Nederlandse Voedsel- en Warenautoriteit
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To the Minister of Medical Care

Advice from the Director of the Office for Risk Assessment & Research

Risk assessment PFAS in home-produced chicken eggs

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Risk assessment PFAS in home-produced chicken eggs

Background

On 31 August 2023, the NRC newspaper[1] published an article in which it was stated that home-produced chicken eggs in the vicinity of the Chemours chemical plant contained dangerously high concentrations of per and polyfluoroalkyl substances (PFAS). PFAS are man-made substances that are not naturally present in the environment. There are more than 4000 known PFAS. In support of this article, NRC itself commissioned the analysis of home-produced eggs by the Vrije Universiteit (VU) Amsterdam. The eggs were obtained from three private owners, three petting farms and three points of sale (not further defined) within a radius of six kilometres around the Chemours chemical plant in Zuid-Holland Zuid. According to NRC, consumption of these eggs could lead to health risks.

The Netherlands Food and Consumer Product Safety Authority (NVWA) is the competent authority that monitors compliance with laws and regulations for food in the Netherlands. The NVWA is responsible for and authorised to take action in respect of risks pertaining to food safety. Home-produced chicken eggs are not subject to the supervision of the NVWA because they are not placed on the market for commercial sale. Nevertheless, the NVWA attaches high priority to consumer health, and consequently the NVWA is concerned by this situation. Against that background, the Office for Risk Assessment and Research (BuRO) of the NVWA conducted a further investigation into this situation, on its own initiative.

BuRO formulated the following broad research question:

> *Is there a risk to the health of Dutch consumers if exposed to PFAS over a longer period, via the consumption of home-produced chicken eggs?*

Scope

The Research question is focused on the public value of chemical food safety, more specifically on PFAS as a potential contaminant in eggs. Other potential contaminants that could be present in eggs such as dioxins are not further assessed in this advice. Foodstuffs in which eggs are processed, for example cake, were also not included in the risk assessment. Moreover, other public values such as animal welfare were not considered in this advice.

Approach

To answer the above question, BuRO conducted a risk assessment on the basis of the four steps of risk assessment as defined in the Codex Alimentarius. For more details

[1] NRC: Gevaarlijk veel PFAS in eieren van hobbykippen in de buurt van chemiefabriek Chemours

of the risk assessment methodology employed by BuRO, consult the NVWA BuRO website[2]. The content of this advice is subject to external peer review.

Since there is at present no consensus on the approach to calculating the total of PFAS concentrations found in foodstuffs in general and hence also in eggs, in this risk assessment, BuRO will calculate the exposure according to both concentration addition (based on equipotency[3]) and relative potency factors (RPFs[4]). BuRO encourages scientific discussion and further refinement of the method with a view to arriving at the best (and most harmonised) approach to calculate PFAS exposure.

For interpretation of the findings related to the health risks of home-produced eggs possibly contaminated with PFAS, this risk due to the consumption of commercial eggs is also calculated. For calculation of the PFAS concentrations in home-produced eggs and in commercial eggs, use was exclusively made of Dutch data. BuRO has for this purpose specifically searched for public datasets. By way of illustration, a number of European studies have been included in the discussion. To the best of our knowledge, three public datasets were available containing data from the Netherlands. This is confirmed by an external expert in the field of PFAS (personal communication with Wageningen Food Safety Research).

1. A scientific paper dating from 2016 by Zafeiraki et al., that reported on PFAS concentrations in Dutch home-produced eggs (n=73) and commercial eggs (n=22). The eggs sampled in 2014 originated from various regions throughout the Netherlands and not specifically from a location with a known PFAS contamination source. The commercial eggs were obtained from various supermarkets in the Netherlands.
2. Monitoring data for PFAS in commercial eggs (n=160) analysed by WFSR (period 2017 through to 2022). The eggs originated from laying poultry farms and packing stations, for example. Information regarding the husbandry form (e.g. free range[5] or organic) is only known for part of the data such that in this risk assessment no distinction can be made.
3. PFAS concentrations in commercial eggs (n=9) used in a recent risk assessment by the National Institute for Public Health and the Environment (RIVM) into the health risks of PFAS in Dutch food and Dutch drinking water. The foodstuffs analysed in the RIVM study originated from supermarkets, specialist stores and markets.

Subsequently, the total PFAS concentration in eggs was calculated in four different ways using a lower bound[6] and upper bound[7]:

1. The sum of PFOA, PFOS, PFNA and PFHxS (EFSA-4) (based on equipotency)
2. The sum of PFOA, PFOS, PFNA and PFHxS (EFSA-4) (based on relative potency)
3. The sum of all measured PFAS (based on equipotency)
4. The sum of all measured PFAS (based on relative potency)

In this advice, individual PFAS are described according to an abbreviation. The list of abbreviations and full names is presented in Appendix I.

The total PFAS concentrations in eggs calculated on the basis of the upper bound have been reported in the substantiation of this advice, but were not used for the exposure calculation in this risk assessment. This is because the upper bound figures provide fictitious PFAS concentrations, in which concentrations of non-detected PFAS are based on the limit of quantification of the analytical method. The concentrations are therefore determined by the concentration of the limit of quantification and the number of PFAS analysed below the limit of quantification. For the risk assessment,

[2] Methodiek risicobeoordeling chemische stoffen in levensmiddelen en diervoeder
[3] Equal potency of individual PFAS with regard to the toxicological effect.
[4] Relative potency factors indicate the toxic potential of individual PFAS relative to PFOA (index substance).
[5] In addition, the legal requirement to keep chickens indoors in connection with bird flu could influence the actual outdoor access of chickens.
[6] In the case of a lower bound calculation, the values below the limit of quantification (LOQ) are replaced by the value zero.
[7] If an upper bound is used, the values <LOQ are replaced by the value of the LOQ.

upper bound concentrations are therefore not realistic and only serve to demonstrate the maximum uncertainty that PFAS concentrations below the LOQ can introduce.

Office for Risk Assessment & Research (BuRO)

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TRCVWA/2024/730

The total weekly PFAS intake by children and adults through the consumption of home-produced eggs and commercial eggs was calculated on the basis of a realistic scenario. In this scenario, BuRO assumes a mean PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95[8]) consumption quantity of both home-produced eggs and commercial eggs. A scenario was also selected in which a high (P95) PFAS concentration was assumed in home-produced eggs and a high (P95) consumption quantity of these eggs. This latter starting point was chosen because of the possibility that private owners may consume large quantities of home-produced eggs, over a longer period of time, that my be contaminated with a high PFAS concentration. For this scenario, too, the total weekly intake by children and adults was calculated. In addition, scenarios including mean egg consumption have been calculated in Appendix VII.

The mean and P95 PFAS concentration in home-produced eggs was calculated according to the data from the article by Zafeiraki et al. The mean and P95 concentration in commercial eggs was calculated by combining the WFSR monitoring data with data from the RIVM research. For more details pertaining to the approach, reference is made to the substantiation of this advice.

Findings

Hazard identification & characterisation

- PFAS are chemically and thermally stable substances. Because of their stability, PFAS remain present in the environment and in the food chain for a long time. Certain PFAS accumulate in humans and animals. A number of PFAS compounds are relatively easily soluble in water, as a consequence of which these compounds can easily spread via water and aerosols, in the environment. Especially in areas where industrial emissions occur, PFAS concentrations can be relatively high. PFAS may end up in eggs if the chickens ingest food, water or soil contaminated with PFAS.
- Epidemiological studies show an association between prolonged exposure to PFAS and increased serum cholesterol level, a risk factor for cardiovascular disease. Epidemiological studies also suggest a link between PFAS exposure and increased serum levels of the liver enzyme alanine transaminase (ALT), which is a marker for liver damage. The European Food Safety Authority (EFSA) further assumes that effects on the immune system (reduced immune reaction) must be viewed as the most sensitive toxicological effect of PFAS exposure. These effects are observed in both animals and humans.
- PFAS are not acutely toxic. Therefore, EFSA has not derived an acute reference dose (ARfD)[9]. For chronic effects, EFSA has derived a tolerable weekly intake (TWI)[10] of 4.4 ng/kg body weight per week for the sum of four PFAS: PFOA, PFOS, PFNA and PFHxS (EFSA-4) on the basis of equipotency. At present these are the four PFAS compounds that make the greatest contribution to the levels measured in human serum.
- Regulation (EU) 2023/915[11] describes the adopted European maximum levels (MLs) for certain individual PFAS and for the sum of four PFAS in eggs (see Table 1 in the substantiation). The MLs apply to eggs placed on the market for commercial sale.

[8] P95 is the 95th percentile from the consumption distribution.
[9] ARfD is an estimate of the amount of a substance in food or drinking water that can be ingested within a 24-hour period without it having a noticeable effect on health.
[10] Tolerable Weekly Intake (TWI) is an estimate of the amount of a substance that can be ingested on a weekly basis over a lifetime without it having a noticeable effect on one's health.
[11] Regulation (EU) 2023/915 on maximum levels for certain combinations in foods and repealing Regulation (EC) No. 1881/2006.

Exposure estimate

- Depending on the way in which the total PFAS concentration is calculated, the mean total PFAS concentration in home-produced eggs varies between 1.4 ng PFAS per gram total egg - 4.6 ng PEQ[12] per gram total egg. The 95th percentile of the total PFAS concentration in home-produced eggs is between 5.5 ng PFAS per gram total egg - 19 PEQ per gram total egg. These high (P95) concentrations cannot be specifically linked to a location with a known source of PFAS contamination because the investigated home-produced eggs originate from different locations in the Netherlands and not specifically from areas with known PFAS contamination.
- For commercial eggs, the mean (0.044 ng PFAS per gram total egg or 0.058 ng PEQ per gram total egg) and the 95th percentile (0.28 ng PFAS per gram total egg or 0.28 ng PEQ per gram total egg) of the total PFAS concentration is not dependent on the way in which the total PFAS concentration is calculated.
- The mean and P95 consumption of eggs by 1 to 3-year olds is 7.1 and 41.3 grams per day respectively. This corresponds to the consumption of 0.99 and 5.8 eggs per week. The mean and P95 consumption of eggs by 18 to 79-year olds is 18 and 71.7 grams per day respectively. This corresponds to a weekly consumption of 2.5 and 10 eggs.
- The table below provides an overview of the total weekly PFAS intake (ng PFAS/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs. The starting point is a mean and P95 PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95) consumption quantity of eggs. A complete overview is presented in Appendix VII.

[12] PFOA equivalents, the unit in which RPF corrected PFAS concentrations are expressed.

Risk characterisation

- Assuming the data described in this advice (Appendix VI), the total weekly PFAS intake by children and adults through the consumption of home-

	Weekly PFAS intake (ng PFAS/kg body weight per week)			
	Sum EFSA-4 (based on equipotency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	34	Mean concentration	1.1
	P95 concentration	132		
18 to 79-year olds	Mean concentration	12	Mean concentration	0.37
	P95 concentration	46		
	Weekly PFAS intake (ng PEQ/kg body weight per week)			
	Sum of all measured PFAS (based on relative potency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	111	Mean concentration	1.4
	P95 concentration	450		
18 to 79-year olds	Mean concentration	39	Mean concentration	0.48
	P95 concentration	156		

produced eggs is a factor of 20 to 80 higher than the total weekly intake through the consumption of commercial eggs.

- The table below shows the ratio of the total weekly PFAS intake (ng/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs and the maximum safe PFAS intake. Ratios >1 indicate a possible health risk and are highlighted in bold. The starting point is a mean and P95 PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95) consumption quantity of eggs.

- The ratio between the total weekly PFAS intake by children and adults through the consumption of home-produced eggs and the maximum safe intake is greater than 1. This means that the health-based guidance value is exceeded and the weekly PFAS intake through the consumption of these eggs over a longer period of time can result in health risks. It should be noted that the difference in the exceeding of the maximum safe intake by the total weekly PFAS intake by children and adults is considerable. Depending on the scenario on the basis of which the weekly PFAS intake is calculated, the limit is exceeded by between a factor of 2.7 and 35 for adults and a factor of 7.8 and 102 for children. The highest exceeding of the maximum safe intake is found in (small) children. (Small) children are, compared to adults, more vulnerable due to a still developing immune system.

	Ratio between weekly PFAS intake (ng PFAS/kg body weight per week) and health-based guidance value			
	Sum EFSA-4 (based on equipotency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	**7.8**	Mean concentration	0.24
	P95 concentration	**30**		
18 to 79-year olds	Mean concentration	**2.7**	Mean concentration	0.085
	P95 concentration	**10**		

	Ratio between weekly PFAS intake (ng PEQ/kg body weight per week) and health-based guidance value			
	Sum of all measured PFAS (based on relative potency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	**25**	Mean concentration	0.32
	P95 concentration	**102**		
18 to 79-year olds	Mean concentration	**8.8**	Mean concentration	0.11
	P95 concentration	**35**		

- The ratio between the total weekly PFAS intake by children and adults through the consumption of commercial eggs and the maximum safe intake does not exceed 1. The health-based guidance value is not exceeded. The consumption of commercial eggs may represent up to a 53% contribution to the total maximum safe intake of PFAS (Appendix VIII).

Discussion

- A study by the NRC newspaper into the presence of PFAS in home-produced eggs in the region surrounding Chemours (municipality of Dordrecht) shows that eggs from five of the nine locations contain PFAS concentrations that exceed the European food standards for PFAS. Eggs from three of the nine locations contain PFAS compounds emitted in the past by Chemours. Other studies, commissioned by the Municipality of Dordrecht among others, show that home-produced eggs around Chemours above all contain PFOS. On 16 January 2024, the NOS[13] broadcasting cooperation concluded, following a small-scale study, that PFAS were also identified in home-produced eggs originating from far beyond the Dordrecht region. All three studies confirm the picture from this advice that home-produced eggs in the Netherlands may contain PFAS, possibly in large quantities, that cannot be related to a known contamination source.
- In Belgium, too, the PFAS concentration in home-produced eggs has been investigated. To date, researchers have concluded that the action limit of the Federal agency FAVV for PFOS (100 ng/g wet weight) was regularly exceeded in chicken eggs within a radius of 1.5 km from 3M in Zwijndrecht (Belgium). PFAS were also identified in home-produced eggs located far from the PFAS-suspected locations.
- The origin of PFAS in home-produced eggs is unknown. Possible exposure routes are soil particles, animal feed and drinking water. Recent studies into PFAS contamination in home-produced eggs around Chemours and 3M (Belgium) have as yet revealed no clear relationship between a known contamination source or contamination route.
- Assuming a lower bound, many of the individual PFAS concentrations have a zero value. This leads to an skewed distribution of the measured PFAS concentrations. In principle, the median (P50) offers the best description of the central trend in a dataset of this kind. However, BuRO has chosen to use the mean concentration for the risk assessment because, unlike the median, the mean delivers a value greater than zero. It can be concluded on this basis that (individual) PFAS concentrations are also absent in many home-produced chicken eggs. At this moment, however, it is not possible to predict which home-produced chicken eggs will contain high or low PFAS concentrations.
- The laying of eggs is an effective elimination route for a number of PFAS compounds for chickens. Laying efficiency could potentially have an influence on the PFAS concentrations in eggs, and as such could provide an explanation for the discrepancies between PFAS concentrations in home-produced eggs and commercial eggs. The laying efficiency is influenced by factors such as species, age, diet and light regime, among others.

Uncertainties

- The calculation of the weekly PFAS intake through the consumption of home-produced eggs and commercial eggs is based on PFAS concentrations in home-produced eggs and commercial eggs originating from three datasets. This is a limited number which may result in uncertainty regarding the actual PFAS concentration. The findings in the current assessment are, nevertheless, in line with the results of recently conducted studies.
- On the basis of the datasets used in this advice, the calculation of the total PFAS concentration in commercial eggs delivers comparable outcomes for the different calculation methods. On the other hand, the outcome of the calculation of the total PFAS concentration in home-produced eggs is dependent on the calculation method used, even though the conclusions are unequivocal in respect of the risk. The difference between the outcomes from the methods can be explained by the fact that other and/or multiple PFAS with a higher or lower RPF have been identified in home-produced eggs than in commercial eggs.

[13] https://nos.nl/artikel/2505086-ook-pfas-in-hobby-eieren-ver-buiten-regio-dordrecht

- It is possible that PFAS compounds are present below the limit of quantification (LOQ) of the analytical methods. For its exposure calculations, BuRO therefore uses the lower bound. Given the numerous baseline measurements in the dataset, the possibility cannot be excluded that other PFAS are present, in lower concentrations, that are now not included in the assessment. As a consequence, the total exposure to PFAS may be underestimated.
- The samples of home-produced eggs (2014) and samples of commercial eggs (2017 through to 2022) were taken at different times. The PFOS and PFOA levels in the environment may have already decreased slightly over time due to regulations. Viewed from this perspective, it is possible that the samples of home-produced eggs from 2014 may contain a (relatively) higher concentration of PFAS than recently sampled eggs. On the basis of the substance properties, BuRO does not expect the PFAS concentration to change considerably, if at all, over a period of around 10 years.
- In the dataset for the home-produced eggs, there is uncertainty about the precise origin of the eggs. Sixty samples originate from various regions across the Netherlands (Appendix IV). The precise origin cannot be derived in connection with the agreements reached concerning the protection of the personal data of the participants in the study. The origin of the other 13 egg samples was not further defined, although it is certain that they do come from chickens in private ownership. The higher concentrations cannot easily be explained by known contamination sources.
- The total intake of PFAS by Dutch consumers from various food sources is too high, according to RIVM. This high background exposure was not taken into account in the current risk assessment.

Conclusion
Home-produced eggs in the Netherlands can contain high concentrations of PFAS. At this time no relationship can be established with a known source of contamination. It is therefore not possible to predict in advance which eggs from private individuals contain these high concentrations.

The weekly PFAS intake through the consumption of home-produced eggs exceeds the health-based guidance value (i.e. maximum safe intake) considerably. The ratio between the total weekly PFAS intake by children and adults through the consumption of home-produced chicken eggs and the maximum safe intake is ranges from 2.7 and 102. This means that the weekly PFAS intake through the consumption of these eggs over a longer period can result in health risks. This does not apply for the consumption of commercial eggs.

In this risk assessment in respect of the consumption of eggs, no account was taken of the background exposure to PFAS through the consumption of other foodstuffs. According to RIVM, total PFAS intake by Dutch consumers is too high.

In line with recent studies into PFAS concentrations in eggs among consumers around Chemours and 3M (Belgium), the analysis by BuRO reveals no clear relationship between the PFAS contamination in home-produced eggs and a known contamination source. Further research in a broader research programme is needed in order to explain the cause of the PFAS found in the home-produced eggs and to be able to offer a course of action to consumers, for reducing these concentrations.

Advice from BuRO

To the Minister of Medical Care

- Call upon the Netherlands Nutrition Centre to inform consumers about the possible risks of PFAS for public health as a result of the consumption of home-produced eggs.
- Initiate additional (international) research into PFAS concentrations in home-produced eggs, with specific attention for the various sources that may result in the exposure of privately owned chickens to PFAS. In the light of the scale of the PFAS problem, BuRO advises the inclusion of this research in a broader research programme into PFAS.

Yours sincerely,

Prof. Dick T.H.M. Sijm
Director of the Office for Risk Assessment and Research

Substantiation

Hazard identification

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Certain environmental contaminants can transfer to products of animal origin such as meat, milk or eggs via animal feed, soil, water and/or grass. This also applies to PFAS (Göckener et al., 2020; Kowalczyk et al., 2020). At the end of August 2023, the NRC newspaper published a study showing that home-produced chicken eggs from the Dordrecht area contained high concentrations of PFAS.

PFAS is a group name for per and polyfluoroalkyl substances. PFAS are man-made substances that are not naturally present in the environment. There are more than 4000 known PFAS (OECD, 2018) In this advice, individual PFAS are described according to an abbreviation. The list of abbreviations and full names appears in Appendix I.

PFAS are chemically and thermally stable substances. Due to the stable properties and their water and dirt-repellent effect, they are used as coatings in many industrial products and consumer products. Examples include furniture fabric, outdoor and rainwear, and food packaging materials (food contact materials). Because of their stability, PFAS also remain present in the environment and the food chain for long periods of time and some PFAS accumulate in humans and animals. The use of PFAS in many products and industrial emissions and incidents have led to their release into the environment in soil, sludge and surface water, among others. Certain PFAS compounds are relatively watersoluble, allowing these compounds to spread easily in the environment via water and aerosols. Especially in areas where industrial emissions occur, PFAS concentrations can be relatively high. There are also more local contaminations, for example due to the (historical) use of PFAS-bearing fire extinguishing foam or private use of agents for impregnating coats and shoes. The source of a PFAS contamination is sometimes unknown.

At the request of the European Commission, the European Food Safety Authority (EFSA) conducted a scientific evaluation of the health risks for humans of 27 different PFAS present in food (EFSA CONTAM Panel, 2020). The evaluated PFAS included long-chain perfluoroalkyl carboxylic acid (PFCAs) and perfluoroalkyl sulfonic acids (PFSAs).

Hazard characterisation

Most of the 27 PFAS from EFSA's recommendation are easily absorbed via the gastrointestinal system in mammals, including humans (EFSA CONTAM Panel, 2020). PFAS then spread to plasma and other parts of the body. Depending on the type of PFAS, this may also include accumulation in the liver and blood. PFAS are excreted via urine but probably also via faeces, although to date this has only been investigated to a limited extent. PFCAs and PFSAs are not metabolised by humans or animals. Conversely, precursors such as fluorotelomer alcohols (FTOHs) and polyfluorinated alkyl phosphate esters (PAPs) can be transformed into metabolites through biotransformation including PFCAs, while other precursors are converted into PFSAs. Human half-life[14] for PFAS depends on the type of PFAS. The estimated half-life of short-chain PFAS, such as PFBA, PFBS and PFHxA, ranges from a few days to a month. The half-life of long-chain PFAS, such as PFOA, PFNA, PFDA, PFHxS or PFOS, amounts to several years.
PFAS are not acutely toxic. Therefore, EFSA has not derived an acute reference dose (ARfD)[15]. For chronic effects, EFSA has derived a tolerable weekly intake (TWI)[16] for the sum of four PFAS: PFOA, PFOS, PFNA and PFHxS (EFSA-4) based on immunotoxicity as the critical effect (EFSA CONTAM Panel, 2020). At present these

[14] The half life is a measurement for the elimination speed of a substance present in the body. Elimination can occur through metabolism (i.e. conversion to another substance) and excretion.
[15] ARfD is an estimate of the amount of a substance in food or drinking water that can be ingested within a 24-hour period without it having a noticeable effect on health.
[16] Tolerable Weekly Intake (TWI) is an estimate of the amount of a substance that can be ingested on a weekly basis over a lifetime without it having a noticeable effect on one's health.

are the four PFAS compounds that make the greatest contribution to the levels measured in human serum.

Office for Risk Assessment & Research (BuRO)

Date
20 February 2024

Our reference
TRCVWA/2024/730

In humans, these four PFAS have similar toxicokinetic properties, similar accumulation and long half-life's. EFSA concluded that the effect on the immune system is the critical effect; exposure to PFAS is associated with a reduced immune response (namely a reduction in the production of antibodies following vaccination). Based on a German study, in which diphtheria antibody formation was correlated with serum levels of these four PFAS, EFSA derived a $BMDL_{10}$ (benchmark dose lower confidence limit)[17] of 17.5 ng/ml for a one-year-old child. EFSA then used a PBK model to estimate[18] the related intake of the four PFAS by mothers breastfeeding their child during the first twelve months. This modelling was used to derive what the PFAS intake of the mother must have been to reach a serum concentration of 17.5 ng/ml in a one-year-old child. It proved to be a daily intake of 0.63 ng/kg body weight per week. This value resulted in a TWI of 4.4 ng/body weight per week. EFSA did not apply any additional uncertainty factors, as the $BMDL_{10}$ is based on children and a reduced vaccination response is considered a risk factor for diseases rather than a disease itself. This TWI also protects against other described health effects, such as increased cholesterol and ALT concentration in serum and reduced birth weight.

Application of the EFSA TWI in a risk assessment
As the TWI is based on the sum of PFAS, it raises questions regarding the application of this health-based guidance value in a risk assessment. These four PFAS are not the only PFAS present in food, drinking water and soil, among others. It may also be the case that the concentration of only one of the four PFAS is known in food, for example. There are two possibilities for incorporating this TWI in the risk assessment:

1. Concentration addition
In applying the TWI, EFSA assumes equipotency; equal potency of the four PFAS with respect to the toxicological effect on the immune system. EFSA's analysis showed that there was insufficient data to determine the relative potency factors[19] (RPFs) for the individual PFAS in relation to the critical effect (EFSA CONTA Panel, 2020). Following this reasoning, BuRO is only able to apply the EFSA-TWI in a risk assessment in which the concentrations of one or more of the four PFAS are known. Two remarks should be made, however:

- There probably are differences in potency of the four PFAS that are not yet expressed in the TWI based on equipotency. EFSA indicates that there are insufficient data at present to correct for this.
- Other PFAS cannot be assessed using the TWI. EFSA does indicate that some of these substances are likely to cause similar effects but due to the absence in the children's blood in the critical study, they could not be included in the TWI. These other PFAS need to be assessed according to health-based guidance values specifically derived for these individual substances. However, these are not available for all PFAS. In addition, the health-based guidance value, derived on the basis of effects that occur at much higher doses, can result in an underestimation of the risk.

[17] $BMDL_{10}$ is the 95% lowest confidence interval of the estimated dose which results in 10% added risk.
[18] A PBK model is a kinetics model based on human physiology. Computer modelling is used to model the toxicokinetic properties of a substance and estimate the intake leading to a particular serum level in humans.
[19] Relative Potency Factors indicate the degree of hazardousness of substance A, B or C relative to an index substance.

2. RPF method

With respect to the question as to how the EFSA TWI should be applied in a risk assessment, RIVM drew up a memorandum (RIVM, 2021). RIVM recommends using relative potency factors (RPFs) because:

- the method can be applied to individual PFAS, EFSA's four PFAS and other PFAS not included in the EFSA TWI,
- the method can assess PFAS mixtures in different ratios,
- the method includes any differences in the potency between PFAS and
- the method is conceptually simple and practically applicable.

RPFs present the toxic potency of the individual PFAS against PFOA (index substance). RIVM has currently derived an RPF for 23 PFAS based on liver effects (Bil et al., 2021; RIVM, 2021; Bil et al., 2022; Bill et al., 2023). This is a different effect from the immune effect (the most critical effect) on which the EFSA TWI is based. RIVM argues that in the absence of immune-specific factors from studies with humans, RPFs can also be derived based on other effects. The application of the current RPF values in a broader context requires a validation of this calculation method (Bil et al., 2021; RIVM, 2021). RIVM's RPFs can be used to convert an individual PFAS concentration in, for example, egg into PFOA equivalents (PEQ), which can then be compared with the EFSA TWI. For example, an analysis result for egg is made up of a combination of three PFAS (A, B and C). PFAS A is PFOA and has an RPF of 1, which is multiplied by the amount of A that is present. PFAS B and PFAS C have an RPF of 2 (B) (more potent than PFOA) and 0.01 (C) (less potent than PFOA), which are multiplied by the amount of B and C that is present. The concentrations of A, B and C are then added together and expressed in 'x unit' PEQ in order to make it possible to evaluate the toxicity of the mixture as though it only contains PFOA. Two remarks should be made, however:

- The RPFs were determined for a different effect than the critical effect of the TWI derived by EFSA.
- RPFs are currently only applied to the exposure estimate, but should also be applied to the derivation of the TWI.

Since there is at present no consensus on the approach to calculating the sum of the identified PFAS concentrations, BuRO will estimate the exposure in this risk assessment based on concentration addition and the RPF method.

Legal framework

Regulation (EU) 2023/915[20] describes the adopted European maximum levels (MLs) for certain individual PFAS and for the sum of four PFAS in eggs. These maximum levels are summarised in Table 1. The MLs have been established according to the ALARA principle[21]. The MLs have no direct relationship with human health risks.

[20] Regulation (EU) 2023/915 on maximum levels for certain combinations in foods and repealing Regulation (EC) No. 1881/2006.

[21] As low as reasonably achievable, based on the distribution of residue levels found in the foodstuff.

Table 1. Maximum levels (MLs) of PFAS in eggs according to Regulation (EU) 2023/915.

Maximum level (µg/kg)				
PFOS	**PFOA**	**PFNA**	**PFHxS**	**Sum of PFOS, PFOA, PFNA and PFHxS (EFSA-4)**
1.0	0.30	0.70	0.30	1.7

The Netherlands Food and Consumer Product Safety Authority (NVWA) is the supervisory authority that monitors compliance with laws and regulations for food in the Netherlands. The NVWA is responsible for and authorised to take action in respect of risks pertaining to food safety. The above MLs apply only to eggs placed on the market for commercial sale.

Exposure estimate

To calculate the PFAS concentrations in home-produced eggs in the Netherlands and eggs from Dutch supermarkets, three publicly available datasets were used.

1. An scientific paper dating from 2016 by Zafeiraki et al. that reported on PFAS concentrations in Dutch home-produced eggs (n=73) and supermarket eggs (n=22) (Zafeiraki et al., 2016).
2. Monitoring data for PFAS in supermarket eggs (n=160) analysed by Wageningen Food Safety Research (WFSR) (period 2017 through to 2022).
3. PFAS concentrations in supermarket eggs (n=9) used in a recent risk assessment by the National Institute for Public Health and the Environment (RIVM) into the health risks of PFAS in Dutch food and drinking water (Schepens et al., 2023).

Under the heading PFAS concentration in home-produced eggs (dataset 1) and *PFAS concentration in commercial eggs* (datasets 2 and 3), the datasets are described in greater detail. Appendix II provides an overview of the various PFAS analysed in each dataset. This shows that the analysed substances differ per dataset.

The total PFAS concentration in commercial eggs and home-produced eggs was calculated according to the following methods:

1. The sum of EFSA-4 (based on equipotency)
2. The sum of EFSA-4 (based on relative potency)
3. The sum of all measured PFAS (based on equipotency)
4. The sum of all measured PFAS (based on relative potency)

In calculating the sum of EFSA-4 and the sum of all measured PFAS, both based on relative potency, BuRO made use of RPFs as those by RIVM (Bil et al., 2021; RIVM, 2021; Schepens et al., 2023) (Appendix III). For the above described calculation method, mean, P50 and P95 concentrations were calculated on the basis of lower bound[22] and upper bound[23]. Assuming a lower bound, the P50 concentrations were not included in the risk assessment because in many cases these have a value of zero. This can be explained by the many PFAS concentrations below the limit of quantification (<LOQ).

PFAS concentration in home-produced eggs

At the end of 2013, RIKILT in collaboration with RIVM, investigated a number of samples of home-produced eggs originating from a number of addresses in the vicinity of Harlingen, for the presence of dioxins and PCBs in response to a suspected contamination at a waste incinerator in Harlingen (RIKILT, 2014). Subsequently, in 2014, RIKILT investigated the presence of dioxins and PCBs in home-produced chicken eggs in the Netherlands. In total, 60 samples of home-produced eggs were investigated, originating from four areas in the Netherlands (Friesland, Rijnmond,

[22] If a lower bound is used, the values <LOQ are replaced by the value zero.
[23] If an upper bound is used, the values <LOQ are replaced by the value of the LOQ.

Gelderland/Utrecht and the rest (Southern, Eastern and the Northwestern Netherlands)) (RIKILT, 2014). From personal communication with one of the authors, BuRO has been given to understand that these eggs originated from various regions spread across the entire Netherlands and therefore not specifically from a location with a known PFAS contamination source (Appendix IV). The precise origin of the eggs cannot be derived due to the agreements reached on the protection of the personal data of the participants in the original 2014 study. Zafeiraki et al. subsequently used these 60 samples of eggs collected from private owners, in the framework of their study into the presence of dioxins and PCBs, in order to analyse the PFAS concentration (Zafeiraki et al., 2016). In total, Zafeiraki et al. analysed 73 home-produced eggs. The origin of the remaining 13 egg samples was not further defined, although it is certain that they originated from chickens in private ownership.

The measurements by Zafeiraki et al., were performed in the egg yolk. PFAS accumulate in egg yolk (Zafeiraki et al., 2016), making a correction on the basis of the relative volume possible. For that reason, BuRO has applied a factor three correction for the conversion of PFAS concentrations in egg yolk to the total egg; the standard weight ratio between egg yolk:egg white in a chicken's egg is 1 to 3 according to WFSR (personal communication). It is thereby assumed that the PFAS concentration in the total egg is a factor of three lower than in the egg yolk in which PFAS accumulate.

The concentrations of PFAS reported by Zafeiraki et al. in home-produced eggs originate from eggs sampled in 2014. Possibly regulations have led to a decrease of PFOS- and PFOA levels in the environment. Therefore, from this perspective these egg samples of home-produced eggs from 2014 may contain (relatively) higher concentrations of PFAS than recently sampled eggs. In addition, the PFAS concentrations reported by Zafeiraki et al. were measured in home-produced eggs using analytical methods that are less sensitive compared with today's methods. This may specifically result in an underestimation of the possible presence of non-detectible PFAS. However, this is the only publicly available dataset in which PFAS concentrations are measured in home-produced eggs from the Netherlands (see also Excel file in Appendix V).

The PFAS reported by Zafeiraki et al. as being present in home-produced eggs consist primarily of PFOS (detectably present in 64 of the 73 eggs). PFOA (20 eggs), PFDA (23 eggs), PFNA (13 eggs), PFUnA (15 eggs) and PFHxS (5 eggs) were also measured. In 31 eggs, more than one PFAS was measured, up to a maximum of six different PFAS per egg. Because all eggs were investigated for the presence of ten different PFAS, many results are shown as below the LOQ.

Table 3 provides an overview of the total PFAS concentrations calculated by BuRO in home-produced eggs, based on data from the article by Zafeiraki et al. (dataset 1).

PFAS concentration in commercial eggs
Zafeiraki et al. reported on PFAS concentrations in eggs (n=22) originating from various supermarkets across the Netherlands (Zafeiraki et al., 2016). These concentrations are based on analytical methods with a lower sensitivity in comparison with the recent monitoring data that are available for commercial eggs. Certainly given the large number of concentrations below the LOQ (just one sample contains a measurable PFOS concentration), this represents a greater risk of underestimating the total PFAS concentration due to the presence of individual PFAS below the (high) LOQ. With that in mind, BuRO decided to not include these data in the calculation of PFAS concentrations in commercial eggs.

The Ministry of Agriculture, Nature and Food Quality (LNV) has commissioned Wageningen Food Safety Research (WFSR) to analyse samples of agricultural products of animal origin for dioxins, polychlorinated biphenyls (PCBs), brominated flame retardants and PFAS. The matrices are: meat, milk, eggs and fish[24]. In respect of PFAS, data are available from 2017 onwards. WFSR has made the concentrations measured between 2017 and 2021 available online (Monitoring dioxins, PCBs, PFAS and flame retardants in agricultural and fishery products (collection) (4tu.nl)). The data relating to 2022 have been requested from WFSR by BuRO. Sampling takes place during the primary production process and during the processing of the products (for example at poultry laying farms or packing stations). Table 2 provides an overview of the number of sampled commercial eggs and, if known, the husbandry form from which these eggs originate. The limited data for 2017 show that PFAS concentrations above the LOQ were only identified in free range eggs and not in organic or regular eggs. The information relating to the husbandry form is not known for all data, so that no distinction can be made between them, in the risk assessment. In addition, the legal requirements to keep chickens indoors in relation to bird flu outbreaks could influence the actual outdoor access of chickens.

Table 2. An overview of the number of commercial eggs sampled and the husbandry form per year derived from WFSR monitoring (dataset 2). Unlike regularly farmed laying hens, laying hens kept for organic and free-range egg production are allowed outdoors.

Calendar year	Number of sampled commercial eggs (n)	Husbandry form
2017[#]	29	Regular (10), organic (10) and free range (9)
2018	18	Unknown
2019	39	Unknown
2020	20	Unknown
2021	4	Unknown
2022	50	Free range
Total	160	

[#]The data from 2017 are not included in the calculation of PFAS concentrations in commercial eggs because these data are based on analytical methods with a lower sensitivity as compared with the current analytical methods. This may result in an underestimation of the PFAS concentration.

The monitoring data from WFSR for the year 2017 are also based on analytical methods with a lower sensitivity. Certainly given the large number of concentrations below the LOQ, this represents a greater risk of underestimating the total PFAS concentration due to the presence of individual PFAS below the (high) LOQ. Calculations by BuRO indeed show that the lower bound concentration in commercial eggs is lower if the data from 2017 are included. For that reason, BuRO has decided to also not include these monitoring data in the calculation of PFAS concentrations in commercial eggs.

In 2023, RIVM investigated the intake of PFAS by Dutch consumers via food and drinking water. As part of the investigation, a selection of foodstuffs, representative for what the Dutch population eats and drinks, was sampled and analysed. The foodstuffs originated from supermarkets, specialist stores and markets. In this study, RIVM also reported PFAS concentrations of nine commercial eggs (dataset 3) (Schepens et al., 2023).
Ultimately, the WFSR datasets (period 2018 through to 2022) and the data from the RIVM investigation were combined (i.e. total number of eggs n=140) to calculate the concentrations in commercial eggs. See also the Excel file in Appendix V.

The PFAS reported present in commercial eggs from the monitoring programme consist primarily of PFOA (18 eggs) – a quantifiable concentration of PFOS was identified in one egg. In the RIVM dataset, other PFAS are also measured, but these concentrations are way lower.

[24] WUR Monitoring dioxines, PCB's, PFAS en vlamvertragers in agrarische- en visserijproducten

Table 3 provides an overview of the total PFAS concentrations calculated by BuRO in commercial eggs based on the data from WFSR monitoring (period 2018 through to 2022; dataset 2) and the RIVM study (dataset 3).

The total PFAS concentrations in home-produced eggs and commercial eggs were calculated in four different ways, as reproduced in Appendix VI. Table 3 provides an overview of the total PFAS concentrations calculated according to method 1 (sum of EFSA-4 based on equipotency) and method 4 (sum of all measured PFAS based on relative potency). The results of these two methods are shown because method 1 enables a direct comparison with the health-based guidance value and because method 4 takes into account all measured PFAS. Methods 2 and 3 represent a combination of method 1 and method 4 and are shown in the appendix to enhance readability. On the basis of the datasets used in this advice, the calculation of the total PFAS concentration in commercial eggs delivers comparable outcomes for the different calculation methods. By contrast, the outcome of the calculation of the total PFAS concentration in home-produced eggs is dependent on the calculation method used (Appendix VI). The difference can be explained by the fact that other and/or multiple PFAS with a higher or lower RPF have been identified in home-produced eggs than in commercial eggs. In the commercial eggs, mainly PFOA (RPF = 1) was identified.

In addition, Table 3 only shows the PFAS concentrations on the basis of lower bound. Upper bound results in fictitious PFAS concentrations in which concentrations of non-detected PFAS are based on the limit of quantification of the analytical method. These concentrations are therefore determined by the concentration of the limit of quantification and the number of PFAS analysed below the limit of quantification. For the risk assessment, upper bound concentrations are therefore not realistic and only serve to demonstrate the maximum uncertainty that PFAS concentrations below the LOQ can introduce.

Table 3. The total PFAS concentrations calculated by BuRO (ng PFAS/gram total egg or ng PEQ/gram total egg for the calculations based on RPFs) in home-produced eggs (n=73) and commercial eggs (n=140). The mean and P95 concentrations are calculated on the basis of lower bound. For sum-calculation of the PFAS, two different methods were used; sum of the EFSA-4 based on equipotency and the sum of all measured PFAS based on RPFs.

	Lower bound	
	Sum EFSA-4 (ng PFAS/gram total egg)	**Sum all measured PFAS (ng PEQ/gram total egg)**
Home-produced eggs (n=73)		
Mean	1.4	4.6
P95	5.5	19
Commercial eggs (n=140)		
Mean	0.044	0.058
P95	0.28	0.28

The ML for the sum of PFOS, PFOA, PFNA and PFHxS (EFSA-4) is 1.7 µg/kg = 1.7 ng/g (Table 1). This means that the mean concentration in home-produced eggs is below this sum ML, while the P95 is well above this limit. As shown in Table 1, MLs were also determined for the four individual PFAS. These limits may be exceeded for another fraction of the samples. The mean and P95 concentrations in commercial eggs are below the sum ML of the four PFAS.

Consumption data
The Dutch National Food Consumption Survey (VCP) maps what Dutch people eat and drink. The VCP consists of two 24-hour food intake surveys on non-consecutive days amongst a representative sample of the Dutch population (N=3,570; VCP 2019-

2021). Data are available on the RIVM Statline website[25] relating to the consumption of eggs by 18 to 79-year olds. For 1 to 3-year olds, these values are available for boys and girls, separately; for this risk assessment, BuRO took the mean of these values for the entire population of 1 to 3-year olds. Table 4 provides an overview of the mean and high consumption (P95) during all days, both in grams per day and number of eggs per day and number of eggs per week. Consumption on all days means that in calculating the consumption, days during the food consumption survey on which no eggs were eaten are taken into account. This results in a long-term (chronic) consumption.

Table 4. The mean and P95 consumption (g/day, number/day and number/week) of eggs by 1 to 3-year olds and 18 to 79-year olds taken from the RIVM Statline website.

Age category	Consumption (g/day)		Consumption (number of eggs/day#)		Consumption (number of eggs/week#)	
	Mean	P95	Mean	P95	Mean	P95
1 to 3-year olds	7.1	41.3	0.14	0.83	0.99	5.8
18 to 79-year olds	18	71.7	0.36	1.4	2.5	10

#Assuming a mean egg weight of 50 grams.

PFAS intake due to the consumption of home-produced eggs and commercial eggs
The weekly PFAS intake (ng PFAS/kg body weight or ng PEQ/kg body weight) by children (12 kg) and adults (60 kg) was calculated according to the following formula:

$$Weekly\ intake\ = \left(\frac{\text{PFAS concentration}\ x\ consumption\ quantity}{\text{Body weight}}\right) x\ 7\ days$$

The following parameters apply:

- PFAS concentration (ng/g or ng PEQ/g): Mean or P95 concentration of the total sum PFAS in home-produced or commercial eggs (lower bound, four calculation methods) (Table 3).
- Consumption quantity (g/day): Mean or P95 egg consumption according to VCP (Table 4)
- Body weight (kg): 12 kg (child); 60 kg (adult).

The total weekly PFAS intake by children and adults through the consumption of home-produced eggs and commercial eggs is calculated for four scenarios. These scenarios are based on the four ways in which the PFAS concentration in eggs can be calculated. Based on these four methods, the weekly intake for adults and children was calculated on the basis of the following combinations:

- Mean PFAS concentration in egg & mean consumption quantity of eggs
- Mean PFAS concentration in egg & high (P95) consumption quantity of eggs
- High (P95) PFAS concentration in egg & mean consumption quantity of eggs
- High (P95) PFAS concentration & high (P95) consumption quantity of eggs

The results of the calculations on the basis of all scenarios are shown in the Excel file in Appendix V and in Appendix VII. Below, in Table 5, only the total weekly PFAS intake by children and adults due to the consumption of eggs is shown, on the basis of the most realistic scenario. In this scenario, a mean PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95) consumption quantity of eggs are assumed. A high (P95) PFAS concentration in home-produced eggs and a high (P95) consumption quantity of these eggs are also assumed. The latter starting point was chosen because it is possible that over a longer period of time, private owners will consume large quantities of eggs from their

[25] RIVM: Stateline - Consulted on 27 September 2023.

own chickens, that may be contaminated with a high PFAS concentration. For the consumption of home-produced eggs, this latter scenario is also realistic. For the consumption of commercial eggs from the supermarket this does not apply because the origin of these eggs varies. The results of this calculation (assuming P95 concentrations and P95 consumption quantities) also appear in Table 5.

Table 5. The total weekly PFAS intake (ng PFAS/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs. The starting point is a mean and P95 PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95) consumption quantity of eggs.

	Weekly PFAS intake (ng PFAS/kg body weight per week)			
	Sum EFSA-4 (based on equipotency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	34	Mean concentration	1.1
	P95 concentration	132		
18 to 79-year olds	Mean concentration	12	Mean concentration	0.37
	P95 concentration	46		
	Weekly PFAS intake (ng PEQ/kg body weight per week)			
	Sum of all measured PFAS (based on relative potency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	111	Mean concentration	1.4
	P95 concentration	450		
18 to 79-year olds	Mean concentration	39	Mean concentration	0.48
	P95 concentration	156		

Assuming a mean and P95 PFAS concentration in home-produced eggs, a mean PFAS concentration in commercial eggs and a high (P95) consumption quantity of eggs, the ratio between the weekly PFAS intake by children and adults through the consumption of home-produced eggs and commercial eggs and the maximum safe intake (i.e. the health-based guidance value) was calculated (Table 6). If the ratio is greater than 1, this means that the health-based guidance value is exceeded and a weekly PFAS intake through the consumption of eggs over a longer period could result in health risks. No account is taken of the intake of PFAS from other sources (background exposure). The results of the calculations based on the other scenarios appear in Appendix VIII.

Table 6. The ratio of the total weekly PFAS intake (ng/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs and the maximum safe PFAS intake (i.e. the health-based guidance value). Ratios >1 are highlighted in bold. The starting point is a mean PFAS concentration in egg and a high (P95) consumption quantity of eggs.

	Ratio between weekly PFAS intake (ng PFAS/kg body weight per week) and health-based guidance value			
	Sum EFSA-4 (based on equipotency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	**7.8**	Mean concentration	0.24
	P95 concentration	**30**		
18 to 79-year olds	Mean concentration	**2.7**	Mean concentration	0.085
	P95 concentration	**10**		
	Ratio between weekly PFAS intake (ng PEQ/kg body weight per week) and health-based guidance value			
	Sum of all measured PFAS (based on relative potency)			
	Home-produced eggs		**Commercial eggs**	
		P95 consumption		P95 consumption
1 to 3-year olds	Mean concentration	**25**	Mean concentration	0.32
	P95 concentration	**102**		
18 to 79-year olds	Mean concentration	**8.8**	Mean concentration	0.11
	P95 concentration	**35**		

Risk characterisation

Assuming the data described in this advice, the total weekly PFAS intake by children and adults through the consumption of home-produced eggs is a factor of 20 to 80 higher than the total weekly intake through the consumption of commercial eggs.

Table 6 shows that the ratio for the total weekly PFAS intake by children and adults through the consumption of <u>home-produced eggs</u> and the maximum safe intake is greater than 1. This means that the maximum safe intake (i.e. health-based guidance value) is exceeded and the weekly PFAS intake through the consumption of these eggs over a longer period can result in health risks. It should be noted that the exceedance of the maximum safe intake by the total weekly PFAS intake by children and adults is considerable. Assuming a mean PFAS concentration, the exceedance varies between a factor of 7.8 and 25 for children and a factor of 2.7 and 8.8 for adults. Assuming a high (P95) PFAS concentration, the exceedance varies between a factor of 30 and 102 for children and a factor of 10 and 35 for adults. The highest exceedance of the maximum safe intake is found in (small) children. (Small) children are compared to adults more vulnerable due to a still developing immune system.

Table 6 shows that the ratio for the total weekly PFAS intake by children and adults through the consumption of commercial eggs and the maximum safe intake does not exceed 1. The health-based guidance value is not exceeded. One scenario represents an exception (Appendix VIII), namely in the case of children who eat a large quantity of eggs (P95 consumption) with a high (P95) concentration of PFAS. In this case, the health-based guidance value is exceeded. For commercial eggs, however, it is not likely that children will eat eggs with high concentrations of PFAS over a long period, because these eggs will originate from different poultry farms. For that reason, BuRO has concluded that the long-term consumption of commercial eggs does not lead to health risks to the consumer. In this conclusion, the exposure to PFAS through the consumption of other foodstuffs (i.e. background exposure) is not taken into account. The consumption of commercial eggs can in certain cases (P95 consumption) contribute up to 53% of the total maximum safe intake of PFAS (Appendix VIII).

Discussion

Assuming a lower bound, many of the individual PFAS concentrations have a zero value. This leads to an skewed distribution of the measured PFAS concentrations. In principle, the median (P50) offers the best description of the central trend in a dataset of this kind. However, BuRO has chosen to use the mean concentration for the risk assessment because, unlike the median, the mean delivers a value greater than zero. It can be concluded on this basis that (individual) PFAS concentrations are also absent in many home-produced chicken eggs. At this moment, however, it is not possible to predict which home-produced chicken eggs will contain high or low PFAS concentrations.

Table 3 shows that home-produced eggs contain high concentrations of PFAS. These high concentrations cannot be specifically linked to a location with a known contamination source because the investigated eggs in this advice originate from different locations in the Netherlands and not specifically from areas with known PFAS contamination.

In the spring of 2023, the NRC newspaper collected 40 eggs from three private owners, three petting farms and three points of sale (not further defined) within a radius of six kilometres around the Chemours chemical plant (municipality of Dordrecht). The Vrije Universiteit Amsterdam (VU Amsterdam) analysed the eggs for the presence of PFAS. According to NRC, eggs from five of the nine locations contain PFAS concentrations that exceed European food standards for PFAS. The exact concentrations are not reported. Eggs from three of the nine locations contain PFAS compounds emitted in the past by Chemours. The conclusions of the NRC article match the conclusions from this risk assessment and confirm the picture that home-produced eggs can contain high concentrations of PFAS, which may lead to a risk to consumer health.

The municipalities of Dordrecht, Sliedrecht, Papendrecht and Molenlanden commissioned a study into the presence of PFAS in home-produced eggs in the region surrounding Chemours. At the end of December 2023, the first results were published via a press release. This release revealed that more than three-quarters of the tested eggs contain excessively high concentrations of different types of PFAS[26]. The exact concentrations are not reported. The eggs mainly contain too much PFOS. Other PFAS compounds such as PFOA were also identified but in lower concentrations. GenX is barely identified in the eggs investigated, if at all. These findings are in line with the current analysis by BuRO. It is unclear where the contamination in the eggs comes from, because there is no known emission of PFOS by Chemours. The preliminary study results also show no clear link between the PFAS concentration in the soil and the concentration in the eggs. The definitive results of the study are expected in the spring of 2024.

[26] Dordrecht Teveel PFAS in eieren van hobbykippen

The NOS broadcasting cooperation commissioned an examination of eggs from twelve private owners. The eggs originated from well beyond the Dordrecht region[27]. At six of the twelve locations, PFAS were found to be present in the eggs. At three of those locations, the PFAS concentration was above the concentrations considered responsible by the EU (ML). The exact concentrations are not reported. The origin of the PFAS is unclear. This small-scale study confirms the picture that is also reflected in this advice. PFAS can occur in home-produced eggs throughout the Netherlands and cannot be directly related to a known source of contamination.

In Denmark, the National Food Institute (DTU) has investigated the presence of PFAS in egg yolks from organic and conventional products (free range and cage eggs). The analysis results revealed higher PFAS concentrations in organic eggs as compared with non-organic eggs. The PFAS pattern in organic eggs matched the PFAS pattern in fishmeal added to organic chicken feed (DTU, 2023). BuRO has identified this as a possible signal for further investigation into the chicken feed used by private owners.

In Italy, Nobile et al. investigated the presence of PFAS in 65 commercial eggs purchased on North Italian markets. The eggs originated from various husbandry systems (caged chickens, organic, indoor and outdoor free range). Six PFAS compounds were identified, namely PFBA, PFOS, PFNA, PFOA, PFUnDA and PFDoA. The concentrations of PFOS, PFOA and PFNA identified were below the ML. According to the authors, possible sources for PFAS intake by laying hens could be the feed (i.e. fishmeal) or drinking water. The intake of PFAS through the consumption of eggs represents no risk to the health of Italian consumers (Nobile et al., 2023).

In Poland, Mikolajczyk et al. investigated the presence of PFAS in 45 commercial eggs (organic, free-range and cage eggs). Irrespective of the husbandry system, low PFAS concentrations were found in the eggs. Food and water represent potential exposure sources for hens. Hens that are able to range freely outdoors can ingest rainworms and soil. The authors concluded that the intake of PFAS via the consumption of Polish commercial eggs represented no significant contribution to total PFAS intake (Mikolajczyk et al., 2022).

Over the past few years, the University of Antwerp has conducted a series of studies into PFAS concentrations in chicken eggs and vegetables collected from private owners at various distances from 3M in Zwijndrecht, Belgium. Soil and water samples were also gathered at these private locations(Flemish government, 2021;2022). The studies are not yet concluded, but for the time being, the following conclusions have been drawn (Flemish government, 2022):

- The action limit of the Federal agency FAVV for PFOS in eggs (100 ng/g wet weight) was regularly exceeded in chicken eggs within a distance of 1.5 kilometres (with a maximum of 571 ng/g wet weight) and on one occasion at a distance of 2.5 km.
- In eggs and soil, concentrations fell gradually as the distance from 3M increased.
- Concentrations in the soil showed some positive correlation with the concentrations in the eggs.

To gain more insight into the presence of PFAS in the daily living environment, the Environment department and OVAM (Flemish Public Waste Processing Corporation) conducted a limited study with 19 participants (17-18 year olds) living far from the PFAS-suspected locations. One of the matrices investigated was home-produced eggs from the participants’ own hens. The study revealed that PFOA, PFDoA and PFOS could be quantified in 95% of the eggs, and PFTrA and PFTeA in 84% of the eggs. PFDA was observed in 53%, PFBA in 32% and PFNA in 26% of the eggs. Other PFAS components were only observed at low concentrations, if at all, in the eggs. The authors observed that high median PFAS concentrations were observed in old hens, in self-reared hens, if a grass mixture was offered in the coop, if sauces were fed to the hens, if grass was present in the coop, if there was limited free-range space and if the free range space was more overgrown. The observers also noted that lower

[27] NOS: Ook PFAS in hobby-eieren ver buiten regio Dordrecht

median PFAS concentrations were observed in eggs if the hens were fed scraps and skins of vegetables and fruit NOT from the owners' garden and if the hens were fed outside on the ground. Given the limited study population, further study will be needed to determine whether the listed observations can be applied more generally (Colles et al., 2022).

In December 2010, EFSA called for monitoring of the occurrence of PFAS in foodstuffs and the submission of the resultant data to EFSA. EFSA describes the mean PFOS, PFOA, PFNA and PFHxS concentrations in eggs and egg products (EFSA CONTAM Panel, 2020). On the basis of this data, BuRO calculated the total mean (Appendix IX). Assuming lower bound calculations, the total mean PFAS concentration in eggs and egg products from the EFSA publication is higher than the total mean PFAS concentration in commercial eggs from the Netherlands and lower than the total mean PFAS concentration in home-produced eggs in the Netherlands (Table 3).

As part of the national animal feed plan, the NVWA measured PFAS concentrations in corn silage, grass silage, lucerne and fishmeal. On the basis of these analyses, RIVM and WFSR, among others, determined which PFAS concentrations may be present in the animal feed before MLs in animal products are exceeded. RIVM and WFSR have concluded that the MLs in eggs are not exceeded due to exposure of laying hens via long-term consumption of lucerne with the measured PFOS concentrations and with PFOA, PFNA and PFHxS concentrations equal or below the LOQs. The MLs in eggs are also not exceeded through exposure of laying hens via short-term consumption of fishmeal with the measured concentrations of the four PFAS (RIVM & WFSR, 2023). Since this study shows that the laying of eggs is an effective elimination route for a number of PFAS, BuRO has concluded that laying efficiency could have an influence on the PFAS concentrations in eggs. This is a possible explanation for the discrepancies between PFAS concentrations in home-produced eggs and commercial eggs. The laying efficiency is influenced by factors such as species, age, diet and light regime, among others.

In this risk assessment in respect of the consumption of eggs, no account was taken of the background exposure to PFAS through the consumption of other foodstuffs. RIVM calculated that the contribution to the intake of PFAS by Dutch consumers (1 to 79-year olds) is greatest for the consumption of fish (24% - 30%), drink (29% - 45%; excluding drinking water), dairy products (13% - 17%), meat and meat products (6.1% - 7.9%) and vegetables (4.2% - 5.4%). The contribution through the consumption of commercial eggs was 2.9 - 3.7%. The differences in percentage depend on whether a consumer consumes drinking water that originates from groundwater or surface water. Drinking water originating from surface water makes a greater contribution to the PFAS intake (27%) than drinking water originating from groundwater (6%). The total PFAS intake by Dutch consumers is too high, according to RIVM (Schepens et al., 2023).

Uncertainties

The calculation of the weekly PFAS intake through the consumption of home-produced eggs and commercial eggs is based on PFAS concentrations in home-produced eggs and commercial eggs originating from three datasets. This is a limited number which may result in uncertainty regarding the actual PFAS concentration. The findings in the current assessment are, nevertheless, in line with recently conducted research.

To calculate the weekly PFAS intake through the consumption of home-produced eggs and commercial eggs, a number of different methodologies were employed in order to calculate the total PFAS concentration in the egg. On the basis of the datasets used in this advice, the calculation of the total PFAS concentration in commercial eggs gives comparable outcomes for the different calculation methods. On the other hand, the outcome of the calculation of the total PFAS concentration in home-produced eggs is dependent on the calculation method used (Table 3), even though the conclusions are unequivocal in respect of the risk. The difference between

the outcomes from the methods can be explained by the fact that other and/or multiple PFAS with a higher or lower RPF have been identified in home-produced eggs than in commercial eggs. In the commercial eggs, PFOA (RPF =1) is the most commonly observed form. BuRO encourages scientific discussion and further refinement of the method with a view to arriving at the best (and most harmonised) approach to calculating exposure to PFAS.
Another uncertainty is the possible presence of PFAS below the LOQ of the analytical methods. In its exposure calculations, BuRO assumes the more realistic lower bound scenario, but given the numerous non-detects in the dataset, the possibility cannot be excluded that other PFAS are present at lower concentrations that have not been included in the current assessment. As a consequence, the total exposure to PFAS may be underestimated. Moreover, due to development of the methodologies, the LOQ differs between the older and more recent data, which represents a further uncertainty in the assessment.

The samples of home-produced eggs (2014) and samples of commercial eggs (2017 through to 2022) were taken at different moments in time. The samples of home-produced eggs from 2014 may contain a (relatively) higher concentration of PFAS than recently sampled eggs. On the basis of the substance properties, BuRO does not expect the PFAS concentration to change considerably, if at all, over a longer period. However, a Danish study shows that the median PFOS concentration in the blood of Danish children and adults has decreased considerably over the past 30 years. The greatest decrease has been observed in the years since 2000 (i.e. the phasing out of PFOS by 3M). A similar but less marked decrease is observed for PFOA. For other PFAS (PFDA, PFNA, PFHpA, PFHpS and PFHxS), no clear trend over time has been observed (Hull et al., 2023).

In the dataset for the home-produced eggs, there is uncertainty about the precise origin of the eggs. Sixty samples originate from various regions across the Netherlands (Appendix IV). The precise location cannot be derived in connection with the agreements reached concerning the protection of the personal data of the participants in the study. The origin of the other 13 egg samples was not further defined, although it is certain that they do come from chickens in private ownership. The higher concentrations cannot easily be explained by known contamination sources. This matches the conclusions of the recent study into PFAS concentrations in home-produced eggs in the area around Chemours and 3M in Belgium.

The total intake of PFAS by Dutch consumers from various food sources is too high, according to RIVM. This high background exposure was not taken into account in the current risk assessment.

Conclusion

Home-produced eggs in the Netherlands can contain high concentrations of PFAS. At this time no relationship can be established with a known source of contamination. It is therefore not possible to predict in advance which eggs from private individuals contain these high concentrations.

The weekly PFAS intake through the consumption of home-produced eggs exceeds the health-based guidance value (i.e. the maximum safe intake) considerably. The ratio between total weekly PFAS intake by children and adults through the consumption of home-produced chicken eggs and the maximum safe ranges between 2.7 and 102. This means that the weekly PFAS intake through the consumption of these eggs over a longer period can result in health risks. This does not apply for the consumption of commercial eggs.

In this risk assessment in respect of the consumption of eggs, no account was taken of the background exposure to PFAS through the consumption of other foodstuffs. According to RIVM, total PFAS intake by Dutch consumers is too high.

In line with recent studies into PFAS concentrations in eggs among consumers around Chemours and 3M (Belgium), the analysis by BuRO reveals no clear relationship between the PFAS contamination in home-produced eggs and a known contamination source. Further study on this topic in a broader research programme is needed in order to reveal the cause of the PFAS found in the home-produced eggs and to be able to offer a course of action to consumers, for the reduction these concentrations.

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Appendix I. List of abbreviations individual PFAS

Table 7. List of abbreviations individual PFAS

Per and polyfluoroalkyl substances abbreviation	**PFAS**	**CAS number**
PFBA	Perfluorobutanoic acid	375-22-4
PFPeA	Perfluoropentanoic acid	2706-90-3
PFHxA	Perfluorohexanesulfonic acid	307-24-4
PFHpA	Perfluoroheptanoic acid	375-85-9
PFOA	Perfluorooctanoic acid	335-67-1
PFNA	Perfluorononanoic acid	375-95-1
PFDA	Perfluorodecanoic acid	335-76-2
PFUnDA	Perfluoroundecanoic acid	2058-94-8
PFDoDA	Perfluorododecanoic acid	307-06-7
PFTrDA	Perfluorotridecanoic acid	72629-94-8
PFTeDA	Perfluorotetradecanoic acid	376-06-7
PFBS	Perfluorobutane sulfonic acid	375-73-5
PFHxS	Perfluorohexane sulfonic acid	355-46-4
PFHpS	Perfluoroheptane sulfonic acid	375-92-8
PFOS	Perfluorooctane sulfonic acid	1763-23-1
PFDS	Perfluorodecane sulfonic acid	335-77-3
GenX (HFPO-DA)	2,3,3,3-tetrafluor-2 (heptafluorpropoxy) propionic acid	13252-13-6
NaDONA	Sodium salt of ammonia 4,8-dioxa-3H-perfluorononanoate (ADONA)	958445-44-8*
9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanonane-1-sulfonate	73606-19-6
11Cl-PF3OUdS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonate	83329-89-9

*Applies for ADONA.

Appendix II. Analysed PFAS

To calculate the PFAS concentrations in home-produced eggs and supermarket eggs, three datasets were used.

1. An academic article dating from 2016 by Zafeiraki et al. that reported on PFAS concentrations in Dutch home-produced eggs and supermarket eggs (Zafeiraki et al., 2016).
2. Monitoring data for PFAS in supermarket eggs analysed by Wageningen Food Safety Research (WFSR) (period 2017 through to 2022).
3. PFAS concentrations in supermarket eggs used in a recent risk assessment by the National Institute for Public Health and the Environment (RIVM) into the health risks of PFAS in Dutch food and drinking water (Schepens et al., 2023). An overview of the analysed PFAS per dataset.

Table 8 provides an overview of the various analysed PFAS per dataset.

Table 8**.** An overview of the various analysed PFAS per dataset.

PFAS	Home-produced eggs (n=140)	Commercial eggs (n=73)	
	Dataset 1	Dataset 2	Dataset 3
GenX		X	X
NaDONA		X	
PFBA		X	
PFBuS	X	X	X
PFDA	X	X	X
PF-DoA	X		
PFDoDa		X	X
PFDS		X	X
PFHpA	X	X	
PFHpS	X		X
PFHpS		X	
PFHxA	X	X	X
PFHxS	X	X	X
PFNA	X	X	X
PFOA	X	X	X
PFOS	X	X	X
PFPeA		X	X
PFTeDA		X	X
PFTrDA		x	X
PFUnA	X		
PFUnDA		x	X

Appendix III. Relative potency factors

Table 9. Overview of measured PFAS and the related relative potency factors on the basis of (Bill et al., 2021). If a range is reported for the RPF by BuRO, the highest value is selected as RPF. This is in line with the most recent calculations by RIVM (Schepens et al., 2023).

PFAS	RPF	Comment
11Cl-PF3OUdS	(-)	no RPF available, not included in calculation
9Cl-PF3ONS	(-)	no RPF available, not included in calculation
GenX	0.06	In article referred to as HFPO-DA
NaDONA	0.03	In article referred to as ADONA
PFBA	0.05	
PFBuS	0.001	In article referred to as PFBS
PFDA	10	In article range 4 to 10
PFDoDA	3	
PFDS	2	
PFHpA	1	In article range 0.01 to 1
PFHpS	2	In article range 0.6 to 2
PFHxA	0.01	
PFHxS	0.6	
PFNA	10	
PFOA	1	
PFOS	2	
PFPeA	0.05	In article range 0.01 to 0.05
PFTeDA	0.3	
PFTrDA	3	In article range 0.3 to 3
PFUnDA	4	

Appendix IV. Origin of 60 samples of home-produced eggs

Figure 1 provides an overview of the origin (location) of the 60 samples of home-produced eggs analysed by Zafeiraki et al. for the presence of PFAS.

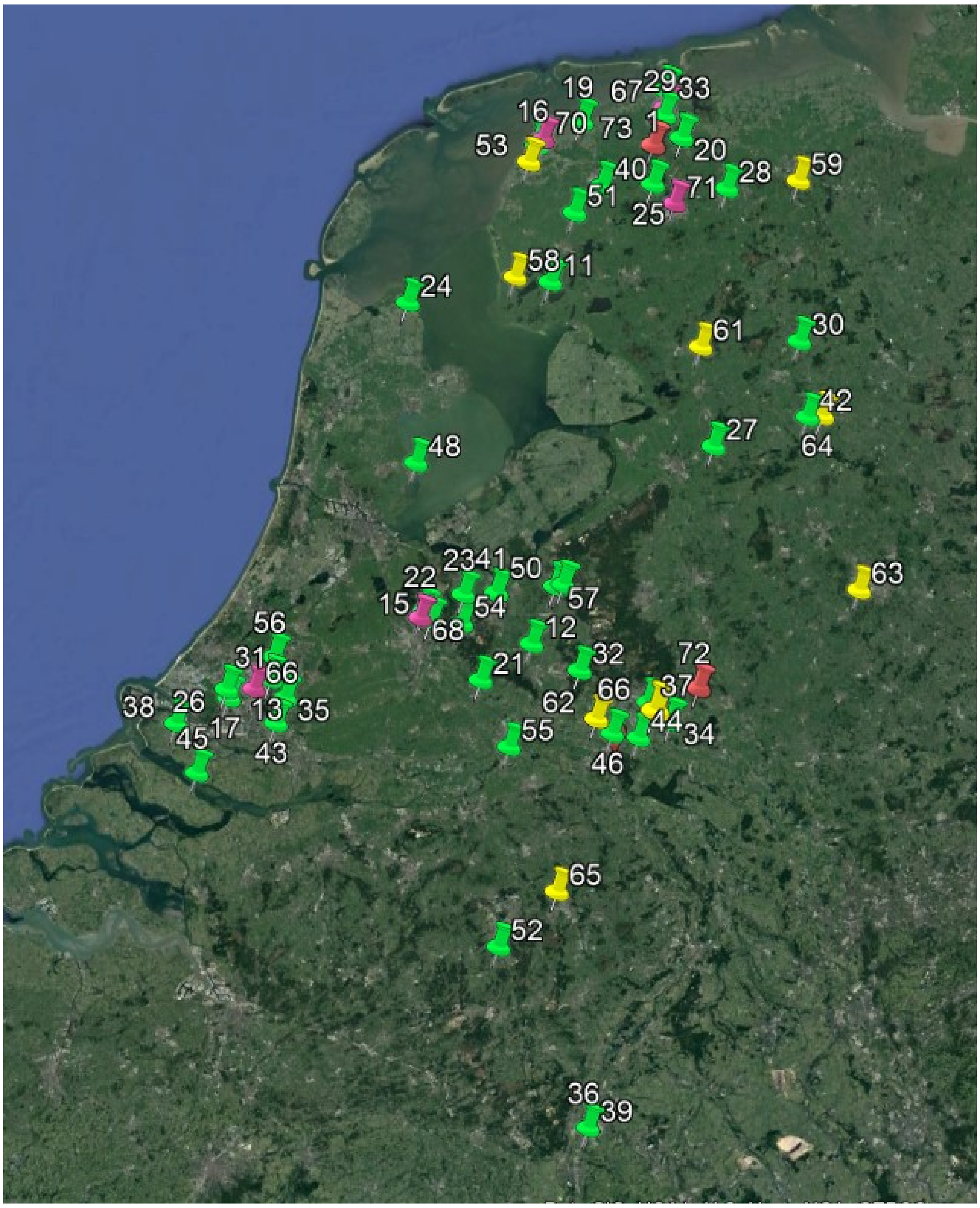

Figure 1. An overview of the origin of the *60* samples of home-produced eggs analysed by Zafeiraki et al. for the presence of PFAS. The pin marks show the PFAS concentration. The different colours represent the following PFAS concentrations: green <17 ng/g total egg; yellow 1.7 – 3.4 ng/g total egg; purple > 3.4 – 6.8 ng/g total egg and red > 6.8 ng/g total egg. The ML for the sum of PFOS, PFOA, PFNA and PFHxS is 1.7 µg/kg = 1.7 ng/g (Table 1).

Appendix V. Raw data and calculations

See separate attached Excel file.

Appendix VI. PFAS concentrations in home-produced eggs and commercial eggs

Table 10. The total PFAS concentrations calculated by BuRO (ng PFAS/gram total egg or ng PEQ/gram total egg for the calculations with RPFs) in home-produced eggs (n=73) and commercial eggs (n=140). The mean and P95 concentrations are calculated on the basis of lower bound. For the adding up of the PFAS, four different methods were used; the sum of EFSA-4 based on equipotency, the sum of EFSA-4 based on RPFs, the sum of all measured PFAS based on equipotency and the sum of all measured PFAS based on RPFs.

	Lower bound			
	Sum EFSA-4 (ng PFAS/gram total egg)	**Sum EFSA-4 (ng PEQ/gram total egg)**	**Sum all measured PFAS (ng PFAS/gram total egg)**	**Sum all measured PFAS (ng PEQ/gram total egg)**
Home-produced eggs (n=73)				
Mean	1.4	3.2	1.6	4.6
P95	5.5	13	6.4	19
Commercial eggs (n=140)				
Mean	0.044	0.055	0.045	0.058
P95	0.28	0.28	0.28	0.28

Appendix VII. Total weekly PFAS intake

Table 11. The total weekly PFAS intake (ng PFAS/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs.

	Weekly PFAS intake (ng/kg body weight per week)					
	Sum EFSA-4 (based on equipotency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	5.9	34	Mean concentration	0.18	1.1
	P95 concentration	23	132	P95 concentration	1.2	6.7
18 to 79-year olds	Mean concentration	2.99	12	Mean concentration	0.093	0.37
	P95 concentration	12	46	P95 concentration	0.59	2.3
	Sum EFSA-4 (based on relative potency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	13	77	Mean concentration	0.23	1.3
	P95 concentration	56	324	P95 concentration	1.2	6.7
18 to 79-year olds	Mean concentration	6.7	27	Mean concentration	0.12	0.46
	P95 concentration	28	112	P95 concentration	0.59	2.3
	Sum of all measured PFAS (based on equipotency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	6.7	39	Mean concentration	0.19	1.1
	P95 concentration	26	153	P95 concentration	1.2	6.7
18 to 79-year olds	Mean concentration	3.4	13	Mean concentration	0.094	0.38
	P95 concentration	13	53	P95 concentration	0.59	2.3
	Sum of all measured PFAS (based on relative potency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	19	111	Mean concentration	0.24	1.4
	P95 concentration	77	450	P95 concentration	1.2	6.7
18 to 79-year olds	Mean concentration	9.7	39	Mean concentration	0.12	0.48
	P95 concentration	39	156	P95 concentration	0.59	2.3

Appendix VIII. Ratio of total weekly PFAS intake and the maximum safe PFAS intake

Office for Risk Assessment & Research (BuRO)

Date
20 February 2024

Our reference
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Table 12. The ratio of the total weekly PFAS intake (ng/kg body weight per week or ng PEQ/kg body weight per week for the calculations with RPFs) by children (1 to 3-year olds) and adults (18 to 79-year olds) through the consumption of home-produced eggs and commercial eggs and the maximum safe PFAS intake (i.e. the health-based guidance value). Ratios >1 are highlighted in bold.

	Ratio of weekly intake and health-based guidance value					
	Sum EFSA-4 (based on equipotency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	**1.3**	**7.8**	Mean concentration	0.042	0.24
	P95 concentration	**5.2**	**30**	P95 concentration	0.26	**1.5**
18 to 79-year olds	Mean concentration	0.68	**2.7**	Mean concentration	0.021	0.085
	P95 concentration	**2.6**	**10**	P95 concentration	0.13	0.53
	Sum EFSA-4 (based on relative potency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	**2.99**	**17**	Mean concentration	0.052	0.304
	P95 concentration	**13**	**74**	P95 concentration	0.26	**1.5**
18 to 79-year olds	Mean concentration	**1.5**	**6.04**	Mean concentration	0.026	0.11
	P95 concentration	**6.4**	**26**	P95 concentration	0.13	0.53
	Sum of all measured PFAS (based on equipotency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	**1.5**	**8.8**	Mean concentration	0.042	0.25
	P95 concentration	**5.99**	**35**	P95 concentration	0.26	**1.5**
18 to 79-year olds	Mean concentration	0.77	**3.07**	Mean concentration	0.021	0.085
	P95 concentration	**3.04**	**12**	P95 concentration	0.13	0.53
	Sum of all measured PFAS (based on relative potency)					
	Home-produced eggs			**Commercial eggs**		
1 to 3-year olds		Mean consumption	P95 consumption		Mean consumption	P95 consumption
	Mean concentration	**4.3**	**25**	Mean concentration	0.054	0.32
	P95 concentration	**18**	**102**	P95 concentration	0.26	**1.5**
18 to 79-year olds	Mean concentration	**2.2**	**8.8**	Mean concentration	0.028	0.11
	P95 concentration	**8.9**	**35**	P95 concentration	0.13	0.53

Appendix IX. PFAS concentrations – EFSA

In December 2010, EFSA called for monitoring of the occurrence of PFAS in foodstuffs and the submission of the resultant data to EFSA. EFSA received data from the national authorities in Austria, Belgium, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Malta, Norway, Slovenia, Spain and the United Kingdom. Data submitted up to and including 16 May 2018 were included in the analysis of the EFSA opinion (EFSA CONTAM Panel, 2020). EFSA describes the mean PFOS, PFOA, PFNA and PFHxS concentration in eggs and egg products (EFSA CONTAM Panel, 2020). Table 13 provides an overview of the total mean PFAS concentrations in egg and egg products based on the concentrations as reproduced in the EFSA opinion, as calculated by BuRO.

Table 13. The total mean PFAS concentrations calculated by BuRO (ng PFAS/g or ng PEQ/g) in egg and egg products calculated with lower bound and upper bound. For the adding up of the PFAS, two different calculation methods were used; sum of the EFSA-4 based on equipotency and the sum of EFSA-4 based on relative potency.

PFAS	**N**	**LB**	**UB**
PFOS	174	0.27	0.32
PFOA	177	0.106	0.21
PFNA	124	0.000	0.098
PFHxS	107	0.000	0.06
Sum EFSA-4 (EP)		0.38	0.69
Sum EFSA-4 (RPF)		0.65	1.9