Food Research International 137 (2020) 109499

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Monograph

A ranking method of chemical substances in foods for prioritisation of monitoring, based on health risk and knowledge gaps

Gro Haarklou Mathisen[a], Jan Alexander[a,b], Christiane Kruse Fæste[a,c], Trine Husøy[a,b], Helle Katrine Knutsen[a,b], Robin Ørnsrud[a,d], Inger-Lise Steffensen[a,b,*]

[a] Norwegian Scientific Committee for Food and Environment, P.O. Box 222 Skøyen, NO-0213 Oslo, Norway
[b] Norwegian Institute of Public Health, P.O. Box 222 Skøyen, NO-0213 Oslo, Norway
[c] Norwegian Veterinary Institute, P.O. Box 750 Sentrum, NO-0106 Oslo, Norway
[d] Institute of Marine Research, NO-5817 Nordnes, Bergen, Norway

A R T I C L E   I N F O

Keywords:
Data gaps
Food contaminants
Monitoring
Prioritisation
Ranking
Risk

A B S T R A C T

Chemical contaminants are present in all foods. Data on the occurrence of contaminants in foods that are often consumed or contain high contaminant concentrations are critical for the estimation of exposure and evaluation of potential negative health effects. Due to limited resources for the monitoring of contaminants and other chemical substances in foods, methods for prioritisation are needed. We have developed a straightforward semi-quantitative method to rank chemical substances in foods for monitoring as part of a risk-based food control. The method is based on considerations of toxicity, level of exposure including both occurrence in food and dietary intake, vulnerability of one or more population groups due to high exposure because of special food habits or resulting from specific genetic variants, diseases, drug use or age/life stages, and the adequacy of both toxicity and exposure data. The chemical substances ranked for monitoring were contaminants occurring naturally, unintentionally or incidentally in foods or formed during food processing, and the inclusion criteria were high toxicity, high exposure and/or lack of toxicity or exposure data. In principle, this method can be used for all classes of chemical substances that occur in foods, both unintended contaminants and deliberately added chemical substances. Foods considered relevant for monitoring of the different chemical substances were also identified. The outcomes of ranking exercises using the new method including considerations of vulnerable groups and adequacy of data and a shortened version based on risk considerations only were compared. The results showed that the resolution between the contaminants was notably increased with the extended method, which we considered as advantageous for the ranking of chemical substances for monitoring in foods.

1. Introduction

Food safety is an important prerequisite for good health. With the constant change in food production, processing and dietary habits, there is a continuous need for up-to-date knowledge on the presence of chemical substances in foods. Such knowledge is a critical part of risk assessments of chemical substances in food to ensure food safety. Therefore, monitoring of chemical substances that have a potential to pose a health risk is important (INFOSAN, 2009; van der Fels-Klerx et al., 2015). Data on the occurrence of chemical substances in highly consumed food items and in less consumed but highly contaminated food items are critical for risk assessments related to dietary exposure. Hence, prioritisation of chemical substances for monitoring in foods has to take into consideration i.a. potential health hazards, occurrences and the adequacy of data.

Health-based guidance values (HBGVs), i.e. tolerable daily intake (TDI) or tolerable weekly intake (TWI), define the amount of a specific contaminant that an individual can consume on a regular basis over a lifetime without any appreciable risk to health (EFSA, 2020). Comparison of the HBGVs to the estimated dietary exposure in a geographical region or a population group may be used to rank chemical substances according to the health risk (van der Fels-Klerx et al., 2015).

Abbreviations: BMDL, benchmark dose lower confidence limit; BMR, benchmark response; HBGV, health-based guidance value; MOE, margin of exposure; NOAEL, no observed adverse effect level; TDI, tolerable daily intake; TWI, tolerable weekly intake; VKM, Norwegian Scientific Committee for Food and Environment

* Corresponding author at: Norwegian Institute of Public Health, P.O. Box 222 Skøyen, NO-0213 Oslo, Norway.
E-mail addresses: gro.haarklou.mathisen@vkm.no (G.H. Mathisen), Jan.Alexander@fhi.no (J. Alexander), Christiane.Faste@vetinst.no (C.K. Fæste), Trine.Husoy@fhi.no (T. Husøy), HelleKatrine.Knutsen@fhi.no (H. Katrine Knutsen), Robin.Ornsrud@HI.no (R. Ørnsrud), Inger-Lise.Steffensen@fhi.no (I.-L. Steffensen).

https://doi.org/10.1016/j.foodres.2020.109499
Received 10 February 2020; Received in revised form 20 May 2020; Accepted 24 June 2020
Available online 30 June 2020
0963-9969/ © 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/BY/4.0/).

Table 1
Explanation to categories for ranking of chemical substances in foods for monitoring. When quantitative data on toxicity and exposure were available, scores were given in the categories 1, 4, 5 and 6. When either quantitative toxicity or exposure data was unavailable, scores were given in the categories 2, 3, 4, 5 and 6.

Category	Description	Score
1. Quantitative toxicity and exposure data available	The exposure was above the HBGV or the MOE* was too low	6
	The exposure was close to the HBGV or the MOE* was close to an acceptable value	4
	The exposure was well below the HBGV or the MOE* was sufficiently high	2
2. Toxicity of the chemical	High toxicity	3
	Medium toxicity	2
	Low toxicity	1
3. Dietary exposure to the chemical**	High exposure	3
	Medium exposure	2
	Low exposure	1
4. Vulnerable groups	The exposure was high because of special food habits for one or more groups in the population, or one or more groups in the population were especially vulnerable due to, for example, specific genetic variants, diseases, drug use or age/life stages (<1 year, puberty, pregnant/nursing, elderly)	1
	The exposure was somewhat higher because of special food habits for one or more groups in the population, or one or more groups in the population were somewhat more vulnerable due to, for example, specific genetic variants, diseases, drug use or age/life stages (<1 year, puberty, pregnant/nursing, elderly)	0.5
	No population group with increased exposure because of special food habits or special vulnerability due to, for example, specific genetic variants, diseases, drug use or age/life stages (<1 year, puberty, pregnant/nursing, elderly) was identified	0
5. Adequacy of toxicity data	Toxicity data were insufficient or lacking	1
	Some toxicity data were lacking	0.5
	Sufficient toxicity data were available	0
6. Adequacy of exposure data (occurrence and/or intake)	Exposure data were insufficient or lacking	1
	Some exposure data were lacking	0.5
	Sufficient exposure data were available	0

BMDL (benchmark dose lower confidence limit); HBGV (health-based guidance value); MOE (margin of exposure); NOAEL (no observed adverse effect level); TDI (tolerable daily intake); TWI (tolerable weekly intake).
*MOE was too low/MOE was sufficiently high:

- o For compounds that were genotoxic and carcinogenic (compounds for which no threshold of toxicity can be identified), a MOE <10,000 based on the $BMDL_{10}$ (the lower limit of an one-sided 95% confidence interval on the BMDL, corresponding to a 10% tumour incidence over control), would in general be considered as too low. Considerations with regard to a sufficiently large MOE that would allow to conclude on low risk have to be case-specific and based on the available data.
- o For non-genotoxic compounds (for which a threshold for adverse effects can be identified), a MOE <100 based on the no observed adverse effect level (NOAEL) or BMDL, would in general be considered as too low. Depending on the available data, the necessary size of the MOE may be judged differently.

**Based on occurrence and/or intake, or biomonitoring showing high total exposure, from food as one important source.

Alternatively, the margin of exposure (MOE) may also be suitable to rank chemical substances according to risk. The MOE is calculated under consideration of a reference point such as the no observed adverse effect level (NOAEL) or the benchmark dose lower confidence limit (BMDL) for the critical health effect. NOAEL is the highest dose of a compound, at which no detectable adverse effects occur in experimental animals or in a population (EFSA, 2020). The benchmark dose (BMD) is the minimum dose of a compound that produces a distinct, low-level adverse health effect, i.e. a benchmark response (BMR), usually in the range of a <0.5 to 10% increase in a specific adverse effect (EFSA, 2020). The BMDL is the lower boundary of the 95% confidence interval of the BMD. MOE is the ratio of NOAEL or BMDL for the critical effect and the human exposure (EFSA, 2005a).

Owing to limited resources, there is a need for ranking of chemical substances in foods in accordance with their estimated health risk to enable risk managers to perform a knowledge-based prioritisation of chemical substances for monitoring. Here, we present a straightforward semi-quantitative method for the ranking of chemical substances for monitoring in foods, based on their estimated risk for human health and critical knowledge gaps.

2. Methodology

2.1. Selection of chemical substances for ranking

Expert judgement was used for the selection of chemical substances included in the ranking and for the identification of food items relevant for their monitoring. The chemical groups included were natural toxins, metals and metalloids, persistent organic pollutants (POPs), process-induced contaminants and food contact materials. Veterinary medicine residues and pesticides were excluded as ongoing monitoring programmes are in place in Norway. For other chemicals, there are no established monitoring programmes, therefore, a ranking serving as basis for prioritisation by the risk managers on which substances to monitor for the limited funds available for this purpose each year is needed. Criteria for the selection of chemical substances were high toxicity, high dietary exposure and lack of data on toxicity or occurrence in foods, as further described in the following section.

2.2. Ranking for monitoring method

The method used to rank chemical substances in foods for monitoring was based on considerations of known toxicity and level of exposure (including the occurrence in food and dietary intake) and vulnerability of one or more defined population groups due to high exposure because of special food habits or resulting from specific genetic variants, diseases, drug use or age/life stages. In addition, the adequacy of both toxicity and exposure data was considered. An overview of the scoring is presented in Table 1. When quantitative data on toxicity and exposure were available, a chemical was scored according to the scoring categories 1, 4, 5 and 6. When either quantitative toxicity or exposure data were unavailable, a chemical was scored according to the categories 2, 3, 4, 5 and 6. The highest possible score was 9 and the lowest possible score was 2, based on the sum of either scoring, i.e. categories 1, 4, 5 and 6, or 2, 3, 4, 5 and 6. The awarding of high, medium or low scores for each category was based on expert judgements. The initial scoring was performed by 15 experts who had extensive knowledge of the toxicity and/or exposure of the various

Table 2
Scoring results for metals and metalloids in ranking for monitoring.

Chemical/ chemical group Total score	Category scored*	Score	Rationale for score	References
Lead (Pb) 7.5	1	6	Developmental neurotoxicity in young children and cardiovascular effects and nephrotoxicity in adults were identified as the critical effects. Exposure assessment for the European population showed almost no margin of exposure to the BMDLs for the critical effects.	EFSA (2010)
	4	1	Foetus and children, and high consumers of game shot with ammunition containing Pb.	
	5	0	Sufficient data were available.	
	6	0.5	Data on concentrations in small game shot with ammunition containing Pb were needed.	
Methyl-mercury (MeHg) 7	1	6	MeHg is neurotoxic, and the prenatal and postnatal stages are the most vulnerable. The TWI is 1.3 µg/kg bw and the estimated 95-percentile exposure was in the range of the TWI.	EFSA (2012b)
	4	1	Pregnant women, and high consumers of fish with high levels of mercury may exceeded the TWI.	
	5	0	Sufficient data were available.	
	6	0	Sufficient data were available.	
Arsenic, inorganic (iAs) 6.5	1	6	Reference points for carcinogenic effect are the $BMDL_{01}$ of 0.3–8 µg/kg bw per day and the $BMDL_{05}$ of 3 µg/kg bw per day. The dietary exposure to iAs was within the range of the $BMDL_{01}$.	EFSA (2009b), JECFA et al. (2011)
	4	0.5	High consumers of rice.	
	5	0	Sufficient data were available.	
	6	0	Sufficient data were available.	
Cadmium (Cd) 6.5	1	6	The TWI is 2.5 µg/kg bw. The exposure in the European population was in the range of the TWI, and the 95-percentile exceeded the TWI.	EFSA (2009a)
	4	0.5	Individuals with low iron status have an enhanced intestinal Cd absorption.	
	5	0	Sufficient data were available.	
	6	0	Sufficient data were available.	
Aluminium (Al) 4.5	1	4	A TWI of 1 mg/kg bw and a provisional TWI of 2 mg/kg bw per day have been established. The mean dietary exposure in Norway varied from 0.22 to 0.89 mg/kg bw per week and for high consumers of Al-containing foods the 95-percentile exceeded the TWI but was below the pTWI.	EFSA (2008b), JECFA (2011), VKM (2013b)
	4	0.5	High consumers of food with Al, and one- to two-year old children.	
	5	0	Sufficient data were available.	
	6	0	Sufficient data were available.	
Organic arsenic (oAs) 4	2	1	The toxicity was not well characterised.	Molin et al. (2015), Taylor et al. (2017)
	3	1	Little information on exposure was available.	
	4	0	No particularly vulnerable groups were identified.	
	5	1	Toxicity data were needed.	
	6	1	Occurrence data were needed.	
Chromium (Cr) 3	1	2	The two main Cr oxidation states are CrIII and CrVI. The exposure in European populations was well below the TDI of 0.3 mg/kg bw per day for CrIII. For CrVI, a $BMDL_{10}$ for diffuse epithelial hyperplasia in duodenum in female mice and a $BMDL_{05}$ for haematotoxicity in rats were used to calculate MOE values, and these values indicated low public health concern.	EFSA (2014b)
	4	0	No vulnerable groups were identified.	
	5	0	Sufficient data were available.	
	6	1	Occurrence data were needed.	
Nickel (Ni) 3	1	2	A $BMDL_{10}$ of 0.28 mg/kg bw for reproductive toxicity was established. Exposure assessment for the European population was between 80 and 150 µg/person per day and of no concern.	EFSA (2015c)
	4	1	Intake of Ni from food could be a problem for allergic individuals.	
	5	0	Sufficient data were available.	
	6	0	Sufficient data were available.	

*Explanations of category numbers: 1) Quantitative toxicity and exposure data available; 2) Toxicity of the chemical; 3) Dietary exposure to the chemical; 4) Vulnerable groups; 5) Adequacy of toxicity data; 6) Adequacy of exposure data (occurrence and/or intake).

groups of chemicals included in the ranking, such as metals, mycotoxins, food contact materials etc., through their own research and long experience in chemical risk assessment work. In addition, after the individual scorings were done by the respective experts for each chemical category, all scorings were discussed in the whole working group in order to achieve a consistent way of scoring by expert judgements. When the database was insufficient for taking an informed decision or the uncertainty was high, the medium score was chosen.

2.3. Identification of foods for monitoring of the ranked chemical substances

Food groups considered relevant for monitoring of the included chemical substances were identified by expert judgements based on available occurrence data in foods, preferable from national databases, or if not available, European or international data from databases or scientific papers. The respective food items were selected based on existing data showing considerable prevalence of specific contaminants

Table 3
Scoring results for mycotoxins in ranking for monitoring.

Chemical/ chemical group Total score	Category scored*	Score	Rationale for score	References
T-2 toxins, HT-toxins and modified forms 8.5	1	6	A group TDI for T-2 and HT-2 of 20 ng/kg bw per day was established. The maximum dietary exposure for T-2 and HT-2 toxins exceeded the group TDI for most European population groups.	EFSA et al. (2017a)
	4	1	Infants, toddlers and other children.	
	5	0.5	Toxicity data for T-2 and HT-2 phase I metabolites were needed.	
	6	1	Occurrence data for T-2 and HT-2 in Norwegian grain and grain products and data for modified forms were needed.	
AFLAs 7.5	1	6	AFLAs are carcinogenic causing mainly liver cancer. The calculated AFLA-induced cancer risk exceeded the low-risk value at the current maximum level for chronic dietary exposure.	EFSA (2007), EFSA et al. (2018b)
	4	0.5	Children and vegetarians may have a higher exposure than the mean population.	
	5	0.5	A full risk assessment on human dietary exposure from AFLAs in food were needed considering the toxicological profiles of the different AFLAs.	
	6	0.5	Occurrence data for AFLA in Norwegian grain and food products were needed.	
ENNs 6.5	2	1.0	Cytotoxic effects observed in cell studies have not been observed *in vivo*. There were no reports on acute ENNs-mycotoxicoses in humans or animals.	EFSA (2014a)
	3	3.0	There was a concern with respect to chronic exposure.	
	4	0.5	ENNs can cross the placenta. Toddlers have the highest dietary chronic and acute exposure to ENNs.	
	5	1.0	Toxicity data were needed.	
	6	1.0	Occurrence data in Norwegian grain and grain products were needed.	
AOH and AME 6	2	2	In cell assays observed genotoxicity was not confirmed *in vivo* after multiple applications of a dose exceeding the highest estimated exposure in humans by a factor of at least 10^4.	EFSA (2011b), EFSA et al. (2016)
	3	2	The mean dietary exposure in adults was determined at a level 10^6-times below the highest dose in a mice study that did not indicate genotoxic effects.	
	4	0.5	The dietary exposure in children was expected to be 2–3 times higher than in adults. For vegetarians, the higher intake of food of plant origin might increase the exposure.	
	5	1.0	Toxicity data for AOH/AME were limited. A NOAEL had not been determined, and a TDI had not been established.	
	6	0.5	More data on the occurrence of AOH/AME in Norwegian cereals were needed.	
DON and modified forms 6	1	4.0	The tolerable daily intake of 1 µg/kg bw per day was exceeded by up to 3.5 times in infants and small children for DON alone.	VKM (2013a)
	4	1.0	Infants in Norway had higher consumption of cereal-based foods than other European children.	
	5	0.5	Data on chronic low-level exposure to DON were needed.	
	6	0.5	More occurrence data were needed.	
OTA 5.5	1	4.0	TWI (120 ng/kg bw per day), pTWI (100 ng/kg bw per day) and TDI (3 ng/kg bw per day) were established based on nephrotoxicity. For intake for OTA at 4 ng/kg bw per day, the cancer risk was negligible. European exposure data was below the TDI, but high consumers exceeded the TDI.	EFSA (2006), JECFA (2008), Kuiper-Goodman et al. (2010)
	4	0	No relevant vulnerable groups were identified.	
	5	0.5	More toxicity data were needed.	
	6	1	Occurrence data were needed.	
PAT 3.5	1	2.0	The provisional maximum tolerable daily intake (pmTDI) for PAT was 0.4 µg/kg bw per day. Using European exposure data from consumption of apple-based products, the calculated MOE values indicated no concern.	JECFA (1996)
	4	0	No vulnerable groups were identified.	
	5	0.5	More toxicity data were needed.	
	6	1	Occurrence data were needed.	
ZEN and modified forms 3.5	1	2	The group TDI for ZEN and modified forms was 0.25 µg/kg bw per day. Estimates of chronic dietary exposure were below or in the region of the TDI for all age groups.	EFSA (2016a)
	4	0	Specific vulnerable groups were not identified.	
	5	1	Data on estrogenicity and toxicokinetics of the modified forms (phase I and phase II metabolites) were needed.	
	6	0.5	Data on ZEN in maize-based products was needed. There was limited data on the occurrence of modified forms in food and feed.	

*Explanations of category numbers: 1) Quantitative toxicity and exposure data available; 2) Toxicity of the chemical; 3) Dietary exposure to the chemical; 4) Vulnerable groups; 5) Adequacy of toxicity data; 6) Adequacy of exposure data (occurrence and/or intake).

Table 4
Scoring results for persistent organic pollutants (POPs) in ranking for monitoring.

Chemical/ chemical group Total score	Category scored*	Score	Rationale for score	References
Dioxins and DL-PCBs 8	1	6	A TWI of 2 pg TE/kg bw per week was established and the estimated exposure for the European population was above the TWI.	EFSA et al. (2018c)
	4	1	Young women and children were sensitive groups.	
	5	0.5	Data on the relative potency of individual DL-compounds were needed, in particular for PCB-126.	
	6	0.5	Occurrence data for composite food (e.g. fish gratin, fish cakes) and land-based food (butter, cheese, eggs) were needed.	
PFOS and PFOA 8	1	6	Average exposure was above the provisional TWI in several dietary surveys.	EFSA et al. (2018a)
	4	0.5	High consumers of fish have higher exposure.	
	5	0.5	Data on mode of action were needed.	
	6	1	Data on occurrence in drinking water were needed. For occurrence data in foods, methods with lower LOQ should be used.	
NDL-PCBs 5.5	2	2	NDL-PCB congeners were considered to be of low toxicity.	EFSA et al. (2005g)
	3	2	NDL-PCBs are hardly degradable, highly fat-soluble, enriched in the food chain and can be measured at particularly high concentrations in certain types of seafood with high fat content (e.g. cod liver).	
	4	1	Potentially vulnerable groups were young women nursing babies and people with a high consumption of fatty fish and fish products, seagull eggs and brown crab meat.	
	5	0.5	Data on the toxic mode of action were needed. Interacting effects between different PCB compounds were likely and data were needed.	
	6	0	Sufficient data were available.	
BTBPE, DBDPE, HBB 4	2	1	Oral exposure of rats indicated low toxicity.	EFSA (2012a)
	3	1	Most studies in food showed occurrence levels below the LOQ.	
	4	0	There were no particular vulnerable groups.	
	5	1	Toxicity data were needed.	
	6	1	Occurrence data were needed.	
TBP 4	1	2	Current dietary exposure to TBP does not raise a health concern.	EFSA (2012c)
	4	0	No indication of susceptible groups.	
	5	1	Toxicity data were needed.	
	6	1	Occurrence data were needed.	
D6 4	1	2	A MOE of approximately 40,000 was reported for the general population in Canada.	Danish Ministry of the Environment (2014), Environment Canada and Health Canada (2008)
	4	0.5	D6 was detected in human breast milk samples, and infants may therefore have a high intake.	
	5	1	Toxicity data on acute inhalation toxicity, irritation, sensitisation, multiple dose toxicity, reproductive toxicity, mutagenicity, genotoxicity or carcinogenicity were needed.	
	6	0.5	Occurrence data were needed.	
PBDEs 3.5	1	2	A $BMDL_{10}$ was derived from effects on neurodevelopment in mice as the critical endpoint. MOE values were calculated and indicated no health concerns.	EFSA (2011a)
	4	0.5	Children (1 to 3 years) have high exposure.	
	5	0.5	More toxicity data were needed to establish a HBGV.	
	6	0.5	New occurrence data for food on the Norwegian market were needed.	
HBCDD 3	1	2	Current dietary exposure to HBCDD does not raise a health concern.	EFSA (2011c)
	4	0	There were no particular vulnerable groups.	
	5	0.5	More toxicity data were needed.	
	6	0.5	Updated occurrence data were needed.	

*Explanations of category numbers: 1) Quantitative toxicity and exposure data available; 2) Toxicity of the chemical; 3) Dietary exposure to the chemical; 4) Vulnerable groups; 5) Adequacy of toxicity data; 6) Adequacy of exposure data (occurrence and/or intake).

Table 5
Scoring results for process-induced contaminants in ranking for monitoring.

Chemical/ chemical group Total score	Category scored*	Score	Rationale for score	References
Furans 8.5	1	6	The exposure to furan is of health concern for all age groups, particularly for infants and children.	EFSA et al. (2017b), VKM (2012)
	4	0.5	Infants have the highest exposure.	
	5	1	Toxicity data were needed to establish a TDI.	
	6	1	Occurrence data were needed.	
Acrylamide 8	1	6	The MOE values across all age groups indicated a health concern. Similar results were found for Norwegian children.	EFSA (2015a), VKM (2015)
	4	1	Children have the highest dietary exposure.	
	5	0.5	Data on developmental outcomes were needed.	
	6	0.5	Occurrence data for home-cooked meals and new types of crisp bread and biscuits were needed.	
GEs 8	1	6	GEs are converted to glycidol, which is genotoxic and carcinogenic, following ingestion. Most MOE values were below 25,000; values of 25,000 or higher were considered of low health concern.	EFSA (2016b), EFSA et al. (2018d)
	4	0.5	Infants consuming formula only, and children consuming marine oil supplements.	
	5	1	Data on dose–response for carcinogenesis from chronic lifetime oral administration of glycidol and its esters were needed.	
	6	0.5	Data on GEs in refined fish oil were needed.	
HAAs 7	2	3	Several HAAs have been classified as possible (class 2A) or probable (class 2B) carcinogens.	IARC (2015)
	3	2	Information about the daily HAA intake can vary substantially among epidemiological studies.	
	4	0.5	Persons with high intake of meat, especially read meat prepared as well-done, will have high exposure. Persons with high activity of metabolic enzymes, both phase I and phase II, that affect the metabolism of HAAs in the direction of bioactivation are more vulnerable.	
	5	1	Toxicity data for other endpoints than mutagenicity, genotoxicity and carcinogenicity were needed.	
	6	0.5	Occurrence data were needed, especially taking food preparation methods into consideration.	
PAHs 6	1	4	PAHs were genotoxic compounds. The MOE for high consumers ranged from 9,600 to 10,800.	EFSA (2008a), VKM (2011)
	4	1	People consuming food products containing increased PAH concentrations such as mussels from contaminated waters, grilled meat, food prepared using open fire etc., are more vulnerable.	
	5	0.5	Exposure to mixtures of PAHs is usual, and data on carcinogenic effects of mixtures were needed.	
	6	0.5	Occurrence data for food prepared on fire, grilled food, mussels from contaminated areas etc., were needed.	
3-MCPD and its fatty esters 5.5	1	4	The TDI of 2 μg/kg bw per day was not exceeded in the adult population. A slight exceedance of the TDI was observed for high consumers in younger age groups and in particular in scenarios considering infants receiving formula only.	EFSA et al. (2018d)
	4	0.5	Infants consuming formula only may exceed the TDI.	
	5	0.5	Data on developmental and neurodevelopmental effects, and effects on male reproduction and fertility were needed.	
	6	0.5	Occurrence data were needed.	

*Explanations of category numbers: 1) Quantitative toxicity and exposure data available; 2) Toxicity of the chemical; 3) Dietary exposure to the chemical; 4) Vulnerable groups; 5) Adequacy of toxicity data; 6) Adequacy of exposure data (occurrence and/or intake).

in the food groups or high consumption of these foods, as both can lead to high contaminant exposure of the consumers, and thus contributing most to the exposure of the population to a certain chemical.

3. Results and discussion

3.1. Chemical substances included in the ranking for monitoring

In total, 33 relevant chemical substances or chemical groups were selected by expert judgement as a proof of concept for the development of a ranking method. The inclusion criteria were high toxicity, high exposure and/or lack of toxicity or exposure data. All chemical substances were naturally occurring, unintentionally or incidentally in foods or formed during food processing:

- Metals and metalloids including aluminium (Al), inorganic arsenic (iAs), organic arsenic (oAs), cadmium (Cd), chromium (Cr), lead (Pb), methylmercury (MeHg) and nickel (Ni).
- Mycotoxins including aflatoxins (AFLAs), alternariol (AOH) and alternariol methylether (AME), deoxynivalenol (DON) and modified forms, enniatins (ENNs), ochratoxin A (OTA), patulin (PAT), T-2 toxin, HT-toxin and modified forms, zearalenone (ZEN) and modified forms.
- Persistent organic pollutants (POPs) including brominated flame retardants (polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD), hexabromobenzene (HBB), decabromodiphenyl ethane (DBDPE), 1,2-bis(2,4,6-tribromophenoxy) ethane (BTBPE), 2,4,6-tribromophenol (TBP)), dioxins and dioxin-like polychlorinated biphenyls (DL-PCBs), non-dioxin-like PCBs (NDL-PCBs), perfluoroalkyl substances (PFAS; perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA)) and siloxanes (dodecamethylcyclohexasiloxane (D6)).
- Process-induced contaminants including acrylamide, glycidyl esters (GEs), 3-monochloropropanediol (3-MCPD) and its esters, furans (furan, 2-methylfuran and 3-methylfuran), heterocyclic aromatic amines (HAAs) and polycyclic aromatic hydrocarbons (PAHs).
- Compounds in food contact materials, including bisphenol A (BPA), bisphenol S (BPS), bisphenol F (BPF) and bisphenol AF (BPAF) and the phthalates bis(2-ethylhexyl)phthalate (DEHP), butyl-benzyl-phthalate (BBP), di-butylphthalate (DBP), di-isodecyl phthalate

Table 6
Scoring results for chemical substances/chemical groups in food contact materials in ranking for monitoring.

Chemical/ chemical group Total score	Category scored*	Score	Rationale for score	References
BPF, BPS and BPAF 6.5	2	2	There was not sufficient toxicological data available to assess the toxicity.	ANSES (2013), EFSA (2015b)
	3	2	Biomonitoring data showed an increasing exposure.	
	4	0.5	Knowledge on possible vulnerable groups was needed.	
	5	1	No threshold for toxicity had been established.	
	6	1	Data on occurrence in foods were needed.	
Phthalates (DEHP, BBP, DBP, DIDP, DINP) 3.5	1	2	The TDI is 0.05 mg/kg bw per day, and the exposure was found to be below the TDI. The estimated exposure for Norwegian adults was well below the TDI.	EFSA (2005b), EFSA (2005c), EFSA (2005d), EFSA (2005e), EFSA (2005f), EFSA et al. (2019), Sakhi et al. (2014)
	4	0.5	DEHP had adverse reproductive effects, which were transferred to future generations. The fetus was especially vulnerable to phthalate exposure.	
	5	0.5	More studies on immunotoxicity, neurotoxicity and metabolic effects were needed.	
	6	0.5	More occurrence data were needed.	
BPA 3	1	2	The calculated exposure was below the temporary TDI (tTDI) for BPA for all population groups.	EFSA (2015b)
	4	0	There were no particular vulnerable groups.	
	5	0.5	More toxicity data were needed to establish a permanent TDI.	
	6	0.5	More occurrence data were needed.	

*Explanations of category numbers: 1) Quantitative toxicity and exposure data available; 2) Toxicity of the chemical; 3) Dietary exposure to the chemical; 4) Vulnerable groups; 5) Adequacy of toxicity data; 6) Adequacy of exposure data (occurrence and/or intake).

(DIDP) and di-isononyl phthalate (DINP).

The scoring of selected chemical substances was likewise based on expert judgement. The chemical substances were allocated to experts in the respective fields and evaluated by the established ranking method. Subsequently, the scoring results were discussed among the experts for validation and balancing of individual assessments.

Alternatively to using expert judgement for the scoring, a more systematic approach involving extensive literature searches could have been applied. However, this would have required substantially more effort and time. As the purpose of the present project was to establish a method for the ranking of chemical substances for monitoring and not the performance of risk assessments, the expert-based approach appeared to be appropriate, practical and time-saving.

3.2. Rationale for the scoring and ranking of individual chemical substances or chemical groups for monitoring

The chemical substances were evaluated and scored according to the methodology presented in Table 1. The scoring and the rationale for the scores given are shown in Table 2 for metals and metalloids, Table 3 for mycotoxins, Table 4 for POPs, Table 5 for process-induced contaminants, and Table 6 for compounds present in food contact materials. For metals and metalloids, the total scores ranged from 3.0 for nickel and chromium to 7.5 for lead. For mycotoxins, the total scores ranged from 3.5 for PAT and ZEN and modified forms to 8.5 for T-2 toxins, HT-2 toxins and modified forms. For POPs, the total scores ranged from 3.5 for PBDEs to 8.0 for dioxins and DL-PCBs, and PFOS and PFOA. For process-induced contaminants, the total scores ranged from 5.5 for 3-MCPD and its fatty esters to 8.5 for furans. For compounds in food contact materials, the total scores ranged from 3.0 for BPA to 6.5 for BPF, BPS and BPAF.

We have developed the ranking of chemical substances for monitoring in foods as a tool for priority-setting with regard to risk-based food safety control. The method allows the ranking of chemical substances in different chemical classes and is simply based on the scoring of risk and knowledge gaps by expert judgement considering existing data. Knowledge gaps regarding toxicity and exposure are usually not included in risk ranking methods developed by other agencies (NFA et al., 2018; van der Fels-Klerx et al., 2015). We considered the inclusion of such gaps essential for the comprehensive evaluation of the risk potential of dietary contaminants and for their potential inclusion in food monitoring programs. The method developed by us is useful for the ranking of dietary contaminants, such as metals, mycotoxins, persistent organic pollutants, process-induced contaminants and food contact materials, as shown in this paper. However, in principle, the method can be used for all types of chemical substances occurring in foods, including residues of regulated compounds used for a specific purpose in food production, i.e. food additives, flavourings, pesticides, veterinary medicines and packaging materials. The European Food Safety Authority (EFSA) published in 2015 an external scientific report called "Critical review of methodology and application of risk ranking for prioritisation of food and feed related issues, on the basis of the size of the anticipated health impact" (van der Fels-Klerx et al., 2015), which gave an overview of various risk ranking methods. The included methods ranged from rather simple methods such as the Hazard Index (HI), which is the Estimated Daily Intake (EDI) divided by the HBGV, to more complex methods considering the severity of the health hazard, such as Disability Adjusted Life Years (DALY)/Quality Adjusted Life Years (QALY) or Multi Criteria Decision Analysis (MCDA). The simple methods may be used without much prior experience, whereas the more sophisticated methods need specialist training and experience in order to use them in a correct and meaningful way.

The Swedish National Food Agency (NFA) has developed the "Risk Thermometer Tool" in cooperation with EFSA for the risk ranking of chemical substances and for better risk communication. The method,

Table 7
Comparison of ranking performed considering risk- and uncertainty-based scoring categories (full method) or only risk-based scoring categories (shortened method).

a. Metals and metalloids

Risk and uncertainty			Ni, Cr		oAs	Al				Cd, iAs	MeHg	Pb			
Scores	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
	2.0			3.0			4.0			5.0			6.0		
Risk only	oAs, Ni, Cr						Al						MeHg, Cd, iAs, Pb		

b. Mycotoxins

Risk and uncertainty				ZEN, PAT				OTA		ENNs, AOH and AME, DON		AFLA-s		T-2 and HT-2	
Scores	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
	2.0			3.0			4.0			5.0			6.0		
Risk only	ZEN, PAT						ENNs, AOH and AME, DON, OTA						T-2 and HT-2, AFLAs		

c. Persistent organic pollutants

Risk and uncertainty			HBCDD	PBDEs	DBDPE, BTBPE, HBB, TBP, D6			NDL-PCBs					dioxins and DL-PCBs, PFOS and PFOA		
Scores	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
	2.0			3.0			4.0			5.0			6.0		
Risk only	DBDPE, PBDE, BTBPE, HBB, HBCDD, TBP, D6						NDL-PCBs						dioxins and DL-PCBs, PFOS and PFOA		

d. Process-induced contaminants

Risk and uncertainty								3-MCPD	PAH		HAAs		acrylamide, GEs	furans	
Scores	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
	2.0			3.0			4.0			5.0			6.0		
Risk only							3-MCPD, PAH			HAAs			acrylamide, furans, GEs		

e. Chemical substances in food contact materials

Risk and uncertainty			BPA	phthalates						BPF, BPS, BPAF					
Scores	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
	2.0			3.0			4.0			5.0			6.0		
Risk only	BPA, phthalates						BPF, BPS, BPAF								

which uses MOE, defined as NOAEL/exposure, and integrates severity by adjusting for the severity of the critical health effects, is called severity-adjusted margins of exposure (SAMOE) (NFA et al., 2018). The SAMOE values were divided into five risk classes corresponding to different levels of human health concern (1 - no concern, 2 - no-to-low concern, 3 - low-to-moderate concern, 4 - moderate-to-high concern, 5 - high concern). The SAMOE method depends, however, on good quantitative data for both exposure and toxicity, which are not always available.

Our method is designed specifically for ranking for monitoring and not for risk communication. It is straightforward as it is based on expert judgement of the existing data and uses a simplified scoring system. Due to the consideration of information on vulnerable groups and missing toxicity and exposure data (categories 4–6, Table 1), the results have a built-in safety factor and uncertainty margin, allowing the ranking of chemical substances in foods for which little data are available. By setting the maximum total score for toxicity and exposure to 6 points and the maximum total score for vulnerable groups and adequacy of toxicity and exposure data to 3 points (Table 1), we have built-in weighing factors that ensure the balancing of existing data and expert evaluation. The method is suitable not only for known contaminants in food, but for all chemical substances that occur in foods, both unintended contaminants and deliberately added chemical substances, even if the knowledge level regarding occurrence and toxic potential might be rather low.

3.3. Ranking with or without consideration of vulnerable groups and data adequacy

The scoring of vulnerable groups and adequacy of data (categories 4–6, Table 1) in the ranking may be considered as "uncertainty-based scoring criteria", whereas when they are included together with scoring based on existing knowledge of toxicity and exposure, the method can be considered as "the full ranking for monitoring method". The impact of including the "uncertainty-based scoring criteria" in the ranking was evaluated using the chemical substances in the Tables 2 to 6. The results are shown in Table 7. Whereas ranking by setting scores for all categories, "the full ranking for monitoring method" (Table 1), delivered scores in the range from 2 to 9, the exclusion of the "uncertainty-based scoring" in a shortened version of the method, using only the risk-based categories 1–3 (i.e. toxicity and exposure; Table 1), delivered scores in the range from 2 to 6. Applying "the full ranking for monitoring method", none of the chemical substances received the lowest or the highest possible score, while with the "shortened method" two-thirds of

Table 8
Foods and beverages identified as relevant for the monitoring of the ranked chemical substances.

Contaminant Total score	Baby foods	Bakery wares	Cereal grains and products thereof	Coffee/ tea	Dairy products	Drinking water	Eggs	Fish/ seafood	Meat	Nuts/ seeds/ pulses	Spices	Vegetables/ fruit	Vegetable oils
Metals and metalloids													
Lead 7.5			Cereal products and grains						Game meat (large and small game), minced meat from cervids			Potatoes and leafy vegetables	
Methylmercury 7								Fish and other seafood					
Cadmium 6.5			Cereals and cereal products						Meat and meat products	Nuts and pulses		Vegetables, starchy roots or potatoes	
Inorganic arsenic 6.5			Grain-based processed products, e.g. rice and wheat bread		Milk and dairy products	Drinking water		Fish and other seafood					
Aluminium 4.5			Cereal products produced with baking powder			Drinking water						Agricultural products	
Organic arsenic 4								Fish and other seafood					
Chromium 3						Drinking water							
Nickel 3												Plants accumulating nickel, e.g. cocoa	
Mycotoxins													
T-2 toxins, HT-toxins and modified forms 8.5			Norwegian wheat and oats										
AFLAs 7.5										Peanuts and tree nuts	Spice	Norwegian maize, dried fruits	
ENNs 6.5			Especially Norwegian grains										
AOH and AME 6			Especially Norwegian grains							Sesame and oil seeds		Imported tomato-based products	
DON and modified forms 6			Cereal grains and products thereof										

(continued on next page)

Table 8 (*continued*)

Contaminant Total score	Baby foods	Bakery wares	Cereal grains and products thereof	Coffee/ tea	Dairy products	Drinking water	Eggs	Fish/ seafood	Meat	Nuts/ seeds/ pulses	Spices	Vegetables/ fruit	Vegetable oils
OTA 5.5				Coffee and herbal teas						Tree nut, seeds	Spice	Maize, dried fruits	
ZEN and modified forms 3.5			Especially maize and wheat bran										Vegetable oil
PAT 3.5	Baby food											Fresh fruit, fruit juices	
Persistent organic pollutants													
Dioxins and DL-PCBs 8					Butter, cheese		Eggs	Fish and other seafood. Specifically composite food such as fish gratin and fish cakes					
PFOS and PFOA 8						Drinking water		Fish and other seafood					
NDL-PCBs 5.5					Butter, cheese		Eggs	Fish and other seafood Specifically composite food such as fish gratin and fish cakes					
BTBPE 4								Fish and seafood. Specifically fatty fish and fish liver					
DBDPE 4					Butter, cheese		Eggs	Fish and other seafood					
HBB 4								Fish and seafood					
TBP 4								Fish and seafood					
D6 4								Fish and other seafood					
PBDEs 3.5					Butter, cheese		Eggs	Fish and other seafood. Specifically composite food such as e.g. fish gratin and fish cakes					
HBCDD 3					Butter, cheese		Eggs	Fish and other seafood. Specifically composite food such as e.g. fish gratin and fish cakes					
Process-induced contaminants													

(*continued on next page*)

Table 8 (*continued*)

Contaminant Total score	Baby foods	Bakery wares	Cereal grains and products thereof	Coffee/ tea	Dairy products	Drinking water	Eggs	Fish/ seafood	Meat	Nuts/ seeds/ pulses	Spices	Vegetables/ fruit	Vegetable oils
Furans 8.5	Jarred baby foods		Cereal-based products	Brewed coffee	Milk-based products							Fruit juice	
Acrylamide 8	Baby food	Biscuits, crackers and crisp-breads, bread products	Breakfast cereals	Coffee								Fried potato products	
GEs 8								Fish oils					Refined vegetable oils
HAAs 7								Fried, grilled, barbecued fish	Meat, especially read meat, but also chicken				
PAH 6								Barbequed and grilled fish	Barbecued and grilled meat				
3-MCPD and its fatty esters 5.5		Fine bakery wares, bread and rolls			Margarine			Canned fish (smoked)	Canned meat			Fried potato-based products	Vegetable oil

the chemical substances received the lowest or the highest score. The differentiation between the chemical substances was notably increased with the full method as compared to the shortened version. Compounds scored 2 by the shortened method were scored 3, 3.5 or 4 by the full method. Compounds scored 4 by the shortened method received scores of 4.5, 5.5, 6 or 6.5 by the full method (Table 7). With the full method, higher resolution between chemical substances was even possible for those receiving the highest scores, such as 6.5, 7, 7.5, 8 or 8.5. We therefore consider the inclusion of both risk-based and uncertainty-based ranking categories as advantageous for the identification and ranking of chemical substances in foods for monitoring. However, both methods ranked the contaminants largely in the same order.

3.4. Identification of foods for monitoring

Food groups considered relevant for monitoring were identified by expert judgements based on available occurrence data in foods. The selected food groups included baby foods, bakery wares, cereal grains and products thereof, coffee/tea, dairy products, drinking water, eggs, fish/seafood, meat, nuts/seeds/pulses, spices, vegetables/fruits and vegetable oils (Table 8). For chemical substances in food contact materials, specific food groups could not be identified as their presence in food depends on the type of packaging material used and the character of the contact. Each food group identified as important contained at least one chemical with the highest scores (7.5 to 8.5) in this study. Three food groups stood out as especially relevant for the monitoring of chemical substances: cereal grains and products thereof, fish/seafood and vegetables/fruits. These foods are included in the dietary recommendations published by the Norwegian Directorate for Health, saying; “Eat whole grain foods every day. Eat fish two to three times a week. Eat at least five portions of vegetables, fruit and berries every day.” (Nasjonalt Råd for Ernæring, 2011). The relative importance of each food group varied for the different chemical classes. Whereas metals and metalloids, mycotoxins and process-induced contaminants should be monitored in cereal grains and products thereof, metals and metalloids, POPs and process-induced contaminants should be monitored in fish/seafood, and metals and metalloids, mycotoxins and process-induced contaminants should be monitored in vegetable/fruits. The chemical class identified as relevant for all food groups except drinking water, eggs, spices and nuts/seeds/pulses, was process-induced contaminants. All chemical substances from this class that were evaluated in the present study were scored 0.5 or 1 in category 6 (Table 5) with rationales for the scoring given as “Little data were available on exposure” or “Some exposure data were lacking”, showing that there is an urgent need for monitoring to allow exposure characterisation. As not all chemical substances can be monitored at the same time due to the limited resources available, prioritisation is needed. By restricting the number of the most important food groups for monitoring of each chemical/chemical group, analytical and sampling resources for monitoring could be planned by the risk managers in such a way that several highly ranked chemical substances could be analysed in the same food groups, thus saving resources. It has been suggested that food products consumed in significant quantities and those that may contain elevated contaminant levels should be sampled and tested with high frequency (INFOSAN, 2009). To make sure that foods recommended as healthy are also safe, data on the occurrence of contaminants in these foods should be available.

The actual use of this ranking for prioritisation is to be decided by the risk managers who are in charge of the monitoring. Which substances ultimately to be included in the monitoring will depend on the available funds for monitoring at the time and possibly also other concerns, such as how the various substances can be analysed together, time since last monitoring of the substance, alerts from other countries on health risk from certain substances, media interest etc.

4. Conclusions

A method for ranking of chemical substances in foods was developed. Subsequent use of the ranking is meant as a tool for risk managers in their prioritisation for food monitoring programs as part of a risk-based food control. The method is straightforward as it is based on expert judgement by risk assessors of existing risk- and uncertainty-based data and uses a simplified scoring method. The resolution between the chemical substances was notably increased with the full method, which includes vulnerable groups and adequacy of data, as compared with the shortened version. The methodology can be used to compare different classes of chemicals, as well as to compare subtypes of substances within the chemical classes. In principle, this method can be used for all classes of chemical substances that occur in foods, both unintended contaminants and deliberately added chemical substances. At large, the obtained ranking mirrors the need for monitoring and research to obtain new data as have been identified in many risk assessments opinions by EFSA and VKM and highlighted in research papers.

CRediT authorship contribution statement

Gro Haarklou Mathisen: Conceptualization, Methodology, Writing - original draft, Investigation, Writing - review & editing. **Jan Alexander:** Methodology, Investigation, Writing - review & editing. **Christiane Kruse Fæste:** Methodology, Investigation, Writing - review & editing. **Trine Husøy:** Methodology, Investigation, Writing - review & editing. **Helle Katrine Knutsen:** Methodology, Investigation, Writing - review & editing. **Robin Ørnsrud:** Methodology, Investigation, Writing - review & editing. **Inger-Lise Steffensen:** Conceptualization, Methodology, Writing - original draft, Investigation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work is based on the report “Ranking of substances for monitoring in foods, drinks and dietary supplements - based on risk and knowledge gaps” by the Norwegian Scientific Committee for Food and Environment (VKM, 2019). The authors acknowledge contributions from the members of the Scientific Steering Committee and the Scientific Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food and Cosmetics, and the Scientific Panel on Animal Feed in VKM for their input regarding the selection of chemicals or chemical groups for the ranking and for discussions of the methodology. The members of the Scientific Panel on Contaminants in VKM (Anne Lise Brantsæter, Cathrine Thomsen, Espen Mariussen, Gunnar Sundstøl Eriksen, Heidi Amlund, Ingunn Anita Samdal, Jonny Beyer and Sara Bremer) are especially thanked for their contributions to the assessments.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

References

ANSES (2013). 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.

Danish Ministry of the Environment (2014). Siloxanes (D3, D4, D5, D6, HMDS). Evaluation of health hazards and proposal of a health-based quality criterion for ambient air. Environmental Project No. 1531, 2014. https://www2.mst.dk/Udgiv/publications/2014/01/978-87-93026-85-8.pdf/ Accessed 31 January 2020.

EFSA (2005a). Opinion of the Scientific Committee on a request from EFSA related to A Harmonised Approach for Risk Assessment of Substances Which are both Genotoxic and Carcinogenic. *EFSA Journal, 282*, 1–31.

EFSA (2005b). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Bis(2-ethylhexyl)phthalate (DEHP) for use in food contact materials. *EFSA Journal, 243*, 1–20.

EFSA (2005c). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Butylbenzylphthalate (BBP) for use in food contact materials. *EFSA Journal, 241*, 1–14.

EFSA (2005d). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to di-Butylphthalate (DBP) for use in food contact materials. *EFSA Journal, 242*, 1–17.

EFSA (2005e). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Di-isodecylphthalate (DIDP) for use in food contact materials. *EFSA Journal, 245*, 1–14.

EFSA (2005f). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Di-isononylphthalate (DINP) for use in food contact materials. *EFSA Journal, 244*, 1–18.

EFSA (2005g). Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to the presence of non dioxin-like polychlorinated biphenyls (PCB) in feed and food. *EFSA Journal, 284*, 1–137.

EFSA (2006). Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to ochratoxin A in food. *EFSA Journal, 365*, 1–56.

EFSA (2007). Opinion of the scientific panel on contaminants in the food chain [CONTAM] related to the potential increase of consumer health risk by a possible increase of the existing maximum levels for aflatoxins in almonds, hazelnuts and pistachios and derived products. *EFSA Journal, 446*, 1–127.

EFSA (2008a). Polycyclic Aromatic Hydrocarbons in Food - Scientific Opinion of the Panel on Contaminants in the Food Chain. *EFSA Journal, 724*, 1–114.

EFSA (2008b). Safety of aluminium from dietary intake - Scientific Opinion of the Panel on Food Additives, Flavourings, Processing Aids and Food Contact Materials (AFC). *EFSA Journal, 754*, 1–34.

EFSA (2009a). Cadmium in food - Scientific opinion of the Panel on Contaminants in the Food Chain. *EFSA Journal, 980*, 1–139.

EFSA (2009b). Scientific Opinion on Arsenic in Food. *EFSA Journal, 7*(10).

EFSA (2010). Scientific Opinion on Lead in Food. *EFSA Journal, 8*(4), 1570.

EFSA (2011a). Scientific Opinion on Polybrominated Diphenyl Ethers (PBDEs) in Food. *EFSA Journal, 9*(5), 2156.

EFSA (2011b). Scientific Opinion on the risks for animal and public health related to the presence of Alternaria toxins in feed and food. *EFSA Journal, 9*(10), 2407.

EFSA (2011c). Scientific Opinion on Hexabromocyclododecanes (HBCDDs) in Food. *EFSA Journal, 9*(7), 2296.

EFSA (2012a). Scientific Opinion on Emerging and Novel Brominated Flame Retardants (BFRs) in Food. *EFSA Journal, 10*(10), 2908.

EFSA (2012b). Scientific Opinion on the risk for public health related to the presence of mercury and methylmercury in food. *EFSA Journal, 10*(12), 2985.

EFSA (2012c). Scientific Opinion on Brominated Flame Retardants (BFRs) in Food: Brominated Phenols and their Derivatives. *EFSA Journal, 10*(4), 2634.

EFSA (2014a). Scientific Opinion on the risks to human and animal health related to the presence of beauvericin and enniatins in food and feed. *EFSA Journal, 12*(8), 3802.

EFSA (2014b). Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water. *EFSA Journal, 12*(3), 3595.

EFSA (2015a). Scientific Opinion on acrylamide in food. *EFSA Journal, 13*(6), 4104.

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

EFSA (2015c). Scientific Opinion on the risks to public health related to the presence of nickel in food and drinking water. *EFSA Journal, 13*(2), 4002.

EFSA (2016a). Appropriateness to set a group health-based guidance value for zearalenone and its modified forms. *EFSA Journal, 14*(4), Article e04425.

EFSA (2016b). Risks for human health related to the presence of 3- and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. *EFSA Journal, 14*(5), Article e04426.

EFSA (2020). Glossary. https://www.efsa.europa.eu/en/glossary-taxonomy-terms/, Accessed 08 January 2020.

EFSA, Arcella, D., Eskola, M., Gómez Ruiz, J. A. (2016). Dietary exposure assessment to Alternaria toxins in the European population. EFSA Journal, 14 (12), e04654.

EFSA, Knutsen, H. K., Barregård, L., Bignami, M., Brüschweiler, B., Ceccatelli, S., et al. (2017). Appropriateness to set a group health based guidance value for T2 and HT2 toxin and its modified forms. EFSA Journal, 15 (1), e04655.

EFSA, Knutsen, H. K., Alexander, J., Barregård, L., Bignami, M., Brüschweiler, B., et al. (2017). Risks for public health related to the presence of furan and methylfurans in food. EFSA Journal, 15 (10), e05005.

EFSA, Knutsen, H. K., Alexander, J., Barregård, L., Bignami, M., Brüschweiler, B., et al. (2018a). Risk to human health related to the presence of perfluorooctane sulfonic acid and perfluorooctanoic acid in food. EFSA Journal, 16 (12), e05194.

EFSA, Knutsen, H. K., Alexander, J., Barregård, L., Bignami, M., Brüschweiler, B., et al. (2018b). Effect on public health of a possible increase of the maximum level for ‘aflatoxin total’ from 4 to 10 µg/kg in peanuts and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs. EFSA Journal, 16 (2), e05175.

EFSA, Knutsen, H. K., Alexander, J., Barregård, L., Bignami, M., Brüschweiler, B., et al.

(2018c). Risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food. EFSA Journal, 16 (11), e05333.

EFSA, Knutsen, H. K., Alexander, J., Barregård, L., Bignami, M., Brüschweiler, B., et al. (2018d). Update of the risk assessment on 3-monochloropropane diol and its fatty acid esters. EFSA Journal, 16 (1), e05083.

EFSA, Silano, V., Barat Baviera, J. M., Bolognesi, C., Chesson, A., Cocconcelli, P. S., et al. (2019). Update of the risk assessment of di-butylphthalate (DBP), butyl-benzyl-phthalate (BBP), bis(2-ethylhexyl)phthalate (DEHP), di-isononylphthalate (DINP) and di-isodecylphthalate (DIDP) for use in food contact materials. EFSA Journal, 17 (12), e05838.

Environment Canada and Health Canada (2008). Screening assessment for the Challenge Dodecamethylcyclohexasiloxane (D6). https://www.ec.gc.ca/ese-ees/FC0D11E7-DB34-41AA-B1B3-E66EFD8813F1/batch2_540-97-6_en.pdf/ Accessed 31 January 2020.

IARC (2015). Red meat and processed meat. IARC Monograph / IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. https://monographs.iarc.fr/wp-content/uploads/2018/06/mono114.pdf/ Accessed 31 January 2020.

INFOSAN (2009). INFOSAN Information Note No. 1/2009 - Monitoring for Chemicals in Foods. https://www.who.int/foodsafety/fs_management/No_01_Chem_Mar09_en.pdf/ Accessed 31 January 2020.

JECFA (1996). Joint FAO/WHO Expert Committee on Food Additives. Meeting (44th : 1995: Rome, Italy) & International Programme on Chemical Safety. Toxicological evaluation of certain food additives and contaminants in food / prepared by the forty-fourth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). https://apps.who.int/iris/handle/10665/37491/ Accessed 31 January 2020.

JECFA (2008). Safety evaluation of certain food additives and contaminants. Prepared by the Sixty-eighth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO Food Additives Series 59. http://www.inchem.org/documents/jecfa/jecmono/v59je01.pdf/ Accessed 31 January 2020.

JECFA (2011). Technical Report 966 – Evaluation of certain food additives and contaminants. 74th report of the Joint FAO/WHO Expert Committee on Food Additives. https://apps.who.int/iris/bitstream/handle/10665/44788/WHO_TRS_966_eng.pdf.?sequence=1/ Accessed 31 January 2020.

JECFA, Benford, D. J., Alexander, J., Baines, J., Bellinger, D. C., Carrington, C., et al. (2011). Safety evaluation of certain contaminants in food. Prepared by the Seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA).WHO Food Additives Series: 63. FAO JECFA Monographs 8 (pp. 153-316). https://apps.who.int/iris/bitstream/handle/10665/44520/9789241660631_eng.pdf;jsessionid=6DC429E38045F50DECEBF7B9DF1ABE56?sequence=1/ Accessed 31 January 2020.

Kuiper-Goodman, T., Hilts, C., Billiard, S. M., Kiparissis, Y., Richard, I. D. K., & Hayward, S. (2010). Health risk assessment of ochratoxin A for all age-sex strata in a market economy. *Food Additives and Contaminants Part a-Chemistry Analysis Control Exposure & Risk Assessment, 27*(2), 212–240.

Molin, M., Ulven, S. M., Meltzer, H. M., & Alexander, J. (2015). Arsenic in the human food chain, biotransformation and toxicology - Review focusing on seafood arsenic. *Journal of Trace Elements in Medicine and Biology, 31*, 249–259.

Nasjonalt Råd for Ernæring (2011). Kostråd for å fremme folkehelsen og forebygge kroniske sykdommer. Metodologi og vitenskapelig kunnskapsgrunnlag (In Norwegian). https://www.helsedirektoratet.no/rapporter/kostrad-for-a-fremme-folkehelsen-og-forebygge-kroniske-sykdommer-metodologi-og-vitenskapelig-kunnskapsgrunnlag/Kostr%C3%A5d%20for%20%C3%A5%20fremme%20folkehelsen%20og%20forebygge%20kroniske%20sykdommer%20%E2%80%93%20metodologi%20og%20vitenskapelig%20kunnskapsgrunnlag.pdf/_/attachment/inline/2a6293e0-169e-41bd-a872-f3952dbb22c2:0d09926111d614e6059e804b7f9b21c17bd0c1cd/Kostr%C3%A5d%20for%20%C3%A5%20fremme%20folkehelsen%20og%20forebygge%20kroniske%20sykdommer%20%E2%80%93%20metodologi%20og%20vitenskapelig%20kunnskapsgrunnlag.pdf/ Accessed 31 January 2020.

NFA, Langerholc, T., Lindqvist, R., Sand, S. (2018). Risk ranking of chemical and microbiological hazards in food. EFSA Journal 16, pp. e160813).

Sakhi, A. K., Lillegaard, I. T. L., Voorspoels, S., Carlsen, M. H., Loken, E. B., Brantsaeter, A. L., et al. (2014). Concentrations of phthalates and bisphenol A in Norwegian foods and beverages and estimated dietary exposure in adults. *Environment International, 73*, 259–269.

Taylor, V., Goodale, B., Raab, A., Schwerdtle, T., Reimer, K., Conklin, S., Karagas, M.R., Francesconi, K.A. (2017). Human exposure to organic arsenic species from seafood. Science of the Total Environment, 15 (580), 266-282. https://doi.org/10.1016/j.scitotenv.2016.12.113.

van der Fels-Klerx, H. J., van Asselt, E. D., Raley, M., Poulsen, M., Korsgaard, H., Bredsdorff, L., et al. (2015). Critical review of methodology and application of risk ranking for prioritisation of food and feed related issues, on the basis of the size of anticipated health impact. *EFSA Journal, 12*(1), 710E.

VKM (2011). Forhold mellom BaP og PAH4 i skjell og konsekvenser for gjeldende kostholdsråd i Norge. Uttalelse fra Faggruppen for forurensninger, naturlige toksiner og medisinrester (In Norwegian). https://vkm.no/download/18.59777ce315d3abb2351c0c82/1501508647500/f630899d2e.pdf/ Accessed 31 January 2020.

VKM (2012). Risk assessment of furan exposure in the Norwegian population. Opinion of the Panel on Food Additives, Flavourings, Processing Aids, Materials in Contact with Food and Cosmetics and the Panel on Contaminants of the Norwegian Scientific Committee for Food Safety. https://vkm.no/download/18.175083d415c86c573b5d8007/1500742472221/7b023a9623.pdf/ Accessed 31 January 2020.

VKM (2013a). Risk assessment of mycotoxins in cereal grain in Norway. https://vkm.no/download/18.2994e95b15cc545071615a36/1510054265635/Risk%20assessment%20of%20mycotoxins%20in%20cereal%20grain%20in%20Norway.pdf./ Accessed 31 January 2020.

VKM (2013b). Risk assessment of the exposure to aluminium through food and the use of cosmetic products in the Norwegian population. https://vkm.no/download/18.175083d415c86c573b59c179/1501678206406/a729a67e65.pdf/ Accessed 31 January 2020.

VKM (2015). Risk assessment of dietary exposure to acrylamide in the Norwegian population. Opinion of the Panel on Contaminants. https://vkm.no/download/18.2994e95b15cc5450716151db/1498142208319/40af783860.pdf/ Accessed 31 January 2020.