upon modelling, production controls, or screening tests using Overall Migration Limits (OMLs; maximum total amount permitted to release into food or food simulants).

It is worth noting that any plastic FCM imported into, and traded within, the EU must be certified as compliant.

There are two complementary approaches to regulating FCM safety: negative or positive lists.

- **Negative lists** are regulatory lists of substances which are not approved as FCMs, not approved to be added or incorporated into FCMs, or which are undesirable and have maximum limits (either as a % of the FCM composition, or as an SML).
- **Positive lists** are regulatory lists of substances which have been assessed and explicitly approved as FCMs, providing the substance is below a maximum limit in FCM composition.

Different regulators give different weights to negative or positive list approaches. For example:

In the **United States** FCMs are considered as indirect food additives and are regulated by the Food and Drug Administration (FDA). The positive list system is underpinned by the Title 21 Code of Federal Regulations (21CFR[4]), which provides lists of FCM components that are regulated for use or "Generally Recognised as Safe" (GRAS)[5]. There is also a relatively short list of prohibited FCMs (e.g. part 189D) and substances with thresholds or exemptions.

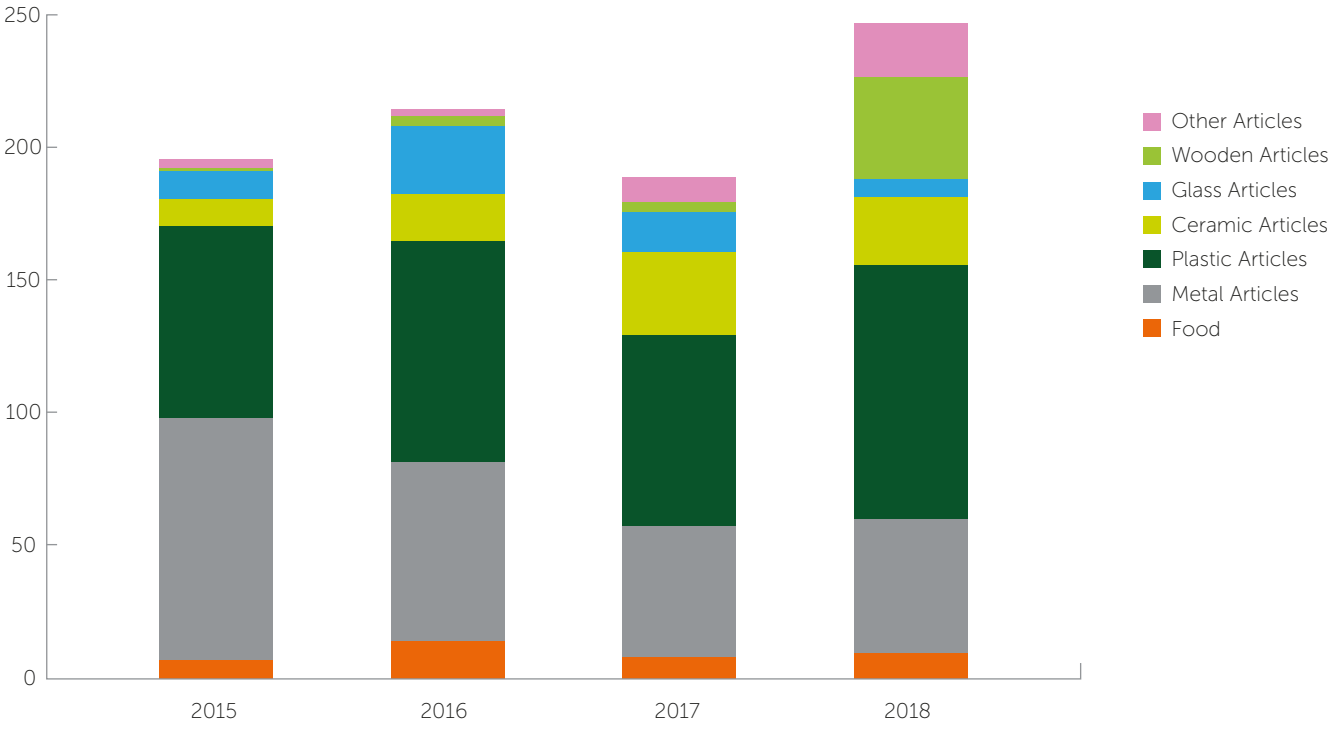
China has recently introduced one of the most comprehensive positive list systems in the world[6]. Regulatory approval is required before additives can be used in a food contact material. This has driven a demand for laboratory testing using the Chinese standard methods in order to support registration submissions from packaging manufacturers.

The **European Union** has a positive list (the "Union List")[2] of FCMs, but also a huge number of individual regulations that restrict or limit specific substances. These are either regulated by material (e.g. cellulose film)[7] or by substance (e.g. bisphenol ethers)[8].

Globally, most reported FCM safety incidents[9] are brought to light by regulatory import/export testing of these articles (**Figure 4**). Apparent trends are skewed by the EU intensified checks requirement[10] that Chinese-origin melamine and polyamide kitchenware is tested for formaldehyde or primary aromatic amines.

Whilst testing of articles using simulants is essential for international trade, it does not provide accurate exposure assessments for foodstuff consumption. Simulants are intended to provide a worst-case scenario, but can never mirror the range of real-life conditions. It remains the case that there is very little testing of FCM contaminant levels in food by either industry or regulators.

Figure 4: Incidents relating to FCM contaminants reported globally

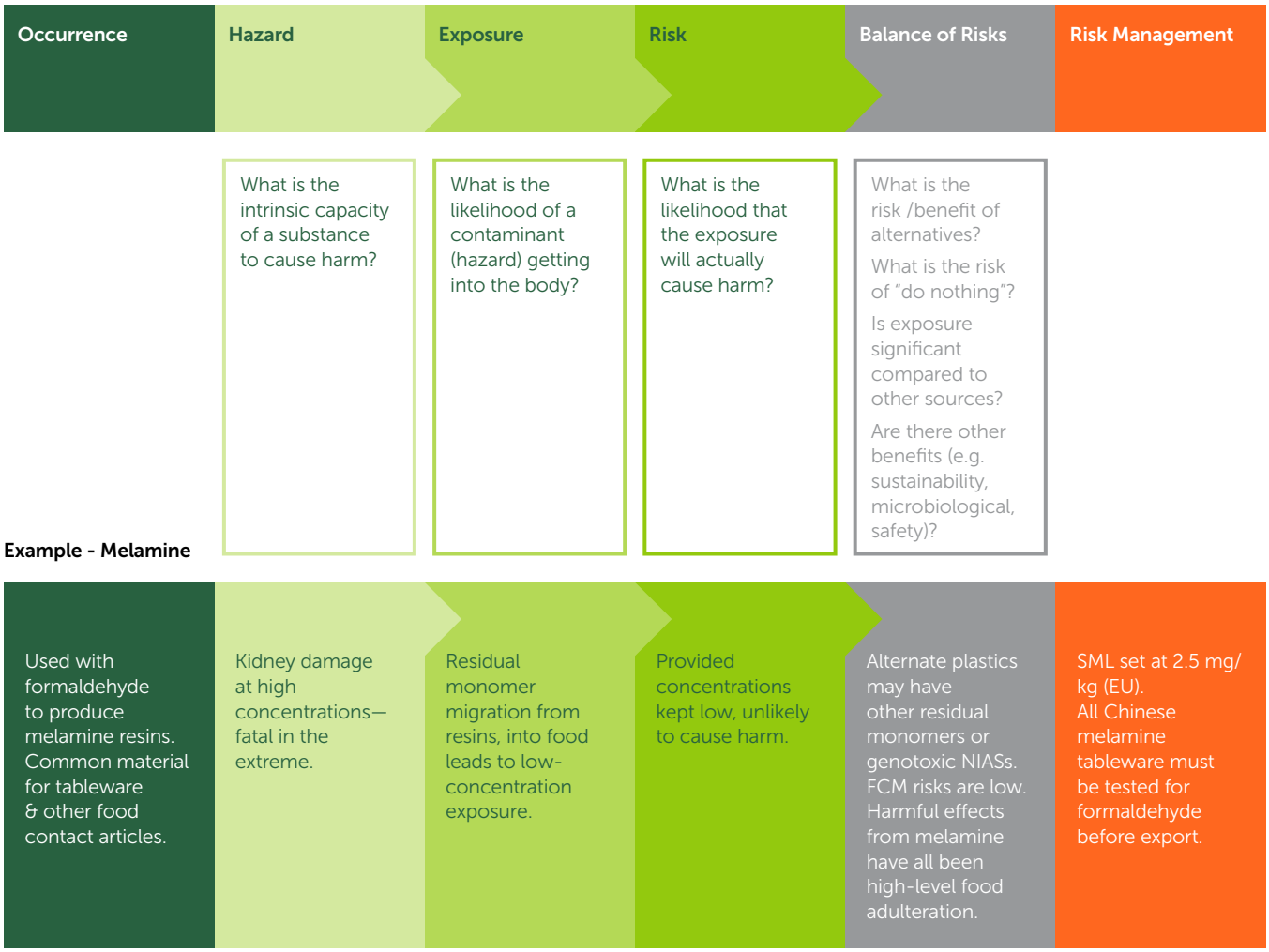


HAZARD VS RISK MANAGEMENT

There is an important distinction between hazard and risk, and between risk assessment and risk management. They can be viewed as sequential steps in a process.

The example of melamine illustrates the difference between these steps, and shows the importance of weighing relevant exposure sources in an assessment, rather than being swayed primarily by the severity of the hazard. While melamine has been shown to cause illness and fatalities when used as food adulterant, its migration from FCMs into food is at much lower level than required to trigger these hazardous effects, hence it poses a relatively low risk to human health.

Figure 5: Risk Management Process



In exceptional cases, risk management decisions may be based predominantly on hazard. This is particularly the case if the hazard is genotoxic or carcinogenic (i.e. there is no "safe" chronic exposure level), with poorly characterised risk in vulnerable consumer groups (e.g. infants), or if the hazard is unacceptably emotive to consumers.

While hazard assessment is relatively straightforward, assessing the exposure levels is more difficult and involves a high degree of uncertainty.

Weighing the balance of risks is usually a policy, rather than scientific, assessment. There is inevitable subjectivity in balancing FCM safety risks against other risks or benefits. There may even be a direct trade-off between different food safety risks. For example, in the UK, cook-in-bag chickens have been promoted to reduce the risk of consumers spreading campylobacter from raw chicken around their kitchen, although this inevitably increases contaminant migration risk from the oven bags.

EXAMPLES

In the following series of examples we explore the approaches to risk assessment for five common and high-profile groups of substances found in FCMs.

Each case highlights the importance of adequate evaluation of hazard, exposure and risk as part of an effective risk management process.

Bisphenol A (BPA) | **Per- and Polyfluoroalkyl Substances (PFAS)** | **Phthalates**

Mineral Oil Hydrocarbons (MOHs) | **Photoinitiators**

Bisphenol A (BPA)

OCCURRENCE — Bisphenol A (BPA)

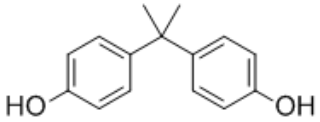
Bisphenol A (BPA) has been produced in large volumes for decades. Its main use is in the production of polycarbonate plastics and epoxy resins, and can be found from flooring adhesives to drinking water pipe linings.

BPA has two principal food contact uses:

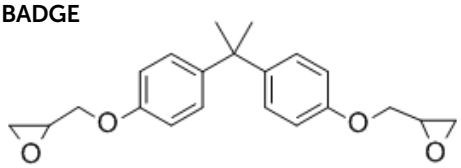
- Protective epoxy resin coatings inside cans. It is used to make Bisphenol A diglycidyl ether (BADGE), until recently the base material of almost all canning epoxy resins. Such resins contain residual BPA.
- Plastic containers, kitchenware and bottles. BPA-based polycarbonate is highly durable.

BPA is also the most common colour-developer in thermal paper (e.g. cash till receipts), a use that is currently being phased out in Europe.

Bisphenol A



BADGE



HAZARD — Bisphenol A (BPA)

The toxicology of BPA is well studied. High-dose animal studies have shown effects including reproductive toxicology, kidney damage, neurological and immune damage[11]. BPA was originally developed as an oestrogenic drug rather than a plastics feedstock; although it never found commercial medical use, it has an inherent oestrogenic effect and there is some evidence of adverse reproductive effects in humans at high doses.

EXPOSURE — Bisphenol A (BPA)

BPA residues and metabolites are detected in human urine around the world. There is disagreement, however, on the relative significance of different exposure sources.

For the most exposed population (cashiers), it is uncontentious that skin absorption from thermal paper is far more significant than ingestion from food. For other populations, there is disagreement whether food ingestion is a significant exposure route relative to other sources.

The main food source of BPA is migration from epoxy resins (canned foods, or coated trays and closures), but it can also migrate from plastic packaging, containers and wraps.

The degree of BPA migration into canned food depends on many factors, including sterilising conditions, shelf-life and storage conditions, and the nature of the food (pH, water content, and fat, sugar and salt contents). This makes extrapolating exposure assessments using simulants highly uncertain. There is also limited data on BPA levels in food compared to tests using simulants.

RISK Bisphenol A (BPA)

Different risk assessment bodies have drawn contradictory conclusions regarding BPA in FCMs, for example:

- EU (EFSA) and US (FDA) – current exposure does not pose significant risk.
- France (ANSES)[12] and Sweden – current exposure poses a significant risk.

BALANCE OF RISKS Bisphenol A (BPA)

In order to market products as "BPA-free", many have substituted BPA with similarly-structured molecules that perform the same technical functions (**Figure 6**). BPS is the most common substitute. The hazards and migration levels of these BPA replacements have not been well studied, nor has their migration into food. It is a reasonable hypothesis that they share similar toxicological effects and pathways, given that they share the same oestrogen-like core structure.

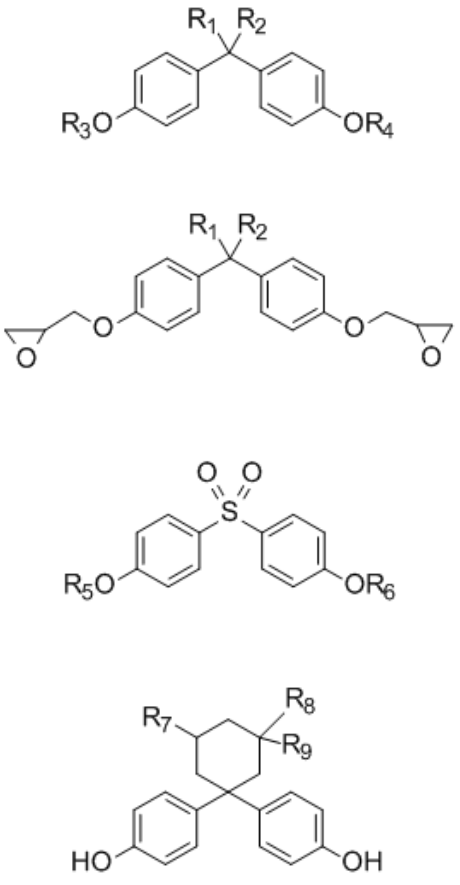
Through lack of evidence we may be unwittingly replacing BPA with chemicals of equivalent, different, or even higher risk.

Figure 6: Examples of bisphenol molecules as substitutes for BPA

	R_1	R_2	R_3, R_4
Bisphenol AF (BPAF)	CF_3	CF_3	OH
Bisphenol AP (BPAP)	Ph	Me	OH
Bisphenol B	Me	Et	OH
Bisphenol E	Me	H	OH
Bisphenol F (BPF)	H	H	OH
Bisphenol S-monoallyl ether (BADGE)	Me	Me	Glycidyloxy
Bisphenol S-monobenzyl ether (BFDGE)	H	H	Glycidyloxy

	R_5	R_6
Bisphenol S (BPS)	H	H
Bisphenol S-monoallyl ether (BPS-MAE)	H	$CH_2CH=CH_2$
Bisphenol S-monobenzyl ether (BPS-MPE)	H	CH_2Ph

	R_7, R_8, R_9
Bisphenol Z (BPZ)	H
Bisphenol TMC (BPTMC)	Me



Some of these alternatives have also been used to form ether analogous (such as BFDGE from BPS) to manufacture coatings, hence pose a migration risk from the unreacted bisphenol residues into food.

Test methods that have traditionally been utilised to monitor BPA/BPS and BADGE/BFDGE are now being expanded to quantify other structural analogues. As most test methods are based on LC-MS, there are few technical blocks to adding multiple structurally-related analytes to the scope. A limiting factor has been the availability of reference standards and the commercial demand for tests. This situation is changing, however, with more reference standards being developed and more laboratory customers asking for tests for a range of bisphenol analogues and corresponding ethers.

The Demise of BPA as a Food Contact Material

In the 1970s and 80s, BPA was lauded as the answer to many food contact material problems.

However, after repeated media reports of BPA's oestrogenic and endocrine disrupting properties, there was a rapid consumer-driven switch to plastic marketed as "BPA-free" in the developed markets. Many regulators placed precautionary bans on BPA in baby food contact materials, which cemented the perception in consumers minds that BPA poses a health risk. However, this does not preclude the use of other bisphenol based plastics, such as bisphenol S (BPS), as a substitute.

Food cans, almost universally, still used BPA-based epoxy resin coatings prior to the French BPA ban in 2015. As well as decimating the French canning industry, this unilateral ban sent shock waves around the world's supply chain. As it is uneconomic for multinational food companies to produce bespoke cans in France, there was a rapid drive for replacement coatings that could be marketed globally. Although resins based on other *bis*-phenols are a short-term fix, the canning industry is acutely aware that they are likely to come under equivalent consumer and regulatory pressure in future, and are working on coatings that will have long-term acceptability.

RISK MANAGEMENT Bisphenol A (BPA)

As a result of the different conclusions from risk assessment bodies, regulations differ in different jurisdictions. For example:

EU
A new SML[13] of 0.05 mg/kg. BPA banned in infants bottles and soothers.

France
BPA banned in food contact materials.

US
BPA banned as a coating in baby bottles and infant formula cans. Some state-specific controls, particularly in foods for young children.

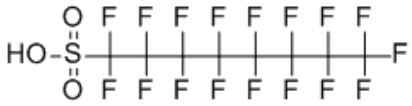
China
SML of 0.6 mg/kg.

Per- and polyfluoroalkyl substances (PFAS)

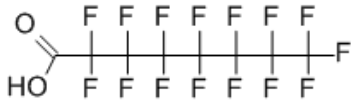
OCCURRENCE Per- and Polyfluoroalkyl Substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) describe a range of surfactants with a polar end-group (typically sulphonic or carboxylic acid) attached to a fluorinated carbon chain (typically C4 – C16 length). Examples include: perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA):

PFOS



PFOA



PFAS have been bulk-produced for over 50 years for use in foams and coatings. They are lipophilic, and environmentally persistent. Contaminants have built up in the environment and in the food chain.

Food contact sources of PFAS arise from fluoropolymers such as polytetrafluoroethylene (PTFE), which are used to produce non-stick kitchenware surfaces (e.g. Teflon™) and grease-repellents in cardboard food packaging. They contain residual PFAS from the manufacturing process, such as polyfluorinated carboxylic acids (including PFOA), fluorotelomer alcohols (FTOHs), polyfluoroalkyl monophosphates (monoPAPs), and polyfluoroalkyl diesterphosphates (diPAPs).

PFOS production was phased out under the Stockholm Convention on Persistent Organic Pollutants, effective from 2004, and PFOA production has also been reduced in recent years in anticipation of its proposed Stockholm listing. They have been replaced with other, less persistent, PFAS.

HAZARD

Per- and Polyfluoroalkyl Substances (PFAS)

Different PFAS vary in toxic effect and potency. PFOS and PFOA remain largely unmetabolised and are excreted through urine, but can also be detected in breast milk and umbilical cord blood. Human epidemiological studies suggest a causal link to low birth weight and increased serum cholesterol levels[14]. No causal links were found to other toxic effects or outcomes in humans.

Confirmed effects in animal studies are more varied, and include liver tumours, interference with the development of neural transmitters in young animals, and impairment of cholesterol and triglyceride release.

EXPOSURE

Per- and Polyfluoroalkyl Substances (PFAS)

PFAS are low in molecular weight and fat-soluble, hence residues readily migrate from non-stick kitchenware into cooking oil and fatty food. Migration can also occur from PFAS-treated cardboard and baking paper into high-fat-content food such as cakes, popcorn and takeaways.

The need for evidence-based exposure assessments

PFAS are ubiquitous in food contact materials, and are proven to migrate into simulants and some foods. It would be easy to assume that FCM-origin migration is widespread.

In fact, although there have been isolated reported incidents of PFAS migration into food, the relatively limited surveys that have been carried out suggest that FCM as a source of PFAS contamination is rare[15]. The main exposure routes are food (particularly fish, meat and dairy products) contaminated as a result of bio-accumulation in the food chain.

This accumulation could in turn have originated from the inefficient decomposition and incineration of waste FCMs in the environment.

This example illustrates the importance of collating analytical evidence to inform risk assessments. There is still insufficient data about PFAS contaminants, particularly on those beyond PFOS and PFOA. Analytical data needs to cover all sources - only then can informed judgements be made about relative risks and appropriate mitigation.

RISK

Per- and Polyfluoroalkyl Substances (PFAS)

High levels of PFAS can be found in water supplies near facilities that manufacture, dispose of, and use PFAS. Bio-accumulation can also be found in the food chain. EFSA[16] consider that there is a significant risk from current total exposure levels to PFOS and PFOA, with the effect on serum cholesterol levels the prime concern.

This conclusion is qualified by the acknowledged uncertainty, due to insufficient sensitivity of analytical methods used. Risk assessors need data from more sensitive test methods to avoid making assumptions about censored (< detection limit) values. They also need analytical data on other PFAS, in order to isolate the effects attributable to PFOS/PFOA alone.

BALANCE OF RISKS

Per- and Polyfluoroalkyl Substances (PFAS)

Although the relative risk from food contact sources is low, PFAS serves no technical function or benefit in fluoropolymers - they are residual impurities from the production process. Fluoropolymer manufacturers are responsible for keeping PFAS 'As Low As Reasonably Achievable' - the ALARA principle.

In terms of overall exposure, the nutritional benefit of maintaining a varied diet outweighs the benefit that would be gained by restricting consumption of fish – one of the most significant sources of PFAS.

RISK MANAGEMENT Per- and Polyfluoroalkyl Substances (PFAS)

The EFSA has estimated Tolerable Weekly Intakes (TWIs) for PFOS (13 ng/kg body weight per week) and PFOA (6 ng/kg bw per week). Most regulators do not consider that additional risk management measures are warranted to achieve this. However, there are exceptions: for example, Denmark[17] is considering setting a maximum limit on fluoropolymers in food-contact cardboard, and in the US[18] three classes of fluoropolymers are banned from use in food-contact cardboard.

PFAS impurities in food-contact fluoropolymers are managed through technical specification of the polymer. There are no EU SMLs for PFAS, but they are captured by an OML of 60 mg/kg.

Phthalates

OCCURRENCE Phthalates

Phthalates are plasticisers (polymer additives) used in almost every conceivable application from food contact materials and household plastics to construction materials and cosmetics. They are low molecular weight esters of phthalic acid.

In food packaging, phthalates are used in cap seals in jars and bottles, found as residues in PVC kitchen films and in some plastic packaging.

Five phthalates are authorised in the EU as food contact materials[1]; these five are the industry standard for FCM use in most other regions of the world as well.

- Dibutyl phthalate (DBP)
- Butyl benzyl phthalate (BBP)
- Bis(2-ethylhexyl) phthalate (DEHP)
- Diisononyl phthalate (DINP)
- Diisodecyl phthalate (DIDP)

HAZARD Phthalates

Phthalates have multiple toxic effects, including on the immune system and neural development, but those that have caused most recent concern are the reproductive effects (testicular atrophy and lowering of sperm count) of DBP, BBP, DEHP and DINP[19]. DINP and DIDP also have toxic effects on the liver.

EXPOSURE Phthalates

Phthalates are readily migrated into fatty food. They have been of concern in food for decades, and are a cornerstone of standard plastics SML tests. Phthalates are also frequently tested for in food, and exposure is well characterised[20]. Statistical distributions of dietary intake have been calculated for different consumer populations and nationalities. The main exposure routes are infant formula milk, dairy products, vegetable oil, bread and meat.

Contamination can arise at every step of production. For example, raw milk has been found to contain phthalates (from feed), and concentration increases through mechanical milking (leaching from plastic machinery), pasteurisation (migration from seals and gaskets in the closed system), and packing into plastic bottles or pouches. In these circumstances it is difficult to isolate the level of phthalate migration from final packaging alone.

RISK Phthalates

There is concern that current exposure levels could be contributing to reductions in sperm count. The European Chemicals Agency (EChA) recently recommended[21] adding DBP, BBP, DEHP and DINP to the list of Substances of Very High Concern (SVHC), and ortho-phthalates are included on the Californian Proposition 65 list[22] of undesirable chemicals that cause cancer, birth defects or reproductive harm.

BALANCE OF RISKS Phthalates

Phthalates have been reduced in food packaging and kitchen films over recent years, by replacing PVC with alternatives such as polyethylene or polypropylene. Replacement plastics also contain other additives that migrate into food (e.g. glycerol monostearate), but none have been identified that raise the same concerns as phthalates.

RISK MANAGEMENT Phthalates

Phthalates exposure is managed in most countries by well-established SMLs, and by maximum limits for individual phthalates in food packaging and kitchen films. Many of these limits are under review, as it is now thought they are not low enough to protect consumers; for example, EFSA is consulting[20] on a recommendation to introduce a lowered group-based TDI guidance value of 0.05 mg/kg body weight per day (previous TDIs from 0.1 – 50 mg/kg), which would have the knock-on effect of lowering EU SMLs.

Mineral Oil Hydrocarbons (MOHs)

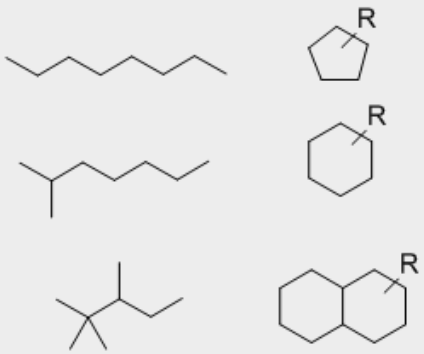
OCCURRENCE Mineral Oil Hydrocarbons (MOHs)

Mineral oil hydrocarbons (MOHs) comprise a diverse group of mixtures of hydrocarbons derived mainly from crude oil but also produced synthetically from coal, natural gas and biomass. They can enter the diet from a wide variety of sources. Examples are from combustion smoke (e.g. oven-dried raisins, or fish exposed to fishing boat diesels) or food-contact lubricants and oils. One source that has attracted recent attention is gaseous migration into food from the newspaper ink in recycled cardboard packaging. Mineral oils are a topic that brings the trade-off between sustainability goals and chemical safety into focus.

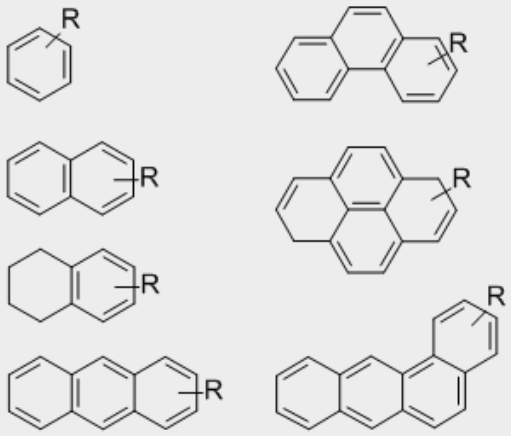
MOHs refer to an uncharacterised and variable mix of substances. In an FCM context, mineral oils are usually broken down into two classes, as shown in **Figure 7**.

Figure 7: Two Classes of Mineral Oil Hydrocarbons

Mineral Oil Saturated Hydrocarbons (**MOSH**) may be straight-chain, branched or cyclic e.g.



Mineral Oil Aromatic Hydrocarbons (**MOAH**) are unsaturated compounds, e.g:



Because of their complexity there is no advantage to considering each compound individually, without data on individual concentrations. In analytical tests MOSH and MOAH are grouped separately and quantified as sums of mixtures.

HAZARD — Mineral Oil Hydrocarbons (MOHs)

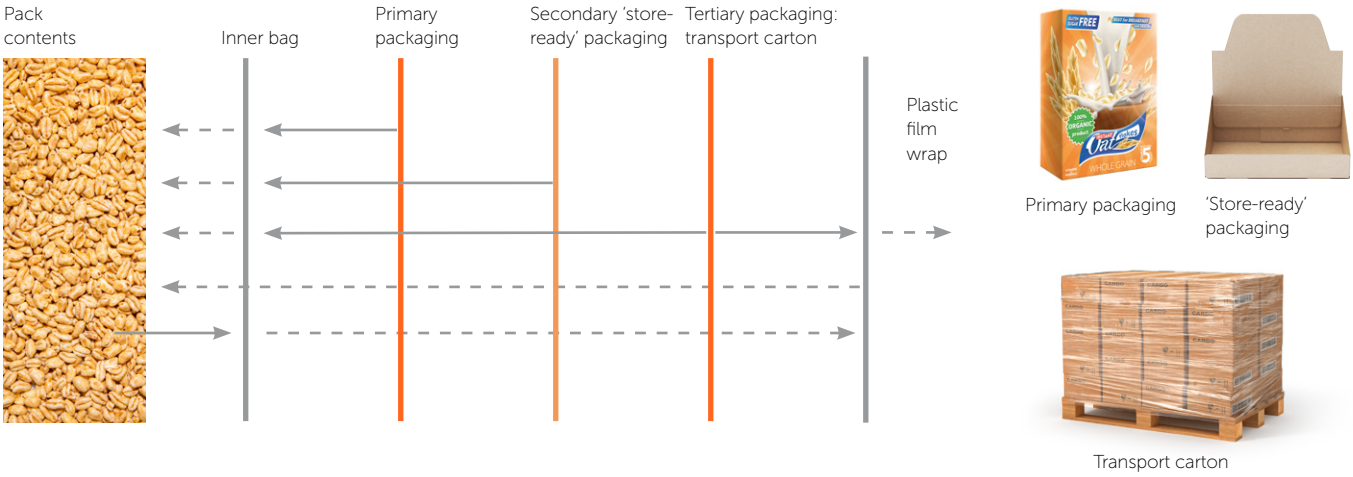
The hazards of MOHs arise from the presence of polyaromatic (3 – 7 ring) MOAH, as these can form genotoxic and carcinogenic DNA adducts. MOHs have low acute toxicity and do not pose significant concern.

EXPOSURE — Mineral Oil Hydrocarbons (MOHs)

MOSH and MOAH have been detected in foods such as dry grains, cereals and dried fruits. Packaging migration into the final product is one potential source, but there are other sources in the supply chain, including primary agriculture and processing. Some of the highest MOH concentrations are in smoked or dried ingredients, such as raisins, and in dry board-packed high-fat foods, such as stuffing mixes.

Modelling the gaseous migration of MOSH and MOAH from packaging into the final product is a complex task. Migration can arise from primary, secondary or tertiary packaging (**Figure 8**), and can be a reversible process. It is temperature-dependent, exacerbated by outer plastic wrap, and mitigated by inner plastic or foil bags.

Figure 8: MOAH/MOSH Gaseous Migration from Cardboard Packaging



Dry goods with a long shelf life, such as flour and cereals, are particularly susceptible to gaseous migration over time. Higher fat dry foods, such as ambient cakes with two to three week shelf lives, readily absorb the hydrocarbon gas and so are susceptible even though their shelf life is shorter.

Estimates of MOSH/MOAH levels in food are highly uncertain. Grob et al.[23] have developed a method to quantify the sums of MOSH and MOAH separately for analysis. Despite a successful ring-test and publication as a European Standard method[24], many laboratories still report a significant quantitative uncertainty and subjectivity in assigning the baseline.

RISK — Mineral Oil Hydrocarbons (MOHs)

Since no dose-response relationship has been established for the genotoxic effects of MOAH, a no-effect (i.e. safe) level cannot be assigned. In addition, a health-based guidance value for MOSH cannot be established due to the absence of toxicological data. More evidence of exposure is still needed for informed risk assessments[25].

BALANCE OF RISKS — Mineral Oil Hydrocarbons (MOHs)

In the absence of regulation, mitigation measures have already been adopted by many food companies but these measures have significant downsides for sustainability goals. For example:

- Use of impermeable inner bags for dry foods (where barrier films were not previously needed) - Increase in single-use plastics.
- Specifying only virgin board (including secondary and tertiary packaging) - Reduced recycling, higher weight, higher energy use.
- Active-carbon adsorbent material in the tertiary packaging - Higher weight, higher energy use, difficult to recycle.

RISK MANAGEMENT — Mineral Oil Hydrocarbons (MOHs)

Risk management proposals are being driven by Germany, which has drafted regulatory MOH limits for food based upon recommendations from the Federal Institute of Risk Assessment (BfR)[26]. Belgium[27] operates a more complex matrix of limits based upon the type of food.

Other countries argue there is insufficient evidence to set regulatory limits or to introduce mitigation controls. This has led to international inconsistency; for example, a recent Dutch "information only" notification of MOHs in Saudi Arabian rice prompted the product to be recalled in Belgium[28]. Food and Drink Europe (the European trade federation) has published an industry best-practice toolbox[29] on mitigating MOH migration.

Regional legal limit variations: a headache when assuring food safety

There is a general food law requirement in most countries that food must be safe. Many territories, including the EU, also have the general requirement that packaging migration which changes the characteristics of food must be prevented with an impermeable barrier. The lack of international regulatory limits, definition, or quantitative test methods for mineral oils do not alter these fundamental legal principles.

Given that a high proportion of dry packaged food contains trace levels of mineral oils, this poses a problem for food manufacturers. Where should they draw the line? The recent pan-European warning[30] about freekeh (smoked grain snacks) containing MOSH at approximately 8,000 mg/kg was uncontentious. This is undoubtedly unsafe. Other regulatory decisions, such as the 2017 Belgian recall[28] of a range of savoury crackers, are much less clear-cut: these recalls were based on Belgian limits, and the products would have been considered safe and legal in many other European countries.

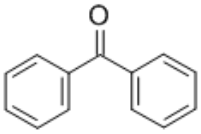
Some multinational brand owners, particularly of breakfast cereals, have opted for compliance by specifying virgin board for their primary packaging and using heavy-duty impermeable inner bags. This response does not suit all brand owners. Consumers would challenge the widespread introduction of impermeable plastic packaging in products where it has never previously been required, such as for oats or dried pasta, due to environmental impact. Some manufacturers have chosen to stay with recycled packaging and conventional inner bags, and accept the mineral oil risk.

Photoinitiators

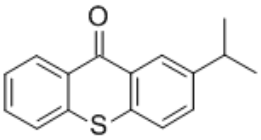
OCCURRENCE Photoinitiators

Photoinitiators are brightening agents used in printing inks and UV-cured varnishes on FCMs, most share a benzoate core but the group encompasses a diverse range of chemical and physical properties. For example:

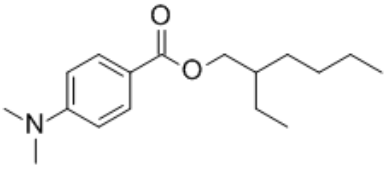
Benzophenone



ITX



Padimate O



Photoinitiators are components of food packaging inks (typically at a concentration of 5-10%) but are also ubiquitous in magazine printing, and so have a secondary food contact source from recycled cardboard. There is evidence of gaseous migration of benzophenone (a volatile photoinitiator) from cardboard to food, in the same manner as mineral oils.

Some of these chemicals occur elsewhere than FCMs. Benzophenone, for example, has been used as a flavouring additive and is naturally present in some foods. It is also used as a cosmetics ingredient. Evidence from all sources needs to be collated in order to make accurate exposure assessments and risk management decisions.

HAZARD Photoinitiators

Different photoinitiators have different toxic effects and potencies. Benzophenone is generally regarded as the most hazardous. It can cause liver and kidney damage in rodents at high concentrations, and has oestrogenic effects. There were media reports in the early 2000s of genotoxicity and reproductive damage, although no mode of action was proposed. However, the EFSA[31] has found that the study behind these reports was unsupported by evidence, and a recent EChA review[32] of benzophenone toxicology concluded it was not genotoxic. In contrast, on the basis of the same study, the US FDA concluded that benzophenone should be considered genotoxic.

EXPOSURE Photoinitiators

Photoinitiator migration into food has frequently been reported, notably leading to a major recall of infant formula milk in 2005 because of the detection of isopropylthioxanthone (ITX).

Risk Management before Risk Assessment?

In 2005, tests on Italian liquid infant formula milk revealed traces of ITX[33]. The photoinitiator was used at the time for printing on the outer sides of Tetrapak® cartons, and had migrated through the inner coating.

There was no evidence that the ITX posed a risk to babies, but equally there had been no systematic risk assessment. In this circumstance, the only responsible option was a precautionary recall. This was conducted by the manufacturer at significant economic cost and brand damage. Tetrapak® stopped using ITX inks with immediate effect.

In response to this event EFSA conducted a rapid risk assessment[34], with the preliminary conclusion that ITX was of low health concern. This conclusion was supported by subsequent more detailed risk assessments, but was too late to affect the recall or resulting adverse publicity.

The lessons from this incident remain relevant today. As new FCM contaminants are highlighted, it is important that there is a systematic programme of chemical analysis, data collation and risk assessment before novel tests are added to regulatory or enforcement schedules.

Breakfast cereals have been raised as a particular concern because of high consumption by children. The type of moisture-proof inner bags often used in breakfast cereal packets do not provide an impermeable barrier to gaseous benzophenone migration. A German study[35] also found benzophenone (up to 60µg/kg) in 25% of cookies, rice, polenta, breadcrumbs and oatflakes that were tested.

RISK — Photoinitiators

The EFSA risk-assessed both ITX and Padimate O following the Italian infant milk recall and concluded that their use in food packaging posed no appreciable risk. They assessed benzophenone in 2009 and concluded that, although breakfast cereals posed no acute risk when considered alone, more data was needed on exposure from non-FCM sources.

Other photoinitiators are rarely tested in food and have not been assessed. There has been little demand for testing and monitoring, either from regulators or from industry. The incremental cost of adding other photoinitiators to existing monitoring tests would be small. Such wider scopes have been validated and published by many research groups or laboratory instrument vendors, and a range of reference standards and internal standards are available.

BALANCE OF RISKS — Photoinitiators

The same sustainability considerations apply to mitigating gaseous benzophenone migration as to mineral oils. Some multinational breakfast cereal brands have switched to specifying virgin cardboard for their primary packaging, or to specifying impermeable rather than vapour-proof inner bags. This has been at the expense of recycling suitability, packaging weight, and more efficient energy use.

RISK MANAGEMENT — Photoinitiators

Germany has set a maximum limit of 600µg/kg for benzophenone and 4-methylbenzylphenone in food, based upon the EFSA-recommended Tolerable Daily Intake (TDI). The US FDA has withdrawn approval for benzophenone as a food flavouring, and set an SML of 1% when used in photoinitiators.

Many food brand and retailer policies specify printing inks that are benzophenone-free, or inks that have been previously recommended by the European Printing Inks Association as “low migration” alternatives to benzophenone.

CONCLUSION

Food contact material contaminants are a growing area of concern and focus, both in the public agenda and in industry. As a potential source of contamination, FCMs are constantly evolving and developing, making it hard for controls and regulations to keep pace. Analytical testing of FCMs is therefore also a challenging arena, and one that needs to factor in many considerations surrounding risk management.

The desirability of using recycled materials inevitably introduces new food contact hazards. It is important to understand and assess any risks presented by these hazards. The introduction, driven by consumer demand, of replacement materials for hazardous FCMs has also in several cases led to potential new risks being introduced, underlining the importance of thorough assessment before action.

Without evidence, risk assessments are little more than educated guesses. More analytical data is needed to inform the exposure models for many FCM contaminants, especially data specific to contaminant levels in food, rather than extrapolating from simulants. In most cases suitable test methods are available and responsible reference material providers are meeting the evolving regulations and trends to provide appropriate products for testing.

If in some instances there is a lack of commercial demand for laboratories to test certain FCM contaminants in food, this is unlikely to be the case indefinitely as consumer awareness grows. Currently the responsibility for funding such "investigative" testing usually falls upon regulators and academics rather than the packaging or food industries, but, much like FCMs themselves, this status quo is likely to evolve and be challenged in the coming years.

The analytical testing community should both respond to and promote public mindfulness of exactly what comes into contact with our food, by applying proper risk assessments with appropriate analytical testing methods that incorporate reliable and traceable reference standards. Once a risk assessment is complete, risk management decisions should be based on a balance of wider policy considerations. These include offsetting the FCM risk against other food safety risks, sustainability goals, and the risk of unintended consequences in the use of substitutes or alternatives. The outcome may be to accept a small risk from FCM contaminants, if it is outweighed by other benefits or is better than alternatives, but it is critical that a mindful approach is taken to the introduction of new FCMs alongside those already commonly used.

ABOUT DR. EHRENSTORFER

Since 1975, Dr. Ehrenstorfer™ has led the way in producing pesticide reference standards. Today, our portfolio has expanded to adapt to changing regulations and technology as we support your needs for high quality reference materials for food and environmental analysis.
lgcstandards.com/drehrenstorfer

ABOUT LGC

LGC is an international leader in the extended life sciences sector, providing a comprehensive range of reference materials, proficiency testing schemes, genomics reagents and instrumentation, as well as research and measurement services. We have cutting-edge expertise in measurement science, serving as the UK National Measurement Laboratory and Designated Institute for chemical and bio measurement. Operating out of 19 countries worldwide, our reference material manufacturing capability includes five facilities accredited to ISO 17034 or its predecessor ISO Guide 34, ensuring our products remain best in class.
lgcgroup.com

ABOUT THE AUTHOR

John Points is a UK-based independent consultant, offering advice on chemical risks and testing strategies to industry, regulators and laboratories in the food, environment and pharmaceuticals sectors.

FOOTNOTES

1 Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food

2 Regulation (EC) No 1935/2004 Of The European Parliament And Of The Council of 27 October 2004 on materials and articles intended to come into contact with food

3 EN 13130-1:2004 Materials and articles in contact with foodstuffs. Plastics substances subject to limitation. Guide to test methods for the specific migration of substances from plastics to foods and food simulants and the determination of substances in plastics and the selection of conditions of exposure to food simulants

4 Code of Federal Regulations – Title 21 – Food and Drugs

5 Online GRAS database at https://www.accessdata.fda.gov/scripts/fdcc/?set=SCOGS (accessed 26 April 2019)

6 GB 9685-2016 National Food Safety Standard: Standard for the Use of Additives in Food Contact Materials, 19 October 2017, http://down.foodmate.net/standard/sort/3/49855.html (Chinese language)

7 Commission Directive 2007/42/EC of 29 June 2007 relating to materials and articles made of regenerated cellulose film intended to come into contact with foodstuffs

8 Commission Regulation (EC) No 1895/2005 of 18 November 2005 on the restriction of use of certain epoxy derivatives in materials and articles intended to come into contact with food

9 https://horizon-scan.fera.co.uk, with data further manipulated by the author

10 Commission Regulation (EU) No 284/2011 of 22 March 2011 laying down specific conditions and detailed procedures for the import of polyamide and melamine plastic kitchenware originating in or consigned from the People's Republic of China and Hong Kong Special Administrative Region, China

11 Scientific Opinion on the risks to public health related to the presence of bisphenol A (BPA) in foodstuffs. EFSA Journal 2015;13(1):3978

12 Opinion of the French Agency for Food, Environmental and Occupational Health & Safety on the assessment of the risks associated with bisphenol A for human health, and on toxicological data and data on the use of bisphenols S, F, M, B, AP, AF and BADGE, 25 March 2013

13 Commission Regulation (EU) 2018/213 of 12 February 2018 on the use of bisphenol A in varnishes and coatings intended to come into contact with food and amending Regulation (EU) No 10/2011 as regards the use of that substance in plastic food contact materials

14 Risk to human health related to the presence of perfluorooctane sulfonic acid and perfluorooctanoic acid in food, EFSA, 22 March 2018

15 http://www.foodstandards.gov.au/consumer/chemicals/Pages/Perfluorinated-compounds.aspx, accessed 28 May 2019

16 Risk to human health related to the presence of perfluorooctane sulfonic acid and perfluorooctanoic acid in food, EFSA, 22 March 2018

17 https://www.food.dtu.dk/english/-/media/Institutter/Foedevareinstituttet/Publikationer/Pub-2018/Rapport-PFAS-in-paper-and-board-for-food-contact-Options-for-risk-management-of-poly-and-perfluorina.ashx?la=da&hash=E30BCD60829A7FE111B58FC5702C7E0005149698, accessed 27/5/19

18 https://www.federalregister.gov/documents/2016/01/04/2015-33026/indirect-food-additives-paper-and-paperboard-components, accessed 27/5/19

19 ECHA, Committee for Risk Assessment (RAC) and Committee for Socioeconomic Analysis (SEAC). Opinion on an Annex XV dossier proposing restrictions on four phthalates (DEHP, BBP, DBP, DIBP).

20 EFSA draft consultation of 6 February 2019. Update of the risk assessment of DBP, BBP, DEHP, DINP and DIDP for use in food contact materials

21 ECHA, Committee for Risk Assessment (RAC) and Committee for SocioeconomicAnalysis (SEAC). Opinion on an Annex XV dossier proposing restrictions on four phthalates (DEHP, BBP, DBP, DIBP).

22 https://oehha.ca.gov/proposition-65/proposition-65-list, accessed 27/5/19

23 On-line coupled high performance liquid chromatography–gas chromatography for the analysis of contamination by mineral oil. Part 1: Method of analysis, Biederman and Grob, Journal of Chromatography 1255 (2012) 56

24 EN16995:2017 Determination of MOSH and MOAH with online HPLC-GC-FID analysis.

25 EFSA Journal 2012;10(6):2704 Scientific Opinion on Mineral Oil Hydrocarbons in Food

26 https://www.bfr.bund.de/en/questions_and_answers_on_mineral_oil_components_in_food-132254.html, accessed 14 April 2019

27 http://www.favv.be/professionelen/levensmiddelen/mineraleolie, accessed 27/5/19

28 http://www.favv-afsca.fgov.be/rappelsdeproduits/2018/2018-12-13.asp, accessed 1 May 2019.

29 https://www.fooddrinkeurope.eu/uploads/publications_documents/Preventing_transfer_of_undesired_Mineral_Oil_Hydrocarbons_into_food_FoodDrinkEurope_BLL_Toolbox.pdf, accessed 28 May 2019

30 https://webgate.ec.europa.eu/rasff-window/portal/index.cfm?event=notificationDetail&NOTIF_REFERENCE=2019.0086, accessed 28 May 2019

31 Toxicological evaluation of benzophenone The EFSA Journal (2009) 1104, 1-30

32 EC No 204-337-6 Substance Evaluation Conclusion As Required By Reach Article 48 And Evaluation Report for Benzophenone

33 http://news.bbc.co.uk/1/hi/world/europe/4459520.stm, accessed 28 May 2019

34 https://www.efsa.europa.eu/en/press/news/051209 accessed 28 May 2019

35 BMELV Project 09HS012, available at http://www.ble.de

DR EHRENSTORFER™

Order online at lgcstandards.com/drehrenstorfer
dr.ehrenstorfer@lgcgroup.com

All trademarks and registered trademarks mentioned herein are the property of their respective owners. All other trademarks and registered trademarks are the property of LGC and its subsidiaries. Specifications, terms and pricing are subject to change. Not all products are available in all countries. Please consult your local sales representative for details. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or any retrieval system, without the written permission of the copyright holder. © LGC Limited, 2019. All rights reserved.