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REVIEW OF PRIORITY CHEMICAL RISKS, FOOD PRODUCTION AND CONSUMER DIETS IN SCOTLAND

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FINAL REPORT

Review of Priority Chemical Contaminant Risks, Food Production and Consumer Diets in Scotland

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Summary

Exposure to chemical contaminants in food poses a potential risk to a range of human health effects which can be either acute or chronic depending on the nature of the chemical, and the overall exposure to it. This exposure is a result of a combination of the level of the contaminant in the food and the amount of that food that is consumed. The risk will vary depending on factors such as the age and body weight of the individual.

A review of evidence relating to chemical contaminant risks from the food chain, specifically in a Scottish context was conducted. Data from a number of sources including scientific literature, grey literature, HorizonScan, and UKFSS surveillance reports were reviewed for chemical contaminant classes and major food types. Further refined searches focussing on Scotland and Scottish produce were also conducted.

No specific significant or chronic chemical contaminant risks which are particular to food in Scotland, or the Scottish diet, were identified in the review. Scottish consumption patterns were not significantly different to the rest of the UK and were very similar for most food groups and consumer age groups. There was some evidence to suggest that the Scottish consumer may eat more food prepared outside the home, e.g. take-away meals.

Some classes of contaminant, may be of particular relevance to economically important food industries in Scotland, such as those related to fish production (e.g. environmental contaminants such as dioxins and PCBs, pollutants from oil or fuel or heavy metals), and some cereal crops (e.g. mycotoxins). Details of these are given by contaminant class in the detailed sections of the report. However, no evidence was found of any contaminant issues specifically associated with Scottish products.

Executive Summary

Analysis of dietary intake information from the National Diet and Nutrition and Survey (NDNS) found no significant difference in consumption patterns for the Scottish consumer compared to the rest of the UK (except an indication of slightly higher proportion of foods consumed that are prepared outside the home e.g. take-away foods). Extensive searches of scientific literature, grey literature and the HorizonScan warning system were undertaken to prioritise the environmental, natural and process contaminant chemical risks which are most likely to impact on key food commodities consumed in Scotland. Data from the last 2 years Scottish Local Authority Food Sampling, as well as evidence from the literature and other surveys, e.g. FSA and EFSA, showed overall compliance with EU standards. These results and the information from the NDNS about Scottish dietary habits indicated that Scottish consumers are not at any particular risk of exposure to chemical contaminants.

Extensive data were available for established contaminants (e.g. metals, mycotoxins). There were fewer reports for other contaminants, such as furan, while for some of the environmental contaminants (e.g. brominated dioxins and biphenyls) there were no publications or reports via HorizonScan. This is not a reflection of the relative risk of the contaminants but indicates the state of the art of the knowledge about them.

While there was no statistically significant difference in overall consumption, UKFSS data and literature reports indicated some local foods and local customary habits may result in higher levels of exposure to some contaminants. For example, acrylamide was the most frequently detected contaminant, and consumption of ‘well fired rolls’ may result in increased exposure to acrylamide and furans. Locally smoked fish may contain higher levels of PAHs compared to products that are not smoked. Although no particular sources of contamination were identified that were associated specifically with Scottish foods, there will always be the possibility of local sources of contamination due to specific geology or industries, e.g. coal mines and coal fired power stations, and other chemical industries.

There was no evidence in the literature of any issues that may affect Scotland’s food and drink sector. Shellfish, fish and aquaculture are associated with certain classes of contaminant such as arsenic, mercury, dioxins and PCBs. There was no evidence of any specific issues with these contaminants in Scottish produce from a recent FSA survey for chemical contaminants in seafood collected from UK marine waters and coastline (FSA, 2017). This was supported by FSS results (Food Standards Scotland, 2014 and 2015), scientific literature and HorizonScan reports where there were no recorded findings for Scottish produce.

Significantly higher levels (compared to the rest of the UK) of mycotoxins, specifically T-2 and HT-2 toxins produced by Fusarium moulds have been found in Scottish unprocessed oats, particularly from northern Scotland. A follow up survey showed that levels of T-2 and HT-2 toxins were not a cause for concern in retail products as the toxin levels were reduced by processing.

Some classes of emerging contaminants (i.e. those contaminants that are not yet regulated but may be regulated in future) are of particular concern to some foods

produced in Scotland and to the Scottish consumer. These include some of the brominated flame retardants (BFRs), and brominated and mixed halogenated dioxins. Some classes of contaminant (PFASs, some mycotoxins, dioxins and PCBs) are currently under (re-)evaluation by EFSA. If there is a revision to health-based guidance values (e.g. Tolerable Daily Intake (TDI)) then action may be needed to ensure the safety of Scottish food and to protect the Scottish consumer.

Overall the main conclusion from this study is that no major issues were identified for food and drink items produced or consumed in Scotland. The published evidence reviewed did not highlight any particular specific risk from contaminants in the diet of Scottish consumers, in relation to current EU standards. This gives reassurance that FSS and wider UK/EU work programmes are well targeted against known issues, particularly where maximum levels are already set. There are gaps in the understanding of the occurrence of and exposure to other chemicals, such as MCPD esters, other processing contaminants, and halogenated POPs that have recently undergone risk assessment by EFSA, and where less data is available. Sampling and analysis should be undertaken for those contaminants, particularly where it has been identified that current TDIs are at risk of being exceeded for vulnerable population groups such as infants and young children (e.g. MCPD esters and furan). It must always be borne in mind that food and feed incidents can occur at any time, and historically have been the result of unexpected events, been discovered accidentally or found as an indirect result of research or other surveillance. Therefore, as well as horizon scanning and intelligence gathering, that should always be carried out in addition to traditional analytical surveillance, it could be worth considering some non-targeted analysis to seek possible 'unknowns' that may otherwise remain undiscovered.

Key **findings** from this study are:

1. Analysis of dietary intake information from the National Diet and Nutrition and Survey (NDNS) found no significant difference in consumption patterns for the Scottish consumer compared to the rest of the UK (except an indication of slightly higher proportion of foods consumed that are prepared outside the home e.g. take-away foods).

2. Data from the last 2 years UK Food Surveillance System (UKFSS) as well as evidence from the literature and dietary information from the National Diet and Nutrition Survey (NDNS), showed that Scottish consumers are not at any particular risk of exposure to chemical contaminants as a result of their dietary habits and presuming similar levels of contamination across Scottish foods. No new or unexpected issues were discovered, in spite of extensive literature research and information gathering.

3. There was no evidence of any significant issues that may affect the major industries in the Scottish food and drink sector. Some industries of high importance to the Scottish economy e.g. shellfish, fish and aquaculture are associated with certain classes of contaminant such as arsenic, mercury, dioxins and PCBs. There was no evidence of any specific issues with these contaminants in Scottish produce from UKFSS results, literature or HorizonScan reports. Surveys of marine fish, aquaculture produce and data from the shellfish monitoring programme do not highlight particular

concerns for Scottish produce (FSS 2014 and 2015). Some literature evidence is starting to emerge about the impact of mycotoxins on aquaculture from an animal well-being and productivity point of view, and this perhaps requires further investigation, although there is no evidence of a consequential risk to human health. However, it is essential that Scottish produce complies with EU regulations to ensure the quality of food produced in order to reassure the consumer and export trade.

4. Caution should be used when considering emerging contaminant classes. Lack of data is not an indication that there is not a potential issue; it is simply an indication of the state of the art of general analytical capability and the maturity of the topic in terms of research and surveillance. Therefore surveillance, and analytical method development if required, should be considered for those contaminants where little data exist. This is highlighted both in literature and UKFSS data by the availability of data from established, and perhaps viewed as straightforward analyses such as metals and some mycotoxins. Conversely there is virtually no data for 'emerging' contaminants, such as PFOS/PFAS, MCPD esters, furan, or pyrrolizidine alkaloids because methodology and targeted monitoring plans are not yet in place.

Key **recommendations** are as follows:

1. The sampling carried out by Scottish Local Authorities (LAs) should be maintained to ensure the data held on the UK Food Surveillance System (UKFSS) database is up to date and relevant, and where possible to check Scottish Food and Feed business operators compliance with current regulations. However this review of the recent data shows gaps for many of the classes of contaminants, particularly those contaminants classed as 'emerging' such as the halogenated environmental contaminants (Brominated Flame Retardants (BFRs), chlorinated paraffins (CPs), polychlorinated naphthalenes (PCNs)) some mycotoxins (ergot alkaloids, modified forms, enniatins and other Fusarium toxins), plant toxins (pyrrolizidine alkaloids, opium alkaloids) and processing contaminants (except acrylamide) suffer from a lack of available data. The UKFSS data available reflects the capability and capacity, in terms of analytical equipment, of the laboratories performing the analyses. There may be barriers to expanding the range of contaminants tested, such as lack of suitable analytical methodology, but this should be addressed. In view of UKFSS limitations, consideration should also be given to accessing and using industry monitoring data.

2. Review the current list of undesirable substances included in the Scottish LAs' sampling programme. New regulations for some contaminants mean additional compounds may need to be included to ensure compliance and to obtain occurrence data where little (or no) data are currently available. This includes MCPD and glycidyl esters, and hydrocyanic acid where new regulations have already been introduced, PFASs where new reports from EFSA are anticipated, the BFRs, ergot alkaloids and pyrrolizidine alkaloids where new regulations are anticipated. There are also other contaminants that are not currently regulated but where there is evidence of exposure and toxicity, and data are limited such as furan, ethyl carbamate, modified mycotoxins, and opium alkaloids.

3. Where data requests exist, Commission Recommendations are published, or gaps are identified, consider carrying out surveillance. Commission Recommendation 2018/464 is of particular relevance to Food Standards Scotland as it requests data on heavy

metals and iodine in seaweed, a product identified by FSS as being an increasingly important product for Scotland. Monitor EFSA calls for data and current work activity and produce data to ensure that the Scottish consumer and Scottish industry are supported. A new EFSA call for contaminant data was launched on 15 May 2018. It includes many of the contaminants mentioned above, as well as other compounds in the groups; process contaminants; organic contaminants; inorganic contaminants; mycotoxins; and plant toxins. Gaps in data for all of these groups of compounds have been highlighted in the text.

4. Maintain a watching brief on the activities of EFSA particularly where contaminants undergo a (re-)evaluation. If health-based guidance values (e.g. TDI) are revised there could be consequences for Scottish food production and Scottish consumers, and surveillance or research may be required. Classes of contaminant currently under (re-)evaluation include PFASs, some mycotoxins including modified forms, dioxins and PCBs. PFASs occur in soil from biosolids or water application and can transfer into produce grown on it. The Scottish diet contains a large proportion of carbohydrate rich foods, for which many of the processing contaminants and possibly mycotoxins (if cereal products) would be most relevant. Dioxins and PCBs can occur in a range of foods, but the most relevant categories for Scotland would be salmon (farmed and wild) and other seafood due to their high economic value. Food categories that are particularly relevant for these classes of contaminant are highlighted in the main body of this report.

5. Continue with horizon scanning and intelligence gathering activities, particularly in relation to issues that may be important to Scotland. This can include reports from other countries where Scottish produce has exceeded regulatory limits, or can be used to identify potential concerns for imported produce that may affect the Scottish consumer. Scientific literature and conferences can be a source of information that can be used to identify contaminants of emerging concern, as well as subscription to on-line news services. HorizonScan provides information on incidents that have been reported globally, and is useful for monitoring trends to determine if a report is an isolated event or the start of an incident. New tools such as Early Warning systems based on models using trade data may prove useful in alerting to problems as they emerge rather than after an incident has started.

Glossary

AHDB -	Agriculture and Horticulture Development Board
ARfD –	Acute Reference Dose
BaP -	Benzo[a]pyrene
BFR -	Brominated Flame Retardant
BMDL -	Benchmark Dose Lower Confidence Limit
CODEX -	International food standards, guidelines and codes of practice contributing to the safety, quality and fairness of this international food trade.
Competent - **Authority**	the central authority of a Member State competent for the organisation of official controls or any other authority to which that competence has been conferred
Defra -	Department for Environment, Food and Rural Affairs
DON -	Deoxynivalenol
DDGS -	Dried Distillers Grains with Solubles
EFSA -	European Food Safety Authority
FAO -	Food and Agriculture Organization of the United Nations
FDA –	US Food and Drug Administration
FSA –	Food Standards Agency (FSA – E, W & NI)
FSAI -	Food Safety Authority of Ireland
FSS -	Food Standards Scotland
HorizonScan –	an online subscription system for monitoring commodity safety & integrity issues worldwide. HorizonScan in a registered trademark of Fera Science Ltd.
JECFA –	Joint FAO/WHO Expert Committee on Food Additives
LB –	Lower Bound
MCPD -	3-Monochloropropane-1,2-diol
MOEs -	Margins of Exposure
MANCP -	Multi Annual National Control Plan - details the roles and responsibilities of the different authorities and organisations involved in monitoring compliance with, and enforcement of, feed and food law, animal health and welfare rules and plant health requirements.

MLs - Maximum Levels

NIV - Nivalenol

OTA - Ochratoxin A

PAH – Polyaromatic Hydrocarbons

PBB – Polybrominated Biphenyls

PCB – Polychlorinated Biphenyls

PCN – Polychlorinated Naphthalenes

PFAS - Per- and Poly-Fluoro Alkyl Substances

PFOA - Perfluorooctanoic Acid

PFOS - Perfluorooctane sulfonate

PMTDI - Provisional Maximum Tolerable Daily Intake

POP - Persistent Organic Pollutants

RASFF - the EU Rapid Alert System for Food and Feed, an interactive searchable online database covering risks to public health that have been detected in the food chain.

RPA - Rural Payments Agency, an executive agency of Defra

TDI – Tolerable Daily Intake

TEF - Toxic Equivalency Factor

TWI – Tolerable Weekly Intake

TMI – Tolerable Monthly Intake

UB – Upper Bound

UKFSS - UK Food Surveillance System

WHO - World Health Organization

ZON – Zearalenone

Background and aims of the study

Chemical contamination can occur at any stage in the food (and feed) chain. The mechanisms and routes by which contaminants can enter the supply chain are complex. For example, contaminants can arise as a result of farming methods and practices, environmental contamination, or they can occur during transport, storage or processing. There are also many different types of chemical contaminant. Naturally produced contaminants e.g. mycotoxins, and algal biotoxins can occur as a result of a range of factors including poor storage or climatic conditions. Organic compounds e.g. dioxins and PCBs; and inorganic compounds e.g. lead and arsenic can be the result of environmental and geological conditions or the after effects of incidents such as fires. Other compounds such as nitrates, pesticide and veterinary medicines residues, and plant toxins e.g. pyrrolizidine alkaloids, can arise due to horticultural or agricultural practices or misuse of licenced agrochemicals or veterinary medicines. Process contaminants e.g. acrylamide, are formed during food processing or heat treatment, and will be dependent on the conditions used and the foodstuff.

Exposure to chemical contaminants in food poses a potential risk to human health which can be wide ranging, and acute or chronic depending on the nature of the chemical, and the overall exposure to it. This exposure is a result of a combination of the level of the contaminant in the food and the amount of that food that is consumed. The risk will vary depending on several host factors such as the age and body weight of the individual.

Given this complexity, an up to date review of the available evidence relating to chemical contaminant risks to the food chain, specifically in a Scottish context was requested by Food Standards Scotland. While it was not anticipated that there would be significant or chronic chemical contaminant risks which are particular to food in Scotland, or the Scottish diet, this was a supposition. Surveillance and monitoring for chemical contaminants in foods consumed in Scotland are not routinely undertaken by FSS, with local authorities undertaking limited sampling of targeted foods at the retail level; and whilst there are many published papers on the individual chemical contaminants in particular foods, it is important to understand how this evidence relates to production methods and dietary intake risks which could be of particular relevance to Scotland. Examples of risks which could have the potential to contaminate foods produced in Scotland include mycotoxin levels in oats and barley, and marine contaminants in fishery products. Scottish consumers may also be exposed to contaminants such as acrylamide in starchy foods and certain heavy metals in particular types of oily fish. The scope was limited to environmental and process chemical contaminants, and did not consider any microbiological hazards, or contamination from pesticide or veterinary medicines residues. Shellfish toxins were also excluded from this review.

This review has been conducted to support the work of Food Standards Scotland in prioritising and targeting intervention strategies for controlling the transmission of chemical contaminants at all stages of the food chain. The review highlights current and emerging chemical contaminant risks from food and feed commodities available in Scotland and those which are most likely to be associated with the foods that are known to be most commonly consumed by the Scottish population. It also highlights evidence gaps for prioritisation through future research and surveillance programmes.

This review will help FSS to ensure that the chemical contaminants component of its strategy for reducing foodborne illness is based on the most up to date, expert scientific evidence and that advice, guidance and research is effectively targeted to the areas of risk which are of most significance to Scotland.

The aim of this review is to provide FSS with recommendations, based on expert scientific opinion and up to date evidence, on the chemical contaminants which are likely to present the most significant risks to foods consumed in Scotland and the diets of Scottish consumers.

Approach and Methodology

This review prioritises the chemicals which have the greatest potential to contaminate food commodities available in Scotland, as well as current and emerging contaminant risks which are most likely to be associated with the dietary preferences of Scottish consumers. It is risk based and takes into account both the nature of the chemical hazard (i.e. potential to cause an adverse health effect), occurrence data and consumption habits of the Scottish consumer.

It covers naturally occurring organic chemical contaminants e.g. mycotoxins, plant toxins, industrial organic pollutants e.g. dioxins, PCBs; per- and poly-fluoro alkyl substances (PFASs); inorganic heavy metals e.g. lead, arsenic, mercury; and process contaminants e.g. furan and acrylamide.

In addition to summarising information on the various classes of chemical contaminant, the review addresses exposure and risk to the Scottish consumer. The most recently available dietary consumption information was obtained from the National Diet and Nutrition Survey (NDNS). Dietary consumptions for specific food categories were summarised for Scottish and UK populations to identify any differences. Other sources of data were investigated for information about Scottish dietary patterns, using data on food purchased into homes in Scotland (Food Standards Scotland, 2015a and 2016).

Literature review – On-line literature searches

Fera Information Centre (FIC) has access to commercial databases – especially those of the Dialog, Web of Science, and OVID hosts - covering all scientific disciplines through the Athens IP access, as well as the use of open access databases such as PubMed, ScienceDirect and various government hosted databases. The FIC also subscribes to circa 150 current journals.

Using these resources, literature searches for information on possible chemical contaminants in the food supply chain; in particular with relevance to Scottish consumers dietary patterns were performed. Search terms were drawn up by the project team and sent to FSS for comment and approval. Some additional terms were added and the final list was agreed.

These terms were used for the searches, through access to the hosts Science Direct, Ovid and Web of Science. A number of databases of obvious potential relevance to this study were interrogated, these included, but were not limited to:

- Web of ScienceTM Core Collection (1981-present)
- BIOSIS Citation IndexSM (1985-present)
- CABI : CAB Abstracts® and Global Health® (1973-present)
- Current Contents Connect® (1998-present)
- FSTA® - the food science resource (1969-present)
- KCI-Korean Journal Database (1980-present)
- MEDLINE® (1950-present)
- Russian Science Citation Index (2005-present)
- SciELO Citation Index (1997-present)
- Zoological Record® (1993-present)

Literature review – grey literature

In addition to the peer-reviewed literature 'grey literature' sources were searched. These included:

- USA National Technical Information Service (NTIS)
- PubMed
- Bielefeld Academic Search Engine (BASE)
- COPAC (allows users to search the catalogues of ca. 90 libraries including the UK national libraries, University libraries, and specialist libraries)
- Royal Society of Chemistry
- Canada Institute for Scientific and Technical Information (CISTI)
- Barbour Food Safety Professional
- FAO – Codex Alimentarius
- US National Technical Information Service (NTIS)
- OpenGrey System for Information on Grey Literature in Europe
- Canada Institute for Scientific and Technical Information (CISTI)
- SciTech Connect (US Dept. of Energy)
- Lanl.arXiv.org (Quantitative Biology) (Cornell University)
- OAIster (Worldcat)

- IAEA INIS (International Atomic Energy Agency) International Nuclear Information System
- IAEA (NUCLEUS) Nuclear Regulatory Information
- Ipsum (UK Online Patent Information)
- Espacenet (European Patent Office)
- EPO (European Patents)
- USPTO (United States Patents)
- WIPO Patentscope (World Intellectual Property Organization
- Management and Business Studies Portal (BLDSC) (includes some marketing data)
- TMview (Trade Marks)
- Designview (Designs EU)
- DTIC (Defense Technical Information Center) (Military science multi-disciplinary technical reports)
- Google Scholar

Literature review search terms

The search terms were split onto four categories that fell under the headings; Chemical and environmental contaminants, natural toxins, processing contaminants and emerging contaminants. In each case covering all the individual food types of relevance that fell under the broad headings given by the FSS Tender call:

- Red meat and game
- Fish and shellfish
- Dairy products
- Oats / cereals
- Fruits and vegetables

So, for example, for the group red meat and game, additional terms including beef; lamb; pork; bacon; ham; offal; venison; rabbit; hare; quail; goose; duck; woodcock; pheasant; grouse; partridge were included to ensure any relevant publications would be found. The searches were separated by contaminant class to make the results more manageable as it was anticipated there would be a large number of results. For the same reason the search was limited to a 2 year period. A copy of the search terms used is given in Appendix 1.

Due to the global nature of food and feed production and distribution, the literature search was not limited to Scottish produce. Whilst there may be a greater prevalence of locally consumed food, the Scottish consumer has access to foods from around the world, particularly from other European countries, but also from third countries. Similarly, results relating to particular food contamination incidents from other countries were not excluded from the search on the basis that there may be a potential for similar incidents to occur in Scotland, or for lessons to be learnt from elsewhere.

A separate search was conducted including search terms for Scotland, in order to identify any contaminant issues that may be related to food produced in Scotland (and potentially exported) or for cases reported within Scotland that may be influenced by Scottish consumer habits.

Horizon Scan

HorizonScan is a commercial tool offered by Fera (and is a registered trademark of Fera Science Ltd.). It is a global database based on MySQL of raw material and commodity issues across all food integrity areas running from 1999. It combines data from worldwide systems such as the EU Rapid Alert System for Food and Feed, and food safety authorities' websites that publish recall and alerts on a regular basis to give a rapid overview of potential and emerging food safety issues. The current total number of records is around 100,000 with daily updates. Each record represents a new case reported on a specific health risk detected in one or more consignments of food. During the data entry process, reports are categorised based on the hazard, the commodity and the country of origin. HorizonScan has been interrogated for each commodity/commodity group previously detected as relevant for the Scottish population. Only chemical contaminants within the scope of this review are presented. Further searches specifically for Scotland were also carried out, but this resulted in very few additions.

After carrying out searches, the data were transferred to Microsoft Excel (version 2016) for visualisation.

The data reported were reviewed in terms of both chemical contaminant and food commodity and combined with the knowledge of exposure for the Scottish consumer.

Consideration of Scottish dietary habits, and impact on exposure

To assess differences between the Scottish and other UK diets, the most recent data were obtained from the National Diet and Nutrition Survey (NDNS). This rolling programme collected a stratified sample of continuous 3- or 4-day dietary consumption diary records from individuals in England, Wales, Northern Ireland and Scotland. To account for the pattern of non-response and the specific sample selection process, a sample weight was assigned to each individual. This weight expresses how representative each individual is within their country and when used in the analysis allows us to minimise any systematic bias. Adults and children can be considered separately.

In the assessment shown here, person level dietary summaries were used, as these include aggregated amounts consumed for individual food groups. These summaries have been pre-computed from the raw diary entries of all foods consumed. It was therefore not necessary to use separate recipe data to convert complex dishes into their constituent raw materials. Four raw files were obtained from the UK data service archive (www.ukdataservice.ac.uk) and modified for our analysis using the following steps:

Files (ndns_rp_yr1-4a_personleveldietarydata_uk.tab, ndns_rp_yr1-4a_indiv_uk.tab) were extracted for years 1-4, which correspond to 2008/9 – 2011/12 of the NDNS rolling program.

Similarly, Files (ndns_rp_yr5-6a_personleveldietarydata.tab, ndns_rp_yr5-6a_indiv.tab) were extracted for years 5-6 (2012/13 – 2013/14).

A re-weighting procedure was applied so that the years 1-4 and 5-6 datasets could be combined. This reweighting is exactly as described in the document accompanying the data release, and removes any bias caused by the different sample sizes in different years. The resulting combined sample, in combination with the modified weightings, was treated as a representative sample of the UK. The Scotland samples were labelled separately so that they could be compared against the other UK populations combined. The combined dataset comprises 9374 individuals (1858 from Scotland).

The total amount consumed per person, and per food type, was converted into a daily average. This took account of the number of diary days over which the individual recorded their food consumption (3 or 4 days).

Individuals and their dietary consumptions were linked, and each consumed amount divided by bodyweight. Bodyweight scaling is conventional in dietary risk assessment, and health-based guidance values (e.g. acute reference dose or average daily intakes) are typically expressed in terms of mg/kg-bw/day or other bodyweight scaled form. Some individuals had missing bodyweights in the NDNS. These were replaced by the appropriate average bodyweight of a corresponding child/adult and male/female.

Results

Scientific Literature review results

Searches were carried out over a few iterations to refine the search terms. Because of the decision not to restrict search terms to results with terms relating to Scotland, the output gave a large number of returns. In order to reduce this to a manageable size, it was also agreed with FSS that it was preferable to limit the search to a 2 year period (2016-2017) rather than to limit geographically or to limit further by contaminant category. A separate search using the term *Scot* was also used to find papers relevant to Scotland.

Once the searches had been finalised, and duplicates removed, the results were saved in EndNote files. These files were reviewed by Fera experts to remove any results that were not relevant, or that fell outside the scope of this review. For example, for natural toxins this included references for shellfish toxins or studies on the use of feed additives to reduce mycotoxin toxicity, or toxicological studies on the effects of mycotoxins on various animal species.

Even when limited to a 2 year period, the output from the literature search was too large to conduct a conventional review, paper by paper. Table 1 lists the number of results found for each group of search terms. The output had an emphasis on contaminant categories that were more established and where analysis and measurement techniques were widely available and less costly to conduct. Therefore, a more traditional systematic approach to reviewing the literature may have resulted in a bias towards legacy contaminants which was not the purpose of this exercise.

It was agreed with FSS that the approach to use for this review was to address the contaminant classes that had been agreed for the literature search, and to critique each class using the outputs from the search to support the discussion and any conclusions drawn. The literature search results were reviewed carefully for any papers that were of special relevance for Scotland, and if found would be reviewed in full. Even within the search specific for Scotland, the majority of the papers were not relevant and had been found as they contained a similar phrase, e.g. Nova Scotia.

Table 1 Outputs from the on-line literature searches

Search Group	Number results before review	Number results after review
Chemical & environmental contaminants	1568	555
Natural toxins	1430	466
Processing contaminants	471	298
Emerging contaminants	725	48

The results from the literature search are supplied as separate EndNote files. They contain the results from the full global search of scientific literature, the grey literature, and the third has terms for Scotland included. Note that the search that included terms for Scotland may have also identified other references where wording including '…Scot…' were present.

Grey literature review results

Using the search terms, and time frame agreed, the grey literature searches resulted in tens of thousands of results. An initial review found that many of the results were in fact from scientific and peer reviewed publications and were the same results as had been found in the other search. To reduce the number of results and avoid duplication, 'Google Scholar' was removed from the searches, and revised searches carried out. An emphasis was placed on ensuring that official publications, e.g. from EFSA, were included. The overall number of results was reduced from 3437 (where most were the same as the scientific literature results) to 78.

Results of review of consumption

The resulting consumption outputs are presented for individual food/drink groups as average grams per day per kg bodyweight. The results are presented in Appendix 3 and focus on those food groups likely to be important in exposure and risk assessments, taking account of the scenarios identified in the literature search and expert review. A risk assessment is primarily concerned with those individuals within a population receiving the highest exposures. We have selected an arbitrary high percentile (95th) in presenting the results. This represents a high consumer, within each of the food and country groupings shown, however mean values and the range are shown in Figure 1.

The focus is on differences between Scottish and other UK sub-populations for consumption of relevant food types.

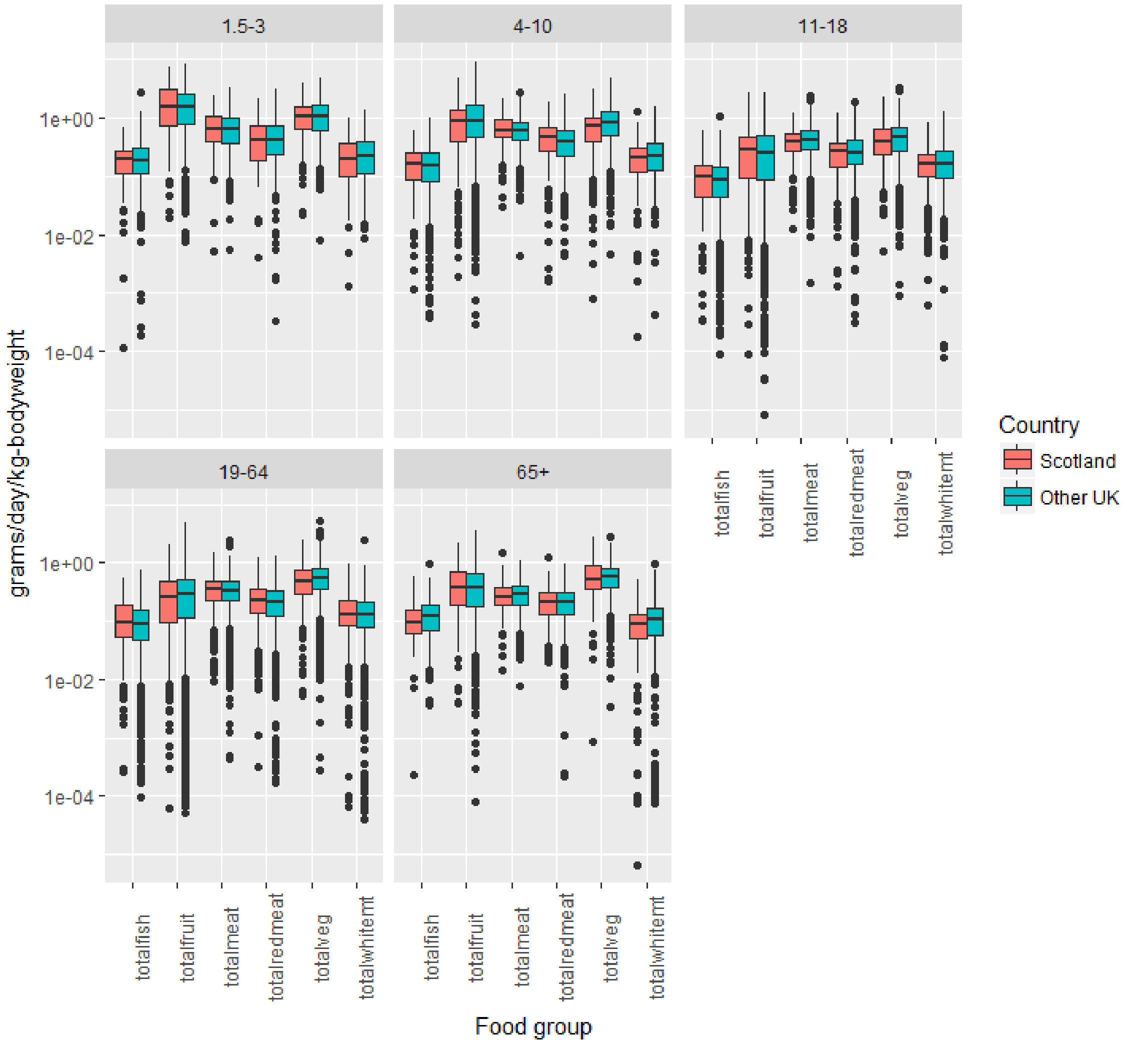

Figure 1. For non-zero consumers, differences in bodyweight-scaled consumption amounts between Scotland and other UK countries. Each age group is displayed in a separate panel. The boxes extend from the 25th to 75th percentile consumer, within which the median is shown as a horizontal bar. The whiskers extend 1.5 times the interquartile range and the points are amounts outside this range.

Table 2. 95th percentile values, compared by country and population group, corresponding to the general food groups plotted in Figure 1

Food type	**Adult (g/day/kg-bw)**		**Child (g/day/kg-bw)**	
	Scotland	**Other UK**	**Scotland**	**Other UK**

Fruit	1.09	1.05	3.13	2.81
Vegetables	1.24	1.28	1.76	2.00
Red meat	0.57	0.53	1.03	0.99
White meat	0.31	0.33	0.54	0.58
Meat	0.73	0.68	1.28	1.30
Fish	0.27	0.27	0.35	0.36

There was no indication that Scottish consumers' overall diets include more extreme amounts than the rest of the UK in any of these categories.

Information on the Scottish diet was also reviewed from foods and drinks purchased into the home in Scotland using data from Kantar World Panel (Food Standards Scotland, 2016). Using the contribution to total calories as an indication of consumption frequency, breads and morning goods were the group that made the largest contribution to overall calorie purchase, making up nearly 10% of the calories consumed. Biscuits, cakes and pastries, confectionery, crisps and savoury snacks and regular soft drinks were all within the top 20 food and drink categories contributing to total calorie purchase into the home, together contributing over 20% to overall calorie purchase (21.6%). Other top contributors were milk and cheese (8.8%), red meat and products (5.8%), yellow fats (5.4%) and savoury home cooking (4.4%). Other carbohydrate rich food (potatoes, breakfast cereals, other carbs and sugar) contributed a further 10% of calorie purchase and total alcohol contributed 4.2%. Another study to determine if nutritional aims were being met in the Scottish population found little change in dietary habits from 2001 to 2012. Total daily bread consumption gradually decreased over the period 2001 to 2012 (from 111g to 93.4g), such that the mean consumption in 2012 was significantly lower than that in 2001. This was accounted for by a steady decrease in white bread, however daily intakes of brown/wholemeal bread had increased. There were no real changes for consumption of the main groups (red meat, oil rich fish, fruit & vegetables, fat and fibre), although saturated fat and total sugar did decrease between 2001 and 2012. The subjects studied were, on average, eating 2-3 portions of fruit and vegetables a day compared to the recommended 5. It was also noted that in the most deprived areas there was higher consumption of total sugar and energy dense foods, while in the least deprived areas, fruit & vegetables, oil rich fish, fibre and saturated fat were consumed in higher amounts. There was no difference between the most and least deprived groups for red meat and fat intake (Food Standards Scotland, 2015a).

The above information indicates that, regarding food types, surveillance should be targeted to carbohydrate rich foods, including breads, cakes, pastries and snacks as they contribute a major part of the calorie intake of Scottish consumers, and therefore will presumably make the largest contribution to any possible chemical exposure, with milk and cheese and red meat and products ranked next, although this will also depend on the likelihood of the presence, concentration and toxicity of any potential contaminant.

Food industries of economic significance to Scotland

Turnover in food and drink in Scotland has risen by 44% since 2007 to over £14 billion (Scotland Food and Drink, 2017). Scotland's food and drink industry today is its fastest growing exports sector. Overseas Scottish food and drink exports were worth approximately £6 billion in 2017 - almost £570 million more than 2016. Food exports were valued at about £1.6 billion, up 15% (£214 million) from 2016. Fish and seafood accounted for the majority of Scottish food exports and were worth approximately £944 million, up 23% from 2016. Scotch Whisky exports also increased by around £356 million compared to 2016 to almost £4.4 billion (Scottish Government, 2018).

In addition, Scotland makes a major contribution to the UK exports of food and drink, worth £18 billion in 2015, with exports to over 200 overseas countries and territories. The top UK products for export are whisky, salmon, cheese, and lamb, all of which are produced in significant amounts in Scotland. Other UK exports significant to Scotland are cereals, animal feed, honey, beer, and gin.

Most economically significant foods produced in Scotland

The main Scottish food production sectors highlighted on the Scottish Development International website in the Trade Section are:

Bakery – Oats are used in breakfast cereal products (e.g. porridge) and also as an ingredient in bakery products (e.g. flapjacks or oat biscuits, traditional Scottish oat cakes, as well as increasingly in bread and rolls). They have seen an increase in popularity due to reported health benefits, and Scottish bakers supply this increased demand. Scottish bakery exports are valued at £100 million. Products very specific to Scotland, such as 'well fired rolls', 'rowies or butteries', Scotch pies and bridies, should be considered into any specific contaminant issues that may be associated with them. Cakes and treats such as Clootie Dumpling, black bun, Selkirk Bannock, Ecclefechan and Border tarts and their ingredients should also be considered in the context of this review; they all use dried fruit as a key ingredient.

Brewing – Scotland has several large breweries, but the majority are small-scale and craft breweries. The UK beer market is worth £2.2 billion.

Dairy – Scotland has over 9% of the UK dairy herd and produced 1.3 billion litres of milk in 2014. There are ~20 cheese producers across Scotland, ranging from large industrial cheddar creameries to independent artisan and farmhouse cheese makers. Cheddar cheese is the main product in Scotland, which accounts for 70-80% of the total output. Scottish dairy exports grew by 41% between 2012 and 2013. The main export market is the EU, which was worth £67.56 million in 2013, especially France, Belgium and the Netherlands (Food and Drink Scotland, 2017).

Distilling - Over 70% of gin made in the UK is branded as Scottish (although the spirit itself is not necessarily produced in Scotland) (Sunday Herald, 2017), and two of the major UK brands of vodka are produced in Scotland. There has been a huge increase in UK gin sales, with 47 million bottles sold in 2017; UK gin sales have doubled in value in the last six years reaching £1.2bn in the 12 months to the end of September 2017 (The Guardian, 2017).

Honey - Scottish honey, and in particular heather honey, is highly valued. Sugar & honey (as a group) Scottish exports were valued at £23 million in 2017, although no breakdown of the relative amounts was given (Scottish Government, 2018).

Red meat – Combined beef, lamb and pork production in Scotland was over 200,000 tonnes in 2016 generating revenue of £818 million. Scottish meat is known for its high quality and therefore value, and Scotch beef and lamb were among the first European red meat products to receive Protected Geographical Indication (PGI) status in 1986.

Salmon - Fresh Scottish salmon is exported to over 60 countries worldwide, with a value of over £600m. It has Protected Geographical Indication (PGI) status granted by European authorities and was named 'Best farmed salmon in the world' by international seafood buyers, 2011 (Scottish Development International, 2018).

Seafood – Scottish seafood is exported to over 100 countries. Two-thirds of the world's langoustine are sourced in Scotland. The top species in Scotland are: cod, crab, haddock, herring, langoustine, lobster, mackerel, monkfish, whiting and scallops as well as wild and farmed mussels and oysters (https://www.sdi.co.uk/trade/sectors/food-and-drink/seafood).

Seaweeds - Scottish seaweeds production has increased; seaweed is known as 'the superfood of the sea', containing 56 essential vitamins and minerals. Currently seaweed is wild harvested, but three experimental or pilot 'seaweed farm' sites have been established (http://www.netalgae.eu/uploadedfiles/DUNNINGHAM_J_&_ATACK_T_(EN).pdf). It is a growing market and the Scottish Government published its Seaweed Cultivation Policy Statement in 2017 (Scottish Government, 2017).

Soft fruits - Scotland is a market leader in soft fruits; the value of Scottish fruit and vegetable exports was £62 million in 2017.

Whisky - With global export sales of nearly £4.4bn in 2016, Scotch whisky makes a major contribution to UK food and drink exports.

HorizonScan Outputs

Searches were carried out for chemical contaminants in the following food groups (global search):

Fish (fresh/frozen), Fish (smoked/cured/dried), Crustaceans, Bivalve molluscs

Beef, Lamb, Deer, Poultry and Poultry products

Cheese, Honey, Spirits and Liqueurs

Fruit and vegetables

Cereals and Cereal products

Seaweed, Algae, Carrageenan

It should be noted that the search only allows discrimination between chemical and microbiological contaminants, therefore some groups of chemicals outside the remit of the exercise (e.g. residues of pesticides or veterinary medicines, presence of shellfish toxins or foreign bodies) will be reported in the outputs.

Outputs for some of the main food categories important to Scotland are given below, with summaries of the findings. Not all searches are presented here, however the charts and tables are all available as supplementary information.

A separate search for issues concerning products exported from/produced in Scotland returned 44 results. The majority (42/44) related to microbiological incidents. Of the other 2, one related to a high sulphite content found in scampi and the other was a report of a radioactive source found in Dalgety Bay mussel beds.

The following reports give highlights of the most frequently reported chemical hazards for food products that are important to Scotland, although none of the reports were found to involve Scottish produce.

Fish (fresh/frozen)

Mercury was the most commonly reported hazard, with 1303 reports over the last 10 years. More details about mercury in fish can be found in the section on mercury (Appendix 3), but the most frequently reported species were swordfish (from Europe and Asia) and shark, so although not of concern to Scottish production, will be relevant for Scottish consumers of imported products. Histamine was next most frequently reported hazard (although outside the scope of this study) with 411 reports.

These results were used to inform the types of hazards to search for in the literature search.

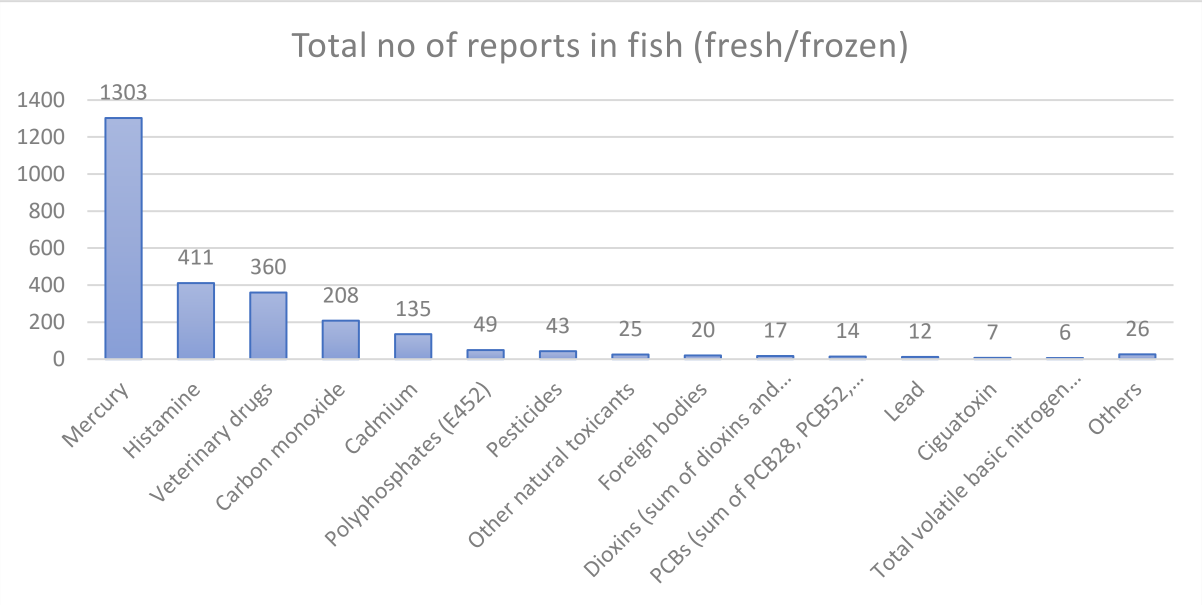

Figure 2. HorizonScan outputs for Fish – Fresh/frozen, total reports for chemical contamination = 2636.

Fish – smoked/cured/dried

Review of individual reports showed the main species affected were tuna, catfish and sardines. Reports were mainly from Asia, Africa and Eastern Europe, no reports related to Scottish products, either because no issues were detected, or Scottish products were not selected for testing. There were 119 reports for histamine (27 % of reports for smoked/cured or dried fish). Histamine was reported in several different fish products including anchovy fillets, sardines, tuna, and mackerel and is outside the scope of this study.

Other than histamine, Benzo(a)pyrene (BaP) and PAH 4 were the most frequently highlighted issues for smoked/cured/dried fish, with a total of 167 reports. The occurrence of PAHs in fish products is mostly due to formation of PAHs during smoking and direct drying and is dependent on a number of variables, including:

fuel (woods and other plant materials, diesel, gases, liquid/solid waste and other fuels); smoking or drying method (direct or indirect); the distance between the food and the heat source; fat content of the food and what happens to it during processing; the duration of smoking and design of the equipment (Codex, 2009). More details about the specific risks and products associated with PAHs can be found in the section on PAHs.

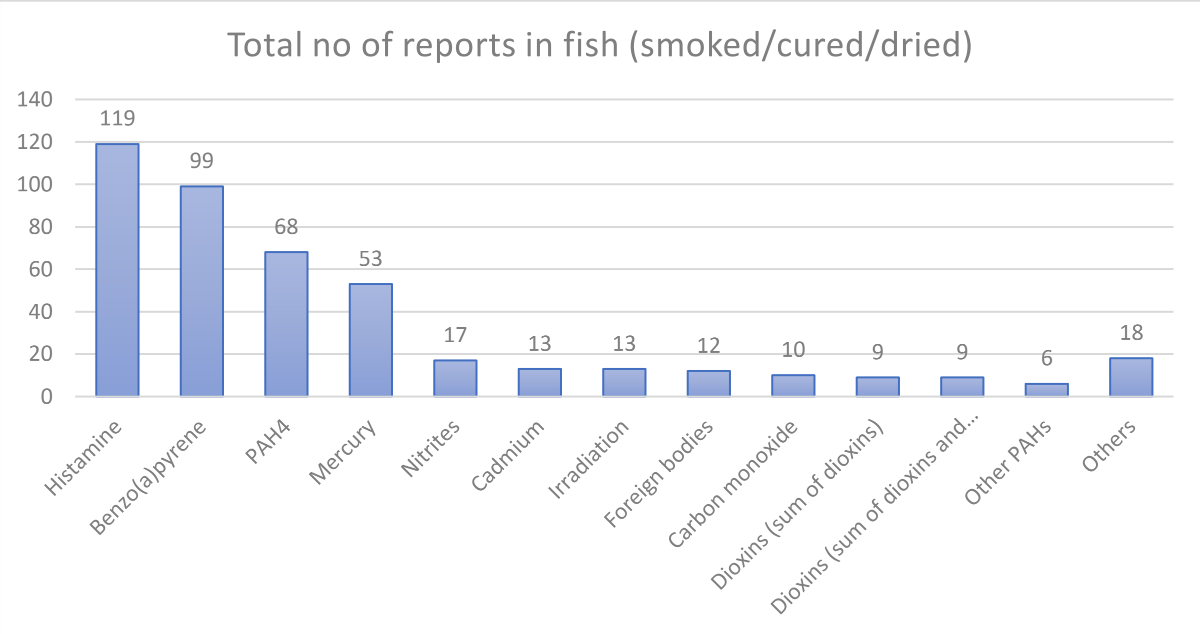

Figure 3. HorizonScan outputs for Fish – smoked/cured/dried, total reports for chemical contamination = 446.

Crustaceans and Bivalve molluscs

After residues of veterinary medicines and presence of sulphur dioxide, cadmium was the most frequently reported hazard for crustaceans. Other metals, mercury and lead, were also reported. There were 383 reports for bivalve molluscs, the majority (286) related to shellfish toxins; cadmium was reported 45 times and lead 5 times. There were no reports for Scottish products in HorizonScan. This could be because no samples were analysed (e.g. Scottish produce is not viewed as high risk during EU trade) or because no issues were detected. Chemical contaminant sampling and analysis of shellfish carried out for Food Standards Scotland found a small number of MPL exceedances for PAHs and cadmium, which on second sampling were below the MPL (Food Standards Scotland, 2014 and 2015). Scotland's Marine Atlas in 2011 reported that trace metal concentrations in sediments were highest in the Inner Firth of Clyde and the Forth estuary and Firth of Forth. The trace metal concentration of coastal sediments was low. The data highlighted an interesting contrast in copper and zinc concentrations in mussels and sediments between the Forth and Clyde Estuaries. Concentrations of these metals are higher in sediments in the Clyde than in the Forth, but higher in mussels in the Forth compared to the Clyde. This may be because the Forth is a more turbid estuary due to the stronger tides which mix the sediments into the water column, resulting in particulate bound metals being more available to filter feeders such as mussels (Scottish Government, 2011).

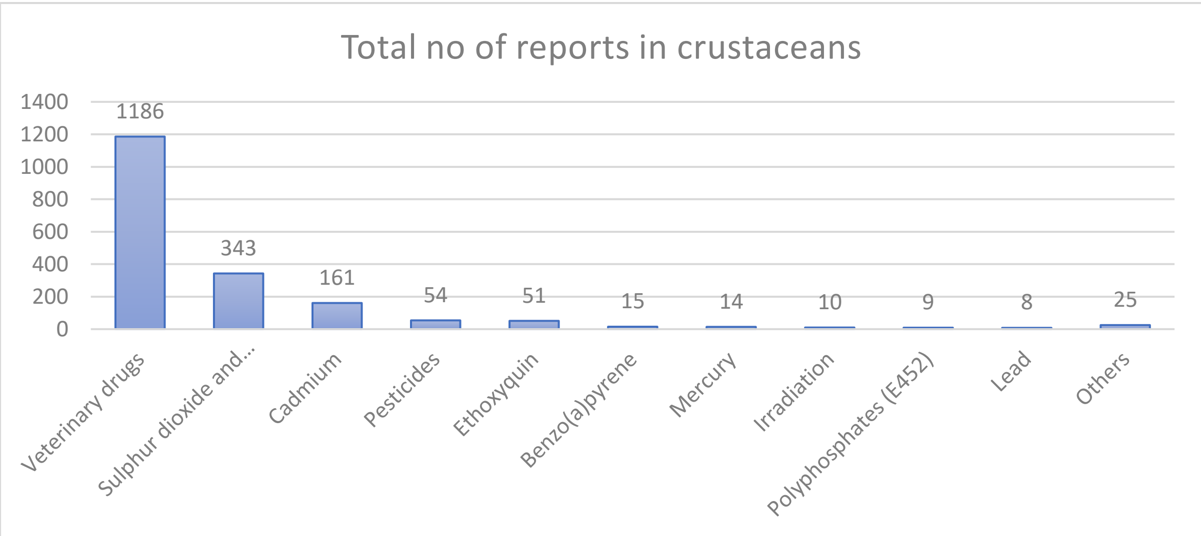

Figure 4. HorizonScan outputs for Crustaceans, total reports for chemical contamination = 1876.

Red meat (beef, lamb and venison)

The majority of reports for beef were for residues of veterinary medicines. For lamb there were 12 reports in total, 2 were for dioxins and PCBs. For deer (venison), there were 6 reports in total, 2 were for lead. None of the reports related to Scotland or Scottish produce.

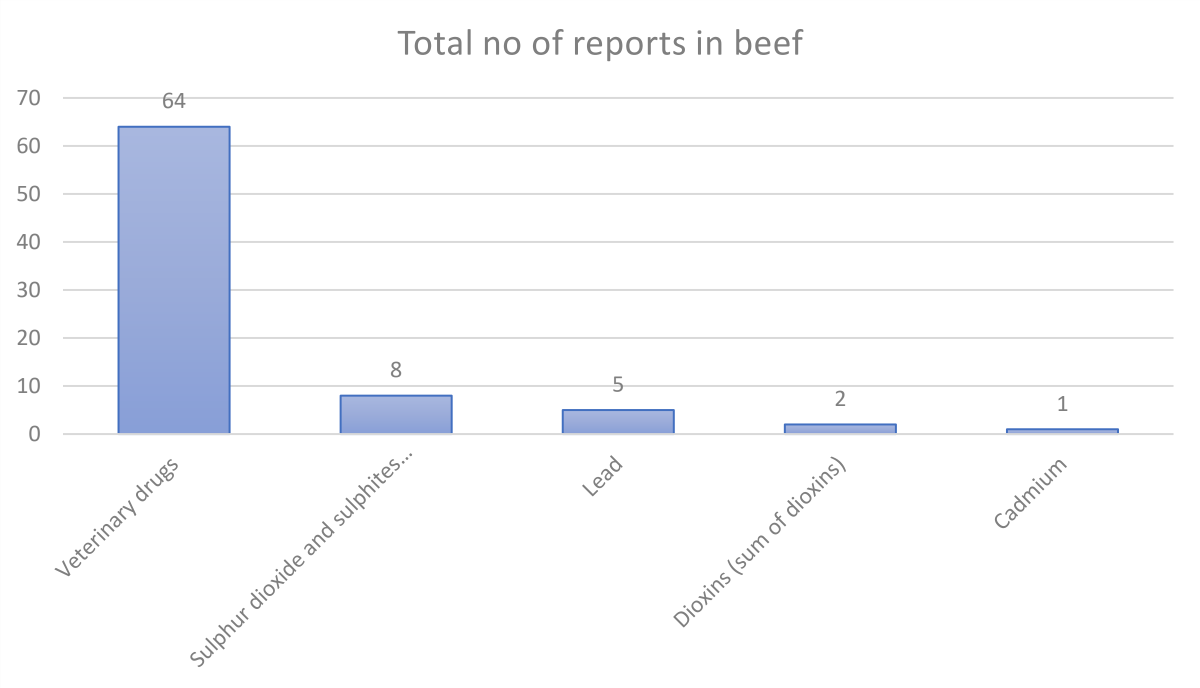

Figure 5. HorizonScan outputs for beef, total reports for chemical contamination = 80.

Cereals and cereal products

The majority of reports for cereal products for chemical contamination were for aflatoxins and pesticides, followed by other mycotoxins, (e.g. OTA, DON), natural toxins (atropine and HCN) and some metals (aluminium, lead and cadmium).

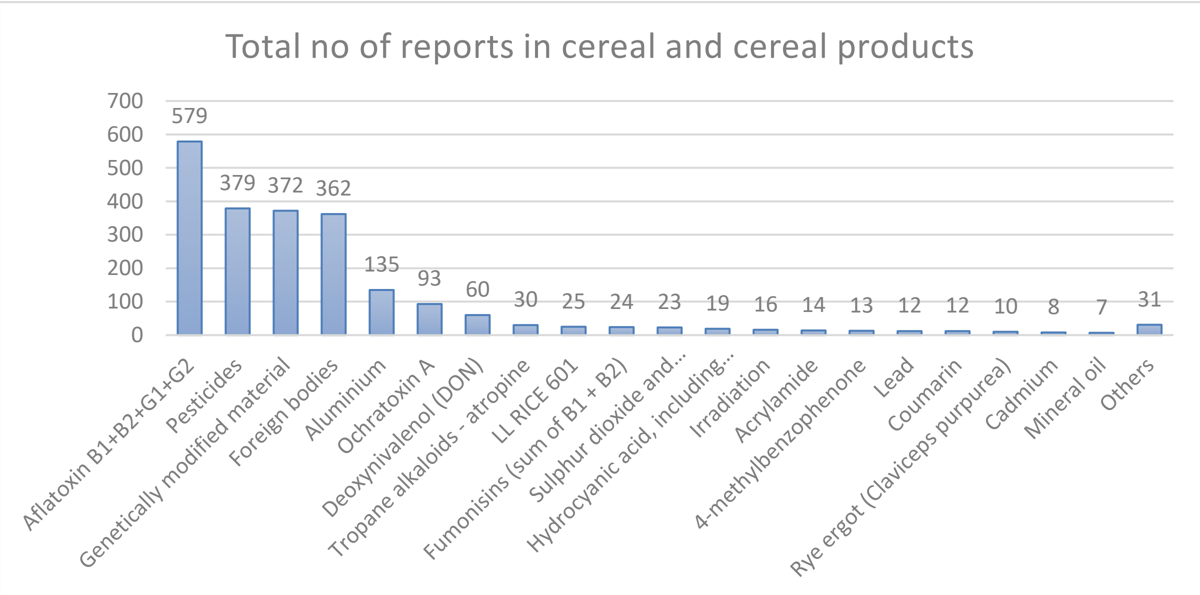

Figure 6. HorizonScan outputs for Cereals and cereal products, total reports for chemical contamination = 2224.

When the groups were refined further the range of contaminants in different products is more apparent. Mycotoxins (deoxynivalenol (DON), OTA and aflatoxins) were the most commonly reported issues for wheat. There were only 6 reports for oats, 2 for cadmium and 1 each for DON, OTA, pesticides and foreign bodies.

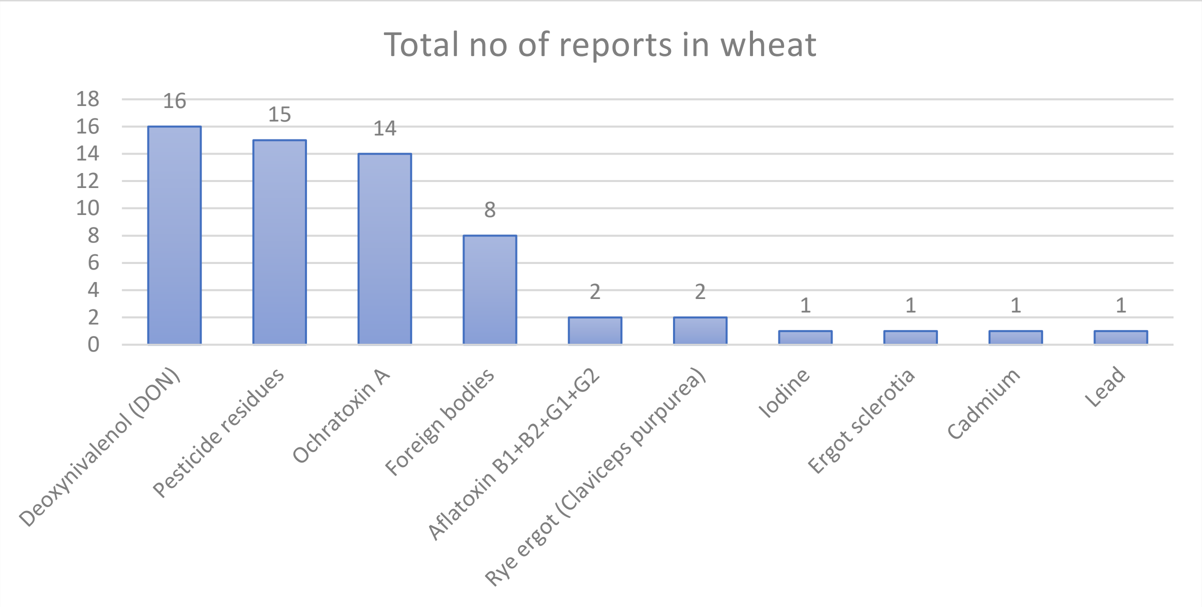

Figure 7. HorizonScan outputs for Wheat, total reports for chemical contamination = 61.

For pastries, biscuits and cakes the most frequently reported chemical contaminants were aflatoxins (from ingredients, either cereal, nuts or dried fruit), hydrocyanic acid (cyanide) found in amaretti biscuits from Italy and macaroons (various flavours) from France and acrylamide which is formed as a result of the baking process. There were also 4 reports each of mineral oil and coumarin. Mineral oils may come from many sources, whereas coumarin is a natural constituent of cinnamon and cassia that is also widely used as an alternative to cinnamon.

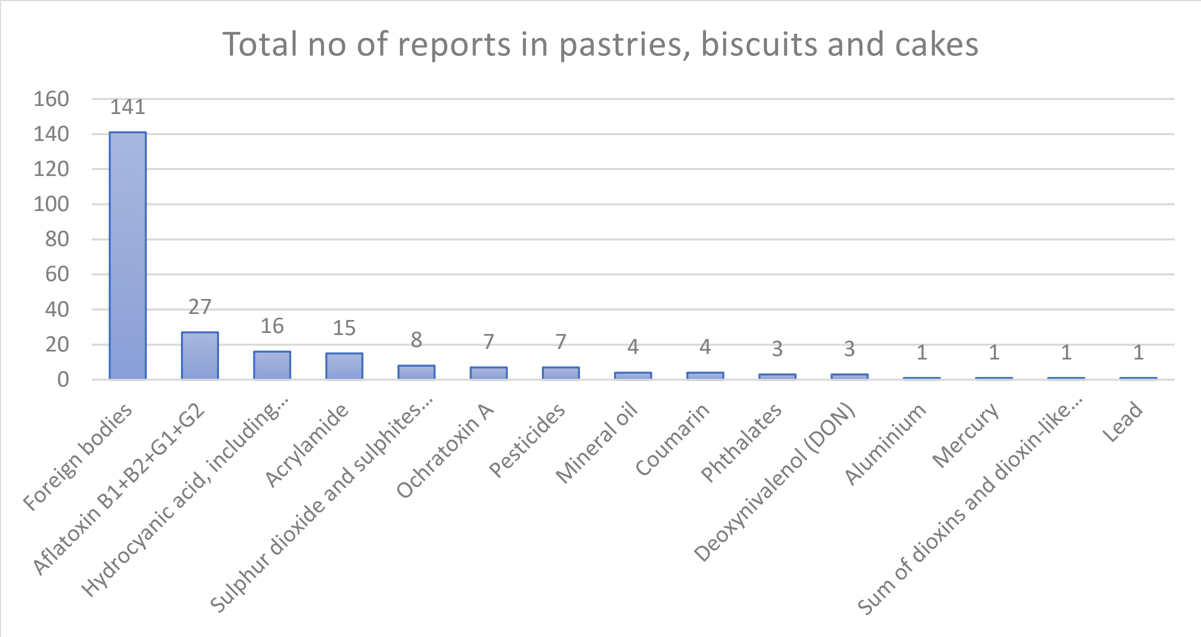

Figure 8. HorizonScan outputs for pastries, biscuits and cakes, total reports for chemical contamination = 239.

Fruits and vegetables

There were thousands of reports for the overall category fruit and vegetables, the majority were for pesticides (Figure 9). Of 35 reports for potatoes, there were 21 reports for pesticides (various countries including UK, Cyprus, and The Netherlands) and 4 reports for aluminium (all China). When this was refined to dried fruit and vegetables a range of other contaminants becomes more apparent. The highest number of reports were for mycotoxins (aflatoxins and OTA), but other contaminants such as lead, PAHs and mineral oil have also been reported.

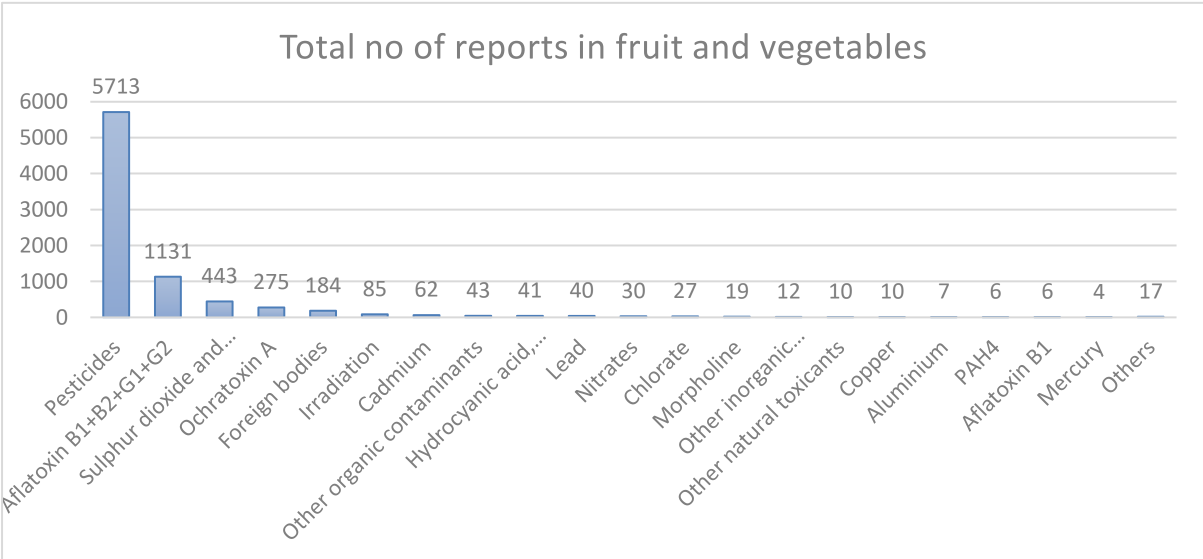

Figure 9. HorizonScan outputs for dried fruit and vegetables, total reports for chemical contamination = 8165

Seaweed, algae and carrageenan

The majority of reports were for iodine. Arsenic, cadmium and aluminium were also reported. None of the reports were for Scottish products. Levels of metals in Scottish estuaries and coastal waters have been found to be low compared to Environmental Quality Standards. Mercury concentrations were below the limit of detection (10 ng/L), but slightly elevated concentrations of cadmium, copper and zinc occurred at the highest concentrations in the Clyde and Forth estuaries (Scottish Government, 2011).

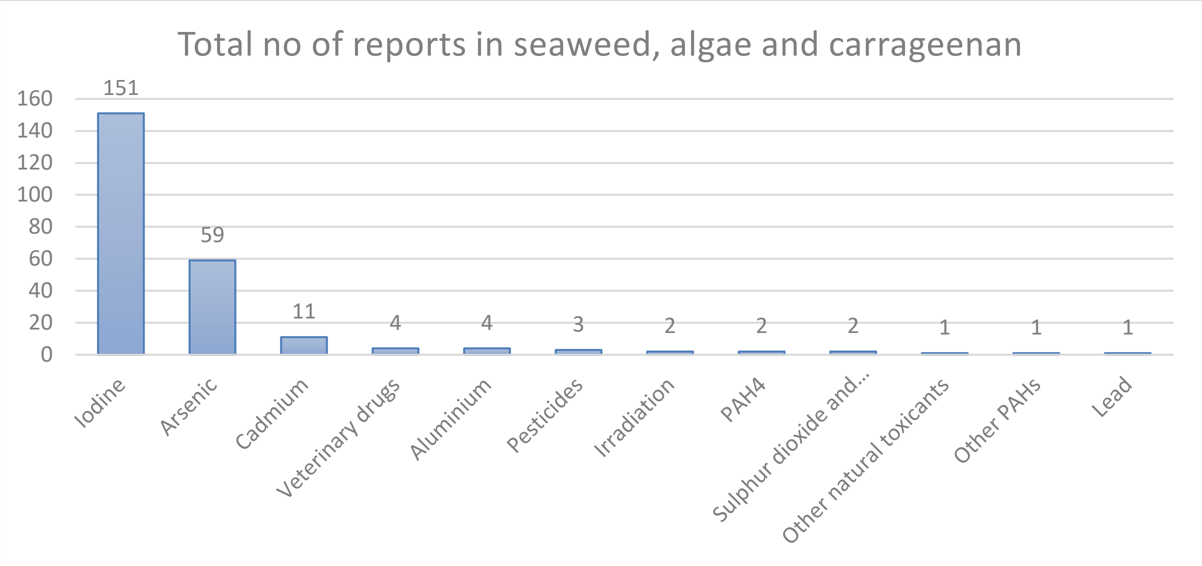

Figure 10. HorizonScan outputs for Seaweed, algae and carrageenan, total reports for chemical contamination = 241.

Spirit drinks and liqueurs

Whisky is the most important commodity for Scotland in terms of value, but it was not possible to obtain a report for this. The group 'spirit drinks and liqueurs' had very few reports overall and only a minor number were for chemical contaminants.

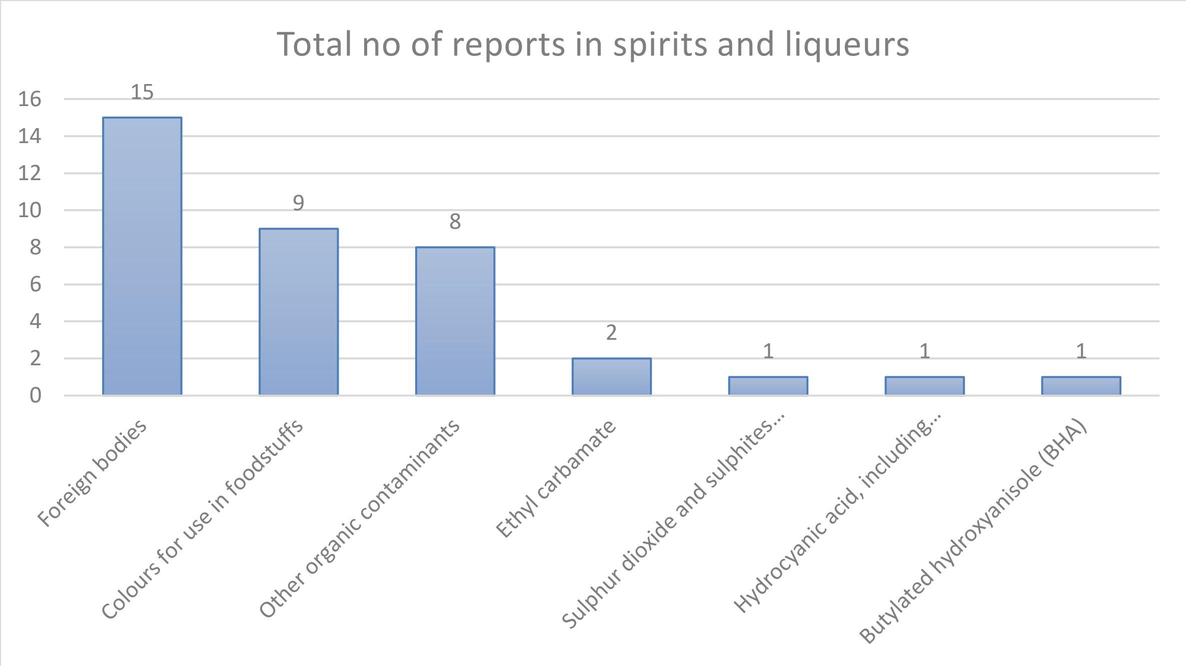

Figure 11. HorizonScan outputs for spirit drinks and liqueurs, total reports for chemical contamination = 37.

Contaminants issues: Global, European and UK level – summary of evidence

The major contaminants identified are summarised with data on the number of publications found, particular relevance for Scotland (intake or food production), as well as a summary of reported incidents found for these contaminants from HorizonScan over the last 10 years.

The main classes of compounds reviewed are:

- Anthropogenic i.e. industrial pollutants such as dioxins and PCBs
- Processing contaminants, e.g. acrylamide, 3-MCPD, furan.
- Natural toxins, i.e. mycotoxins and plant toxins
- Emerging contaminants, e.g. nanomaterials and microplastics

Results from Scottish Local Authority Sampling for 2015-16 and 2016-17 have also been considered as part of this review. The sampling carried out for these studies is targeted based on previous results and to address specific requirements outlined by FSS as part of the Sampling Grants Programme. When considering sample numbers, it should be borne in mind samples may undergo a number of different tests. In 2015-16, 3698 chemical tests were carried out, 811 were for ‘undesirable substances’, this included PAHs and tropane alkaloids. During 2015/16 a total of 155 samples were tested for the presence of acrylamide, of which 22 (14%) exceeded the Indicative Value. The highest number were from bakery and cereal products (19 samples, of which 8 were described as ‘well fired’). The other 3 results were from potato crisps (1 sample) and takeaway potato chips (2 samples). None of the 811 samples tested for the presence of undesirable substances were found to be non-compliant with EU legislation, although the report does not give detailed information about all the analyses carried out (UKFSS, 2016). At the time of writing the report for 2016/17 was not available, but the data were reviewed. There were over 3000 results for ‘undesirable substances’, but many of the tests carried out will have given multiple results (e.g. aflatoxins B_1, B_2, G_1 and G_2 in one test), so the sample numbers cannot be compared yet with 2015/16. Overall there were no significant findings of chemical contamination in the samples tested; a wide range of contaminants such as metals, mycotoxins, nitrate and nitrite and Sudan dyes as well as pesticides and veterinary drugs were included in undesirable substance sampling and analysis. There were single incidences of unsatisfactory results for histamine, aflatoxin B_1, zearalenone, nitrite, iron and sodium. Again, acrylamide produced the highest proportion of exceedances, with 52 out of 196 samples (26.5 %) exceeding the Indicative Value (UKFSS, 2017).

There are some gaps in the contaminants analysed in the UKFSS samples, for example there are no data on environmental contaminants including dioxins, PCBs, and other Halogenated Persistent Organic Pollutants (POPs), and PAHs. New regulations have been introduced for hydrocyanic acid in apricot kernels, and glycidyl esters in oils and fats and infant formula and MCPD and there are no data on their occurrence within the UKFSS dataset. Ongoing discussions are taking place in Europe on MCPD esters and for the introduction of limits for ergot alkaloids and pyrrolizidine alkaloids; there is limited data for these compounds from within the UK, and none in the UKFSS dataset. Since starting this review EFSA have published a call for data where gaps in occurrence data have been identified for a range of contaminants listed below:

Process Contaminants

Furan, 2-methylfuran, 3-methylfuran and 2,5-dimethylfuran; Acrylamide; PAHs; 3-MCPD, 3-MCPD esters and Glycidyl esters; Ethyl Carbamate.

Organic contaminants

Dioxins and PCBs; Non dioxin-like PCBs; Brominated Flame Retardants; PFAS; Chlorinated Paraffins; Mineral oil aromatic hydrocarbons; Melamine and analogues; Benzene

Inorganic

Nitrates; Cadmium; Lead; Arsenic (inorganic and total); Mercury (methylmercury and total mercury) in food; Fluorine; Nitrates and Nitrites in feed

Mycotoxins

Aflatoxins (B_1 in feed, B_1, B_2, G_1 and G_2 and Total in food, M_1 in dairy); Ochratoxin A; Deoxynivalenol (and acetylated derivatives and DON-3-glucoside); Zearalenone; Fumonisins; T-2 and HT-2; Nivalenol and modified forms of all of these;

Alternaria toxins (alternariol, alternariol monomethyl ether, tenuazonic acid, tentoxin); Patulin; Ergot alkaloids; Enniatins; Sterigmatocystin; Beauvericin; Citrinin; Moniliformin; Diacetoxyscirpenol; Phomopsins

Plant toxins

Opium alkaloids; Quinolizidine alkaloids; Pyrrolizidine alkaloids; Glucosinolates; Glyco-alkaloids; Tropane alkaloids; Hydrocyanic acid; Erucic acid;

Specific for feed - Free gossypol; Theobromine; Ricin, Abrin, Crotin I (EFSA, 2018).

These data are needed by EFSA to inform risk assessments and to carry out exposure calculations. With the exception of acrylamide, some mycotoxins, metals and nitrate/nitrite, none of these requested analytes have been included in the UKFSS sampling. Some of these compounds are not of specific relevance for average Scottish consumers or producers, e.g. some of the mycotoxins, such as fumonisins that occur mainly in maize, and phomopsins that occur in lupin seeds and products made from lupin flour, although they may be significant for those on restricted (e.g. gluten free diets). However, the process contaminants such as furans that occur in cereal products, potato products and baked and fried goods and organic and inorganic contaminants that can occur in a range of foods including fish, seafood, meat, seaweed are of significance when Scottish diets and food production are considered.

Specific information for chemical contaminants class by class

Regulations for Contaminants

Currently contaminant levels in food and feed are controlled by a series of European Regulations, Directives, Decisions, Recommendations and Guidance. These are regularly updated with amendments when new evidence, e.g. toxicological data, exposure data or incidence data, becomes available. A list of relevant legislation is given in Appendix 2.

Contaminant classes reviewed

Background information on the main classes of contaminants included in this review is given here. Detailed information about the main contaminants reviewed in this study is given in Appendix 3.

Heavy metals and trace elements

General:

Heavy metals as food contaminants are a well-established and well-studied area, and as expected there were a large number of references for this topic found in the literature search. Heavy metals can arise in food as a result of the geology of the area in which it is produced, or as a result of anthropogenic activity. Any specific areas of Scotland known to have toxic elements as part of its geological make up should be assessed for potential for incorporation into food produced in those areas, as already identified by the FSS Chemical Contaminants Strategy (Food Standards Scotland, 2018). Metal-bearing solids at contaminated sites can originate from a wide variety of anthropogenic sources in the form of metal mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and lead-based paints, land application of fertilizer, animal manures, biosolids (sewage sludge), compost, pesticides, coal combustion residues, petrochemicals, and atmospheric deposition (Wuana and Okieimen, 2011).

This review focusses on elements generally recognised as toxic, and areas that are of specific interest to the Scottish economy and more particularly to the Scottish consumer.

The heavy metals usually considered as a toxic risk include those such as lead, cadmium and mercury, and exposure should be minimised. The same is said for arsenic which is a trace element but not a heavy metal. These compounds are regulated by European legislation (European Commission, 2006). Other trace elements such as iron, zinc and manganese are generally regarded as nutritionally beneficial. The health effect of metals and trace elements can vary according to the oxidation state. There is a third category where exposure at high levels can have adverse health effects, but insufficient quantities in the diet can result in poor nutrition, in turn leading to adverse health effects. This class includes selenium, iodine and copper. Given the focus of this review, it is the first category of toxic elements that are the focus of this report. Commission Recommendation (EU) 2018/464 on monitoring metals and iodine in seaweed should be taken into consideration.

Scotland's Soil Resource - Current State and Threats gives an assessment about the metal content in soils in Scotland (Scottish Government, 2006). In summary it stated some metals can occur naturally, while heavy metals from atmospheric depositions were generally low and predicted to decline. Use of organic wastes and sewage sludge were identified as sources of heavy metal inputs to soil. Their use was projected to continue. Sewage sludge application is regulated and it was recommended a similar framework be considered for other organic wastes (Scottish Government, 2006).

Speciation

Much of the published data for metals in food or feed are based on total element concentrations in a given food. In addition to its oxidation state, metal speciation can be an important factor with regards to health effects. Methylmercury is more toxic than elemental mercury, yet organic forms of arsenic such as arsenobetaine are usually considered less toxic than elemental arsenic.

For the large number of elements that are not discussed in the sections below, no specific concerns relating to Scotland only were identified.

Persistent organic pollutants

Chemicals that fall into this class in general, are characterized by the properties of bioaccumulative potential (i.e. they are found at higher concentrations at higher trophic levels of the food web), environmental mobility (they undergo long-range transport), persistence (i.e. they are stable and do not readily degrade in the environment), and toxicity (i.e. they are harmful to living organisms).

Some of these chemicals have been placed on the Stockholm persistent organic pollutants (POPs) register (http://www.pops.int). Originally, they were limited to 12 classes of chemicals, but this has been extended, and there is potential for further increase. Commission Regulation (EC) No 1881/2006 and amendments specifies limits for dioxins and PCBs.

Natural Toxins

These are toxins that occur naturally in food or feed. There are three main classes; mycotoxins (fungal toxins), phytotoxins (plant toxins) and shellfish toxins. Shellfish may ingest algae and accumulate their toxins, leading to shellfish poisoning, these toxins are not included in the scope of this study.

Mycotoxins are produced by moulds growing on food commodities under certain conditions. They can be formed pre-harvest (i.e. in the field during the growth of the food), or they can occur post-harvest, as a result of poor storage conditions e.g. storing cereals with too high water content; lack of control in drying processes, drying grapes to produce sultanas and raisins; or during transportation, e.g. inside metal shipping containers subject to large temperature changes resulting in condensation. Some mycotoxins are more likely to be formed in tropical, warmer climates e.g. aflatoxins and fumonisins and these pose a greater hazard in imported foods, while others like OTA, DON and T-2 toxin are formed in the UK and are an issue for home grown crops.

Plant toxins are found in a range of plants, many of which are common weeds, such as ragwort or groundsel. They can occur in plants from all over the world; many of the compounds have known pharmacological effects and are used in medicine, e.g. atropine, morphine. There are issues with these compounds being found in food from a number of sources e.g. morphine in poppy seeds; accidental contamination of crops with weeds due to poor horticultural practice or possibly substitution for financial gain are examples. There has also been an increase in different uses for plants that were not previously used as foods to prepare herbal teas and dietary supplements that can result in exposure to some plant toxins.

Regulation (EC) No 1881/2006 and amendments sets maximum limits for:

- mycotoxins - aflatoxins, OTA, citrinin, patulin, fumonisins, DON, ZON and ergot sclerotia and;
- plant toxins - erucic acid, tropane alkaloids (atropine and scopolamine) and cyanogenic glycosides.

Limits for ergot alkaloids and pyrrolizidine alkaloids are under discussion. Commission Recommendation 2013/165/EU gives ‘Indicative Levels’ for the sum of T-2 and HT-2 toxins.

For animal feed, the main legislation is Directive 2002/32/EC on undesirable substances in animal feed (consolidated version 27/12/2013); also of relevance are Commission Recommendation 2006/576/EC on the presence of DON, ZON, OTA, T-

2 and HT-2 and fumonisins in products intended for animal feeding and Commission Recommendation 2006/583/EC on the prevention and reduction of Fusarium toxins in cereals and cereal products.

Processing Contaminants

Processing contaminants are chemicals that are formed in foods as a result of some process that the food has undergone. Usually this involves heat treatment or cooking of some kind but that is not always the case as other processes such as fermentation can also produce processing contaminants. Examples of processing contaminants include acrylamide, 3-MCPD, glycidyl esters, furan and ethyl carbamate. PAHs may also be considered processing contaminants when they occur as a consequence of drying or smoking food. PAHs, MCPD, glycidyl fatty esters, and nitrate is included in Regulation (EC) No 1881/2006.

In April 2018 Commission Regulation (EU) 2017/2158 came into effect. This regulation establishes best practice, mitigation measures and Benchmark Levels (BMLs – previously termed Indicative Values) for the reduction of the presence of acrylamide in food.

Emerging issues

Climate change

The IPCC (Intergovernmental Panel on Climate Change) Definition of Climate Change is “any change in climate over time, whether due to natural variability or as a result of human activity”. The impacts of climate change as a result of increasing average temperatures can include more variable rainfall, rising sea levels, warmer oceans, more forest fires and more extreme events such as floods, storms, cyclones, droughts and landslips.

The Cohort of Presidents, Vice-Presidents, Prime Ministers and cabinet members of 9 small islands developing states at the UN Climate change conference, COP23 in Bonn, November 2017, stated that Climate Change was an ‘alarming threat’ to food safety and security.

Increased flood events may result in mobilisation of contaminated agricultural soils and industrial sites as evidenced in Europe (Lake et al, 2011, 2014 and 2015) and following global extreme weather events such as hurricanes. Warmer oceans enhance the methylation of mercury and the subsequent uptake of methylmercury in fish and mammals, thus increasing human dietary exposure to toxic methylmercury. Evidence supports that Climate Change is changing natural biological systems and increasing the uptake of heavy metals into the food chain. Increased forest fires are resulting in increased formation and mobilisation of environmental contaminants (PAH, dioxins and mercury). There may be an increased need to reuse water for crop irrigation which in turn may result in more contaminants being applied to soil/crops, although there is a European Commission proposal from May 2018 on new rules to stimulate and facilitate water reuse, that includes minimum requirements for water reuse (EC

Europa, 2018). Intensified cropping demands more fertilizer and organic waste use e.g. biosolids, application of some organic wastes such as pig slurry or sewage sludge can add heavy metals to soil, although heavy metal addition by sewage sludge to agricultural soil is regulated (Scottish Government, 2006). Flooding can increase mobilisation of 'legacy' contaminants from polluted rivers and waste sites (Thomson and Rose, 2011).

The issue of Climate Change is also important for mycotoxins and two studies have applied models for cereals grown in Europe. Results from the first study (Van der Fels-Klerx et al. 2016) showed DON contamination in wheat is likely to rise, however there is a large degree of variability associated with this. Research gaps were identified related to the limited number of models for Climate Change and their validation. The second study looked at aflatoxins, with a predictive model suggesting aflatoxin B_1 is likely to become a food safety issue in maize within Europe, if the likely predicted scenario of a +2ºC increase in temperature occurs (Battilani et al, 2016). It seems likely that Climate Change will have an impact on the frequency and concentrations of mycotoxins. The European Commission are considering Climate Change in their 'Comprehensive strategy' for mycotoxin measures, where they include prevention, mitigation, detoxification and regulation as part of a combined approach to control mycotoxins going forward (Frans Verstraete, presentation 2017). There is an acceptance that mycotoxins may increase and strategies are required on how to deal with this, whether it is trying to find more resistant crops (prevention), use of mycotoxin binders and other products or alternative uses for contaminated crops (mitigation), or the development of detoxification processes, in which case these must be defined and acceptability criteria developed.

Another consideration is the potential impact from the proposed EU ban of certain plant protection products. Up to 61 active substances may be lost, including triazole fungicides that are used to control Fusarium Head Blight (FHB), as they fall within the definition of being an endocrine disruptor. The impact of this is not fully understood but will leave farmers with fewer options to control plant diseases, most significantly on wheat and other cereals, other crops that could be affected include oil seed rape, and some fruit and vegetables. Ironically reduction in use of fungicides on cereals could result in more contamination from mycotoxins, some of which are endocrine disrupting.

One option may be to move to organic farming practices. In many cases there are no differences for mycotoxins in cereal crops; if anything, DON levels are lower and there is little difference for others. Many cereal varieties used in organic farming have been shown to have greater resistance to fungal infection and have resulting lower mycotoxin concentrations (Edwards and Jennings 2016). A review of studies comparing the content of several mycotoxins in different products found no significant difference or lower levels of DON, ZEN and HT-2 and T-2 toxins in organic cereals. Weather conditions, year, location, crop rotation and tillage practice were all thought to be more important for DON development than organic farming *per se*. Some studies showed higher patulin levels in organic produce, possibly due to better disease control in conventional orchards (Brodal et al. 2016).

It is recognised by most authorities that Climate Change is a global concern, and not particularly related to the Scottish consumer, however it is most likely to have an impact on cereal growing, and any industries that rely on the sea, including fishing, aquaculture and seaweed cultivation.

Microplastics

In 2016, EFSA published a statement on the 'Presence of microplastics and nanoplastics in food, with particular focus on seafood' (EFSA, 2016a). There have been a number of scientific publications on microplastics since this was published, and the number of new publications is increasing at a spectacular rate; nevertheless, the EFSA Opinion describes the issues, particularly in relation to food very well. The presence of microplastics and nanoplastics in food is a particular problem for seafood because so much plastic ends up in the oceans and these form a source for not only primary sources i.e. those plastics which are manufactured and used as microplastics and nanoplastics such as in cosmetics, but also secondary sources which may result from weathering or degradation of larger plastic materials.

Microplastics and nanoplastics are a concern because of the chemical composition of some of the materials themselves and monomers and plastic additives that may be present. This can include the migration and degradation of plasticizers (phthalates), additives (organotin compounds and nonylphenols (NP)) and monomers (Bisphenol A). A third area of concern arises from the possibility that certain classes of chemical contaminant (PBDEs, PAHs) can adhere to the surface of some types of microplastic and nanoplastic, and due to the relatively large surface area to volume ratio, this can have a consequence of changing their bioavailability and biomagnification properties. The EFSA Opinion estimated that increased exposures of these contaminants due to adherence to microplastic and nanoplastic would be very small.

The EFSA statement includes information on additives and chemical contaminants, including the potential for transfer of these substances into edible tissues, and an estimation of possible human exposure.

There is no legislation for microplastics and nanoplastics as contaminants in food, but there are a broad range of European Union (EU) policies and legislation with regard to marine litter, covering sources and impacts; and there are a number of EU initiatives, relevant to marine litter, including microplastics.

Detailed analysis of the impact of microplastics and nanoplastics is outside the scope of this review but it is highlighted as an area of potential concern in relation to food contaminants and the global consumer. It is recognised as a global concern and not particularly related to the Scottish consumer, although it is recognised that the seafood industry is important to Scotland.

Nanoparticles

EFSA has recently opened a public consultation on its draft guidance for the risk assessment of nanoscience and nanotechnology applications in the food and feed chain (EFSA, 2018a). The guidance covers novel foods, food contact materials, food and feed additives, and pesticides. The new document takes account of scientific developments that have taken place since publication of the previous guidance in 2011, particularly studies that offer new insights into exposure assessment and hazard characterisation of nanomaterials. It also considers nano-specific considerations relating to in vivo/in vitro toxicological studies and outlines a tiered framework for toxicological testing and proposes ways to carry out risk characterisation and uncertainty analysis.

Detailed analysis of the impact of nanoparticles as used in food is outside the scope of this review but it is highlighted as an area of potential concern in relation to food contaminants and the global consumer. It is recognised as a global concern and is not focussed especially on the Scottish consumer.

Endocrine active chemicals

Many of the contaminants reviewed in this document are known to affect the endocrine system, e.g. POPs (including BFRs), ZON compounds and others. In addition, there are also a large number of chemicals with this activity that have not been considered in this review, such as Bisphenol A, and crop protection products. These chemicals need to be considered either in isolation, or together by class, since effects can be either additive or synergistic. The topic of mixtures or 'cocktail effect' is outside the scope of this review.

Platinum group metals – platinum, palladium, rhodium and ruthenium

Since 1993 the internal combustion engines of all new petrol-engined vehicles have been fitted with catalytic converters to control the levels of exhaust emissions. Platinum, palladium and rhodium are used as catalysts and research has shown an increase in the concentration of these metals in roadside dust. There is little information about the biological effects of platinum group metals in food and at present there is no evidence for any adverse health effects from these as a result of dietary exposure. There is no reason to believe that this would be of particular concern to Scotland compared to other countries.

New and emerging (and expanding) industries.

Aquaculture

The review of the literature identified that whilst the aquaculture industry in Scotland was already recognised as important, this is expanding and so is likely to become of increasing importance to the Scottish industry. Where contaminants have been identified as important to the aquaculture industry, this has been identified in the relevant sections above. Mycotoxins are the main concern for this sector. Recent reports have highlighted that even with the limited knowledge and data available, it is clear that the mycotoxin levels in finished feeds might negatively influence the aquaculture industry through animal health though not food safety impacts, affecting growth performance, feed efficiency and making animals more susceptible to diseases (All About feed, 21 May 2018).

Seaweed production

The other development identified by the literature search was the increase in seaweed production. Seaweed (or 'sea vegetables') is being marketed by some as a 'superfood' that is rich in iodine and calcium, and also contains some natural antioxidants, minerals and amino acids. Seaweed is also described as an important source for the future supply of food and feed (additives), pharmaceuticals, cosmetics, biomaterials and bioenergy.

Seaweed farming is a mature multi-billion dollar industry and some Asian countries produce tens of millions of tonnes a year; but although seaweed grows prolifically in Scottish waters, the seaweed farming industry in the UK is still in its infancy in terms of potential development. Seaweeds can be prone to accumulation of certain contaminants types from the sea, with different species of seaweed incorporating contaminants in different ways. For example, inorganic arsenic can be found in hijiki seaweed (a variety popular in some Japanese dishes) at levels that pose a potential health threat resulting in advice to avoid consumption. Other varieties of seaweed contain lower levels of inorganic arsenic (Rose et al, 2007). It has been reported that the burning of seaweed to produce kelp has led to arsenic contamination of the soil in the rural areas where the kelp burning took place. It is suggested that burning transformed low toxicity arsenosugars in the original seaweeds to highly toxic inorganic forms that persist in soils near the burning pits (Riekie et al, 2006). There are also reports that historic use of seaweed as a soil remediator has resulted in local increases in arsenic content of some soils (Scottish Government, 2006).

The European Commission has published a Recommendation that Member States, with food business operator (FBO) collaboration, perform during the years 2018, 2019 and 2020 monitoring on the presence of arsenic, cadmium, iodine, lead and mercury in seaweed, halophytes and products based on seaweed (EU, 2018). Currently there are no limits for the metals in seaweed products except those used as food supplements and additives. A default level is set for mercury, and there is concern consumption of seaweed products could lead to excessive iodine intake. Therefore, the Commission have requested data be collected and submitted to EFSA.

Scottish honey

There has been a major decline in Scottish hive numbers and producers struggle to meet demand. This has led to reports of honey imported from third countries being packaged and labelled as Scottish (The Guardian, 2004). While this affects the trade, it may also pose a hazard as many of the countries of origin (India, Argentina and China) have had issues with occurrence of veterinary drug residues in the honey (The Guardian, 2004). This should be considered as a risk but is outside the scope of this review.

Other emerging and craft industries

Although other emerging industries within Scotland were not identified in the literature search, there is evidence that gin production, including craft gins, is increasing in Scotland. According to Scottish Trade statistics 70% of UK gin is produced in Scotland, either from scratch, or by distilling spirit produced outside Scotland with botanicals to impart flavour. Small-batch distillations, flavoured with botanicals such as rock rose, elder, seaweed, mugwort, tansy, and lavender and other wild plants not commonly used in food are becoming popular. These may pose a health hazard due to either contaminants present or due to active ingredients contained in the botanicals that are not normally consumed. Some of the active ingredients, such as quassin and thujone, are already regulated in Regulation (EC) No 1334/2008. More recently Heriot-Watt

University has created a library of botanicals used in gin production. This library is intended to help inform producers how botanicals will perform if added before or after distillation. The next stage of the work is to test the potentially toxic compounds that could be present and determine if they are safe for consumers and not above threshold limits (BBC, 2018).

Brexit

The UK is currently in the process of leaving the European Union, and this will presumably have associated changes in regulations; increased trade with 3rd countries and other implications that may impact on food safety. This review does not cover the impact of Brexit on contaminants in food.

Health and economic risks for chemical contaminants in foods in Scotland compared with the rest of the UK and with third countries.

Hazard characterisation

The food chemicals that have been identified as a concern for the Scottish consumer and for the Scottish economy that are considered in this report are the same as those classes of chemical of concern in the rest of the UK and elsewhere globally. There is no recognised significant difference in the Scottish genetic makeup or environment that should result in any difference in terms of health effect to the Scottish consumer. The hazard characterisation for each class of chemical contaminant is therefore directly aligned to internationally agreed and published risk assessments.

Exposure assessment

The Scottish diet was found to be very similar to the rest of the UK, although the Scottish consumer may have a slightly greater tendency to eat take-away foods or eat out in restaurants and cafes. The exposure assessment for the Scottish consumer was therefore considered the same as the rest of the UK for dietary intake and consumer exposure estimates.

Economic considerations

Scottish food exports are worth more than £1.6 billion, with total food and drink exports worth approximately £6 billion in 2017 (Food Standards Scotland, 2018). Food and non-whisky drinks currently account for 20% of this export activity, with whisky making up the major part of the remainder (Scotland Food and Drink, 2014). Scotland exports to over 200 overseas countries and territories. The top products for export are whisky, worth £4.4 billion per year; salmon, shellfish, cheese, and lamb as well as gin, beer and honey. Other important industries in Scotland are fish, shellfish, game meats, and oats. Contaminants that are associated with food products from these sectors have therefore been identified as of particular importance in this report.

Conclusions and Recommendations

Analysis of dietary intake information from the National Diet and Nutrition and Survey (NDNS) found no significant difference in consumption patterns for the Scottish consumer compared to the rest of the UK (except an indication of slightly higher proportion of foods consumed that are prepared outside the home e.g. take-away foods). Targeted contaminants surveillance is undertaken by Scottish Local Authorities (LAs) and the results are held on the UK Food Surveillance System (UKFSS). Data from the last 2 years, as well as evidence from the literature and information from the NDNS, showed that Scottish consumers are not at any particular risk of exposure to chemical contaminants as a result of their dietary habits and presuming similar levels of contamination in Scottish foods.

Literature searches by their nature are targeted to find specific information. Based on expert knowledge and current intelligence of possible emerging issues, literature searches were carried out for a broad spectrum of chemical contaminants, including chemicals known from historical incidents, those currently regulated, and any currently under review or recently evaluated by e.g. EFSA in a range of foods and animal feed. Additional searches specific for Scotland were also carried out. A huge amount of information was retrieved, and a full systematic review was not possible. However, each contaminant class was thoroughly reviewed to check for issues related to Scotland. No particular sources of contamination were identified that were associated specifically with Scottish foods. There will however always be the possibility of local sources of contamination due to specific geology or industries that may be a source of contamination, e.g. coal mines and coal fired power stations, and other chemical industries.

It should also be noted that where a contaminant issue is well known, and analytical methodology well established, a large number of analyses will be carried out. Conversely where a contaminant class is a new or 'emerging' issue, fewer laboratories have analytical capability and therefore less data will have been produced. This was shown in the literature searches where large amounts of data were available for established contaminants (e.g. metals, mycotoxins). There were fewer reports for other contaminants, such as furan, while for some of the environmental contaminants currently under review by EFSA, there were no publications or reports via HorizonScan. This is not a reflection of the relative risk of these contaminants, but an indication of the state of the art of the knowledge about them. This was also reflected in the UKFSS data, where there were data for established contaminants that are straightforward to analyse for (e.g. metals, mycotoxins, acrylamide), but there were obvious gaps for 'newer' issues like ergot alkaloids, furan or where the analysis would be very difficult, or expensive or require development work, such as the halogenated POPs. This highlights the need to obtain data, either by using data from other sources, such as industry data if available, EFSA data, or by expanding the remit of the UKFSS surveys or carrying out targeted sampling and analysis projects to obtain data where specific gaps are identified.

While no overall differences in diet were found, UKFSS data and literature reports indicated some local foods and local customary habits may result in higher levels of exposure to some contaminants. For example, acrylamide was the most frequently detected contaminant, and consumption of 'well fired rolls' may result in increased exposure to acrylamide and furans. Locally smoked fish may contain higher levels of PAHs compared to products that are not smoked. The introduction of new EU Regulations for acrylamide and glycidyl esters may mean some FBOs will need to review their current practices to ensure compliance. Eating out more frequently may mean Scottish consumers are more likely to consume fried foods which are a source of furans and acrylamide, although there are no UKFSS data to support this.

There was no evidence of any issues that may affect whisky production, Scotland's largest industry in the food and drink sector. Spent grains and DDGS used for animal feed could be a source of mycotoxins, but as the intake grain used for this industry is usually of a high quality this is not likely to be a major issue. Other food industries of high importance to the Scottish economy e.g. shellfish, fish and aquaculture are associated with certain classes of contaminant such as arsenic, mercury, dioxins and PCBs. There was no evidence of any issues with these contaminants in Scottish produce from UKFSS results, literature or HorizonScan reports. However, it is essential that Scottish produce complies with regulations to ensure the quality of food produced in order to reassure the consumer and export trade. In addition, there was some evidence from the literature that mycotoxins in feed may affect productivity in the aquaculture sector, but it is unlikely to pose a risk to consumers.

Climate Change may have an impact on certain contaminants such as mycotoxins which may increase as a result of global warming or due to an increase in humidity associated with events such as unusual rainfall events and increased flooding. Significantly higher levels of T-2 and HT-2 toxins (compared to the rest of the UK) have been found in Scottish oats, particularly from northern Scotland. A follow up survey of retail products showed that levels of T-2 and HT-2 toxins were not a cause for concern as they were reduced, e.g. by cleaning and production processes and/or diluted by combining grains from multiple sources during processing. Effects such as Climate Change cannot be evaluated in isolation because other factors may compound or negate the effects seen e.g. restrictions on some fungicides may enhance mycotoxins and it is difficult to attribute the impact of one change with other confounders that may be happening at the same time.

Some classes of emerging contaminant (i.e. those contaminants that are not yet regulated but may be regulated in future) are of particular concern to some foods produced in Scotland and to the Scottish consumer. These include pyrrolizidine alkaloids in honey, ergot alkaloids in cereals (oats of special relevance for Scotland), furan and acrylamide in bakery products and some of the brominated flame retardants, and brominated and mixed halogenated dioxins in fish and seafood. Some classes of contaminant (e.g. PFASs, some mycotoxins, dioxins and PCBs) are currently under (re-)evaluation by EFSA. If there is a revision to health-based guidance values (e.g. TDI) then there could be consequences to Scottish food and the Scottish consumer.

The review also looked for new and emerging industries and found increasing production of products such as seaweed and craft gin. These new industries may result in exposure to new classes of contaminant or increases in exposure to some that were not previously a problem, such as iodine which historically consumers have been more likely to suffer a deficiency from. There were many reports of excessive levels of iodine in seaweed but none that related specifically to Scottish seaweed, but no data are available to demonstrate that it is not a possible concern. The European

Commission have recommended that seaweed is analysed for metals and iodine for the next 3 years and that data is reported to EFSA (Commission Recommendation 2018/464). One area that could not be covered was changing shopping habits and the increase in purchase of foods, and of more concern, food supplements via the internet. This is not specific for Scotland, and most of the products will be imported. There are regular reports of issues with food supplements picked up at import checks, however these may be missed if consumers buy direct.

Overall the main conclusion from this study is that no major issues were identified for food and drink items produced in Scotland, or that Scottish consumers are at any particular specific risk from contaminants in their diet. This gives reassurance that current FSS work programmes are well targeted. However, it must always be borne in mind that food and feed incidents can occur at any time and historically have been the result of unexpected events and/or discovered accidentally or as a result of non-direct research or surveillance. Therefore, horizon scanning and intelligence gathering should always be carried out in addition to traditional analytical surveillance.

Recommendations

1. The current sampling carried out by Scottish Local Authorities (LAs) should be maintained to ensure the data held on the UK Food Surveillance System (UKFSS) database are current and relevant. However, review of the recent data shows gaps for many of the classes of contaminants, particularly those that can be classed as 'emerging' such as the halogenated environmental contaminants (BFRs, paraffins, polychlorinated naphthalenes), some mycotoxins (ergot alkaloids, modified forms), plant toxins (pyrrolizidine alkaloids) and processing contaminants (except acrylamide). The UKFSS data available reflects the capability and capacity, in terms of analytical equipment, of the laboratories performing the analyses; however there may be barriers to expanding the range of contaminants tested, such as lack of technical knowledge or suitable analytical methodology, and this should be addressed. Data from other sources where it exists and is available, such as from industry or trade bodies, could be examined for assessment of emerging risks.

2. Review the current list of undesirable substances included in the Scottish LAs' sampling programme. New regulations for some contaminants mean additional compounds may need to be included to ensure compliance and to obtain occurrence data where little (or no) data is currently available. This includes glycidyl esters, MCPD and hydrocyanic acid where new regulations have been introduced; PFASs where new reports from EFSA are anticipated; and the BFRs, ergot alkaloids and pyrrolizidine alkaloids where new regulations are anticipated. There are also other new and emerging contaminants that are not currently regulated but where there is evidence of exposure and toxicity and data gaps exist, such as for furan, MCPD esters, ethyl carbamate, modified mycotoxins, and opium alkaloids.

3. Where data requests exist, Commission Recommendations are published, or gaps are identified, consider carrying out surveillance. Commission Recommendation 2018/464 is of particular relevance to Food Standards Scotland as it requests data on heavy metals and iodine in seaweed, a product identified as being of increasing importance in Scotland. Monitor EFSA calls for data and current work activity, and produce data

to ensure that the Scottish consumer and Scottish industry are supported. A new EFSA call for contaminant data (https://www.efsa.europa.eu/en/consultations/call/180307) was launched on 15 May 2018. It includes many of the contaminants mentioned above, as well as other compounds in the groups; process contaminants; organic contaminants; inorganic contaminants; mycotoxins; and plant toxins. Gaps in data for all of these groups of compounds have been highlighted in the text.

4. Maintain a watching brief on the activities of EFSA particularly where contaminants undergo a (re-)evaluation. If health-based guidance values (e.g. TDI) are revised there could be consequences for Scottish food production and Scottish consumers, and surveillance or research may be required. Classes of contaminant currently under (re-)evaluation include PFASs, some mycotoxins including modified forms, and dioxins and dioxin-like PCBs. The Scottish diet contains a large proportion of carbohydrate rich foods, for which processing contaminants such as acrylamide and possibly mycotoxins (if cereal products) would be most relevant. Food categories that are particularly relevant for these classes of contaminant are highlighted in the main body of this report.

5. Continue with horizon scanning and intelligence gathering activities, particularly in relation to issues that may be important to Scotland. This can include reports from other countries where Scottish produce has exceeded regulatory limits, or can be used to identify potential concerns for imported produce that may affect the Scottish consumer. Scientific literature and conferences can be a source of information that can be used to identify contaminants of emerging concern, as well as subscription to on-line news services. HorizonScan provides information on incidents that have been reported globally, and is useful for monitoring trends to determine if a report is an isolated event or the start of an incident. New tools such as Early Warning Systems based on models using trade data may prove useful in alerting to problems as they emerge rather than after an incident has started.

Appendix 1 – Search terms used for literature searches.

Scotland; Scottish; Scot*

Plus: food*; feed*; diet*; exposure; intake; consumption;

Red meat and game; beef; lamb; pork; bacon; ham; offal; venison; rabbit; hare; quail; goose; duck; woodcock; pheasant; grouse; partridge;

Fish and shellfish; white fish; oily fish; mackerel; herring; haddock; cod; *salmon; *trout; crustacean*; crab; lobster; langoustine*; mollusc*; mussel*; oyster*; *scallop*; aquaculture; farmed fish; smoked fish;

Poultry; poultry product*; chicken; eggs

Dairy products; milk; cheese;

Oat*; cereal*; barley; wheat; malt*;

Fruits and vegetables; fruit*; *berry; *berries; apple*; pear; potato*; root vegetable*; green vegetable*; brassica*; *cabbage; cauli*; parsnip; beetroot; seaweed*; alginate*

Whisky; honey;

Plus:

1. chemical contaminants; environmental contaminants; heavy metals; trace elements; lead; cadmium; mercury; arsenic; inorganic tin; nickel; Pb; Cd; Hg; As; Sn: Ur; uranium; persistent organic pollutants; POPs; *dioxins; PCDD*; PCDF*; PCB*; PAH*; polycyclic aromatic hydrocarbon*; polyaromatic hydrocarbon; flame retardant; BFR; polybrominated diphenyl ether; PBDE; brominated; PFAS*; PFOS; PFOA; polyfluorinated*; polychlorinated*; naphthalene*;

2. Natural toxins; mycotoxin*; masked mycotoxin*; modified mycotoxin*; aflatoxin*; sterigmatocystin; ochratoxin*; fumonisin*; *deoxynivalenol*; T-2 toxin*; HT-2 toxin*; T2; HT2; trichothecene*; nivalenol*; zearalenone*; ZEN*; *ZEL*; *zearalenol*; *ZAL*; *zearalanol*; ergot alkaloids; ergosin*; ergocryptin*; ergometrin*; ergocornin*; ergotamin*; ergovaline; ergotcristin*; patulin; citrinin; Alternaria toxins; alternariol*; tenuazonic acid; altenuene; Fusarium toxins; moniliformin; enniatin*; beauvericin; phomopsin*;

Plant toxins: pyrrolizidine alkaloids; Senecionine-type PAs: acetylerucifoline*; erucifoline*; integerrimine*; jacobine*; jacoline*; jaconine*; jacozine*; retrorsine*; senecionine*; seneciphylline*; Lycopsamine-type PAs; acetylechimidine*; echimidine*; echivulgarine*; lycopsamine*; vulgarine*; Heliotrine-type PAs; europine*; heliotrine*; lasiocarpine*; Monocrotaline-type PAs; fulvene*; monocrotaline*; retusamine*; trichodesmine*; tropane alkaloids; atropine; scopolamine; hyoscine; tropine; cannaboid*; *tetrahydrocannabinol; THC; hydrocyanic acid; cyanogenic glycoside*; opium alkaloids; morphine; thebaine; codeine; noscapine; papaverine; oripaverine; erucic acid; *alkaloid*; solanine; chaconine;

Nitrate; nitrite;

3. Processing contaminants; adulteration contaminant*; melamine; Sudan Dye*; acrylamide; furan; methyl furan; 3-monochloropropane diol; 3-MCPD; 2-monochloropropanediol and fatty acid esters; 2-MCPD esters; 3-MCPD esters; free glycidol; glycidyl fatty acid esters; GE; glycidyl esters; ethyl carbamate; 4 methyl imidazole; 4-MEI; 2 methyl imidazole; 2-MEI; MeIQ; 2-Amino-3,4-dimethylimidazo[4,5-f]quinoline; hydroxy methyl furfural; HMF; *furfural*; nitrosamine*; semi-carbazide;

4. Emerging contaminant*; microplastics; nanoplastics; nanoparticles; biological* active principles; BAPs; botanical*;

Appendix 2. Regulations Relevant to Food and Feed

European Regulations, Directives and Recommendations (Not comprehensive)

Copies of the Regulations are available online on the Eur-Lex website:

https://eur-lex.europa.eu/homepage.html

General

REGULATION (EC) No 178/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety

REGULATION (EC) No 882/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules

Contaminants

COUNCIL REGULATION (EEC) No 315/93 of 8 February 1993 laying down Community procedures for contaminants in food

DIRECTIVE 2002/32 (EC) OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 7 May 2002 on undesirable substances in animal feed

REGULATION (EC) No 2065/2003 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 November 2003 on smoke flavourings used or intended for use in or on foods

COMMISSION REGULATION (EC) No 401/2006 of 23 February 2006 laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs

COMMISSION REGULATION (EC) No 627/2006 of 21 April 2006 implementing Regulation (EC) No 2065/2003 of the European Parliament and of the Council as regards quality criteria for validated analytical methods for sampling, identification and characterisation of primary smoke products

COMMISSION REGULATION (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs

COMMISSION REGULATION (EC) No 1882/2006 of 19 December 2006 laying down methods of sampling and analysis for the official control of the levels of nitrates in certain foodstuffs

COMMISSION RECOMMENDATION (EC) 2006/583 of 17 August 2006 on the prevention and reduction of Fusarium toxins in cereals and cereal products

COMMISSION RECOMMENDATION (EC) 2006/576 of 17 August 2006 on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding

COMMISSION REGULATION (EC) No 333/2007 of 28 March 2007 laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs

COMMISSION REGULATION (EC) No 1126/2007 of 28 September 2007 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards *Fusarium* toxins in maize and maize products

COMMISSION REGULATION (EC) No 565/2008 of 18 June 2008 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards the establishment of a maximum level for dioxins and PCBs in fish liver

COMMISSION REGULATION (EC) No 629/2008 of 2 July 2008 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs

REGULATION (EC) No 1334/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2008 on flavourings and certain food ingredients with flavouring properties for use in and on foods and amending Council Regulation (EEC) No 1601/91, Regulations (EC) No 2232/96 and (EC) No 110/2008 and Directive 2000/13/EC.

COMMISSION REGULATION (EC) No 152/2009 of 27 January 2009 laying down the methods of sampling and analysis for the official control of feed

COMMISSION REGULATION (EU) No 105/2010 of 5 February 2010 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards ochratoxin A

COMMISSION REGULATION (EU) No 165/2010 of 26 February 2010 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards aflatoxins

COMMISSION REGULATION (EU) No 178/2010 of 2 March 2010 amending Regulation (EC) No 401/2006 as regards groundnuts (peanuts), other oilseeds, tree nuts, apricot kernels, liquorice and vegetable oil

COMMISSION REGULATION (EU) No 420/2011 of 29 April 2011 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs

COMMISSION REGULATION (EU) No 835/2011 of 19 August 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs

COMMISSION REGULATION (EU) No 836/2011 of 19 August 2011 amending Regulation (EC) 333/2007 laying down the methods of sampling and analysis for the official control of levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs

COMMISSION REGULATION (EU) No 1258/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs

COMMISSION REGULATION (EU) No 1259/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs

COMMISSION RECOMMENDATION (EU) 2012/154 of 15 March 2012 on the monitoring of the presence of ergot alkaloids in feed and food

COMMISSION REGULATION (EU) No 252/2012 of 21 March 2012 laying down methods of sampling and analysis for the official control of levels of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in certain foodstuffs and repealing Regulation (EC) No 1883/2006

COMMISSION REGULATION (EU) No 594/2012 of 5 July 2012 amending Regulation (EC) 1881/2006 as regards the maximum levels of the contaminants ochratoxin A, non dioxin-like PCBs and melamine in foodstuffs

COMMISSION REGULATION (EU) No 1067/2013 of 30 October 2013 amending Regulation (EC) No 1881/2006 as regards maximum levels of the contaminants dioxins, dioxin-like PCBs and non-dioxin-like PCBs in liver of terrestrial animals

COMMISSION REGULATION (EU) 2016/239 of 19 February 2016 amending Regulation (EC) No 1881/2006 as regards maximum levels of tropane alkaloids in certain cereal-based foods for infants and young children

COMMISSION RECOMMENDATION (EU) 2016/1111 of 6 July 2016 on the monitoring of nickel in food

COMMISSION RECOMMENDATION (EU) 2016/1319 of 29 July 2016 amending Recommendation 2006/576/EC as regards deoxynivalenol, zearalenone and ochratoxin A in pet food

COMMISSION REGULATION (EU) 2017/1237 of 7 July 2017 amending Regulation (EC) No1881/2006 as regards a maximum level of hydrocyanic acid in unprocessed whole, ground, milled, cracked, chopped apricot kernels placed on the market for the final consumer

COMMISSION REGULATION (EU) 2017/2158 of 20 November 2017 establishing mitigation measures and benchmark levels for the reduction of the presence of acrylamide in food

COMMISSION REGULATION (EU) 2018/290 of 26 February 2018 amending Regulation (EC) No 1881/2006 as regards maximum levels of glycidyl fatty acid esters in vegetable oils and fats, infant formula, follow-on formula and foods for special medical purposes intended for infants and young children

COMMISSION RECOMMENDATION (EU) 2018/464 of 19 March 2018 on the monitoring of metals and iodine in seaweed, halophytes and products based on seaweed

UK legislation and advice on contaminants is available from Food Standards Scotland:

Copies of the Regulations are available from: The Stationery Office (http://www.tsoshop.co.uk/) or you can read them online on the Office of Public Sector Information website:

http://www.opsi.gov.uk/si/si2006/20061464.htm

Food Law guide:

http://www.foodstandards.gov.scot/downloads/Scottish_Food_and_Feed_Law_Guide_-_August_2017_1.pdf

Food Law Code of Practice:

http://www.foodstandards.gov.scot/publications-and-research/food-law-code-of-practice-2015

Feed Law Code of Practice:

http://www.foodstandards.gov.scot/downloads/Feed_Law_Code_of_Practice_Scotland_-_2016.pdf

Importing/Exporting Food:

http://www.foodstandards.gov.scot/business-and-industry/safety-and-regulation/imports-exports

Contaminants and Food Contact Materials: guidance for businesses:

http://www.food.gov.uk/business-industry/manufacturers/contaminants-fcm-guidance/#.U16_ahAwZc4

Appendix 3. Results of analysis and review of NDNS consumption data for Scottish consumers

The resulting consumption outputs are presented for individual food/drink groups as average grams per day per kg bodyweight. The results presented below focus on those food groups likely to be important in exposure and risk assessments, taking account of the scenarios identified in the literature search and expert review. A risk assessment is primarily concerned with those individuals within a population receiving the highest exposures.

Table 1. 95th percentile values, compared by country and population group, corresponding to the general food groups plotted in Figure 1

Food type	**Adult (g/day/kg-bw)**		**Child (g/day/kg-bw)**	
	Scotland	**Other UK**	**Scotland**	**Other UK**
Fruit	1.09	1.05	3.13	2.81
Vegetables	1.24	1.28	1.76	2.00
Red meat	0.57	0.53	1.03	0.99
White meat	0.31	0.33	0.54	0.58
Meat	0.73	0.68	1.28	1.30
Fish	0.27	0.27	0.35	0.36

Figure 1**Error! Reference source not found.** represents distributions of non-zero consumption amounts for some broad food groups divided into distinct age-specific subpopulations. There is no indication in the boxplots that Scottish consumers' overall diets include more extreme amounts than the rest of the UK in any of these categories. Figure 12 and **Error! Reference source not found.** show the 95th percentile consumers in the adult and child populations respectively, focussing on drink categories. The amount of beer/cider/lager is lower for adults in Scotland and is similar for the other drink types.

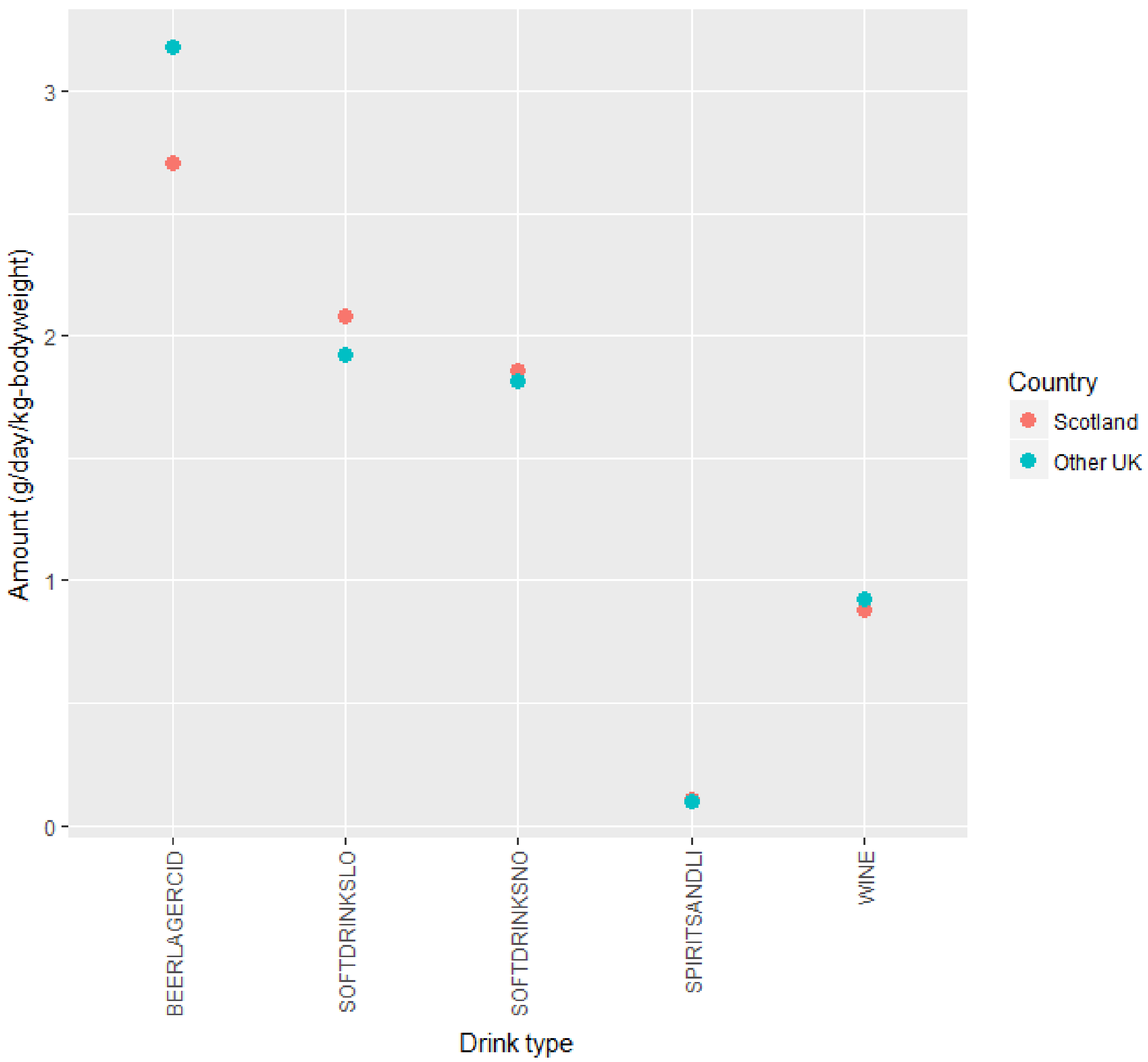

Figure 12. 95th percentile amounts of drinks consumed by adults. The drink types considered are BEERLAGERCID = Beer, lager or cider; SOFTDRINKSLO = low-calorie soft drinks; SOFTDRINKSNO = soft drinks (not low-calorie); SPIRITSANDLI = Spirits and Liquor; WINE = wine.

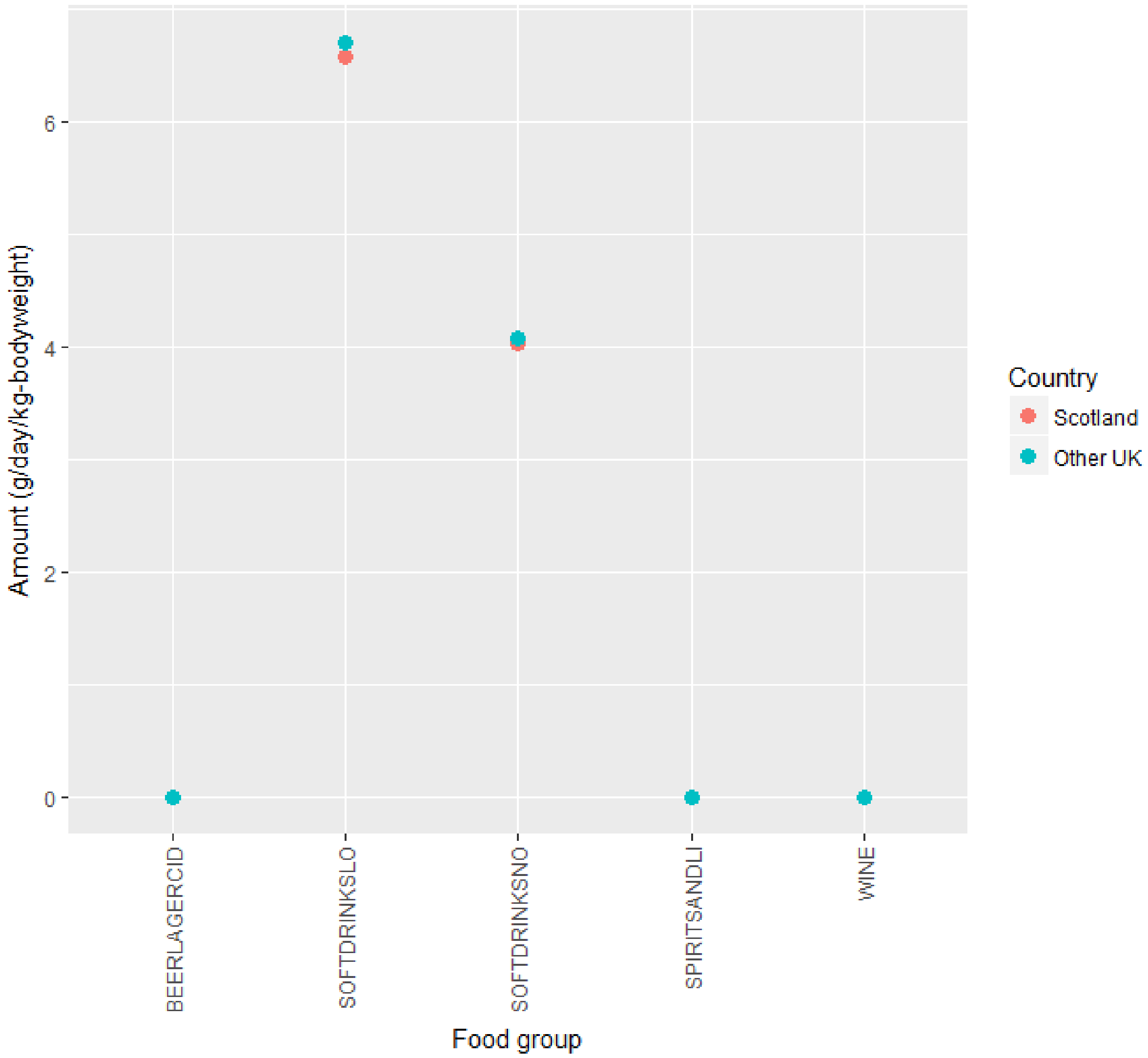

Figure 13. 95th percentile amounts of drinks consumed by under 18s. The drink types considered are BEERLAGERCID = Beer, lager or cider; SOFTDRINKSLO = low-calorie soft drinks; SOFTDRINKSNO = soft drinks (not low-calorie); SPIRITSANDLI = Spirits and Liquor; WINE = wine.

Table 2. 95th percentile values, of consumptions for drinks categories, as plotted in Figures 2-3

Drink type	Adult (g/day/kg-bw)		Child (g/day/kg-bw)	
	Scotland	**Other UK**	**Scotland**	**Other UK**
Beer, lager, cider	2.70	3.18	0	0
Spirits and liquor	0.11	0.10	0	0
Wine	0.88	0.92	0	0
Soft drinks, low calorie	2.08	1.92	6.57	6.70
Soft drinks	1.86	1.82	4.04	4.08

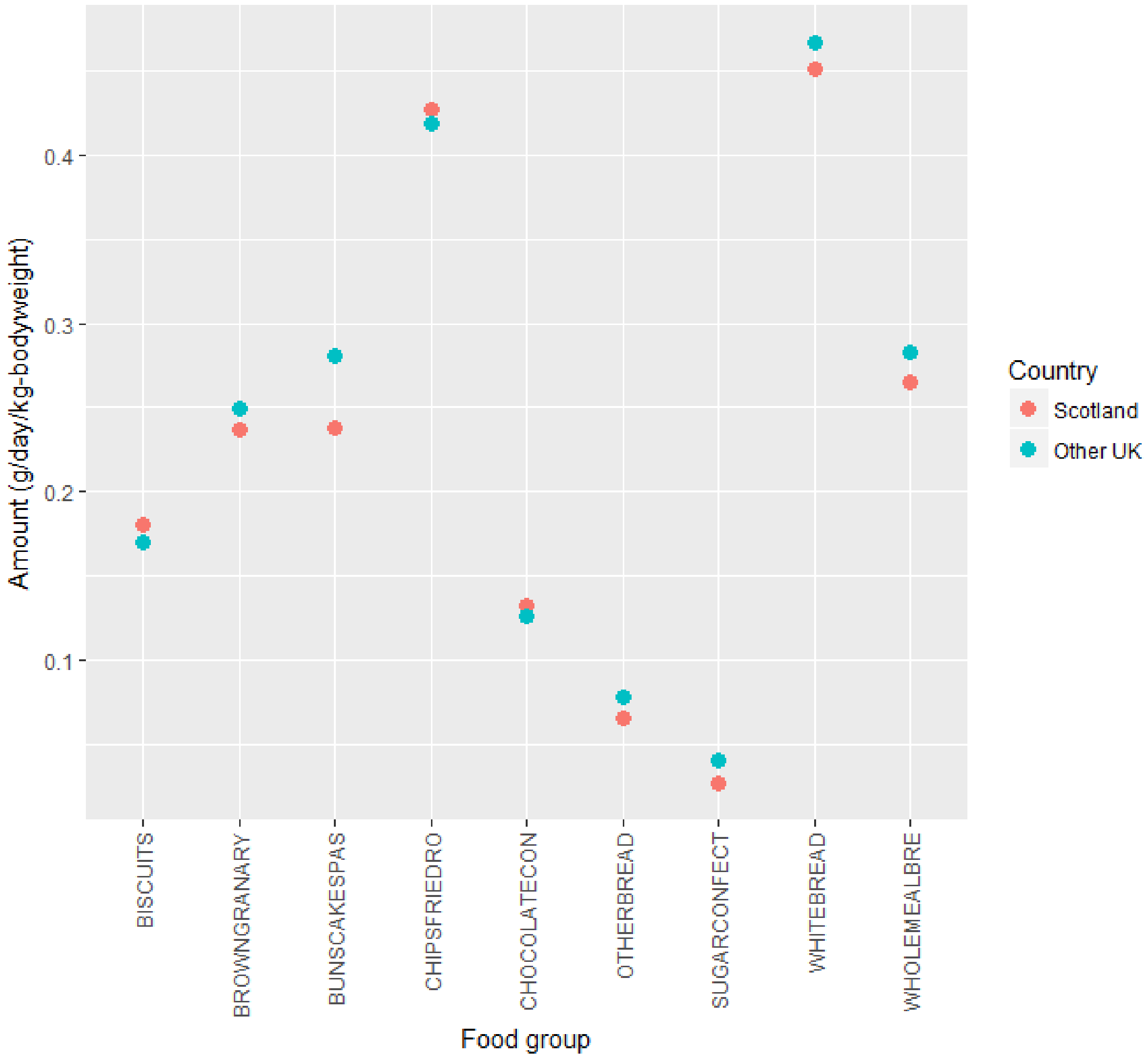

Figure 14. 95th percentile amounts of selected food groups consumed by adults. The food types considered are BISCUITS = Biscuits; BROWNGRANARY = Brown granary bread; CHIPSFRIEDRO = chips, fried or roasted potatoes; CHOCOLATECON = Chocolate confectionary; OTHERBREAD = other bread types; SUGARCONFECT = Sugar confectionary; WHITEBREAD = white bread; WHOLEMEALBRE = wholemeal bread.

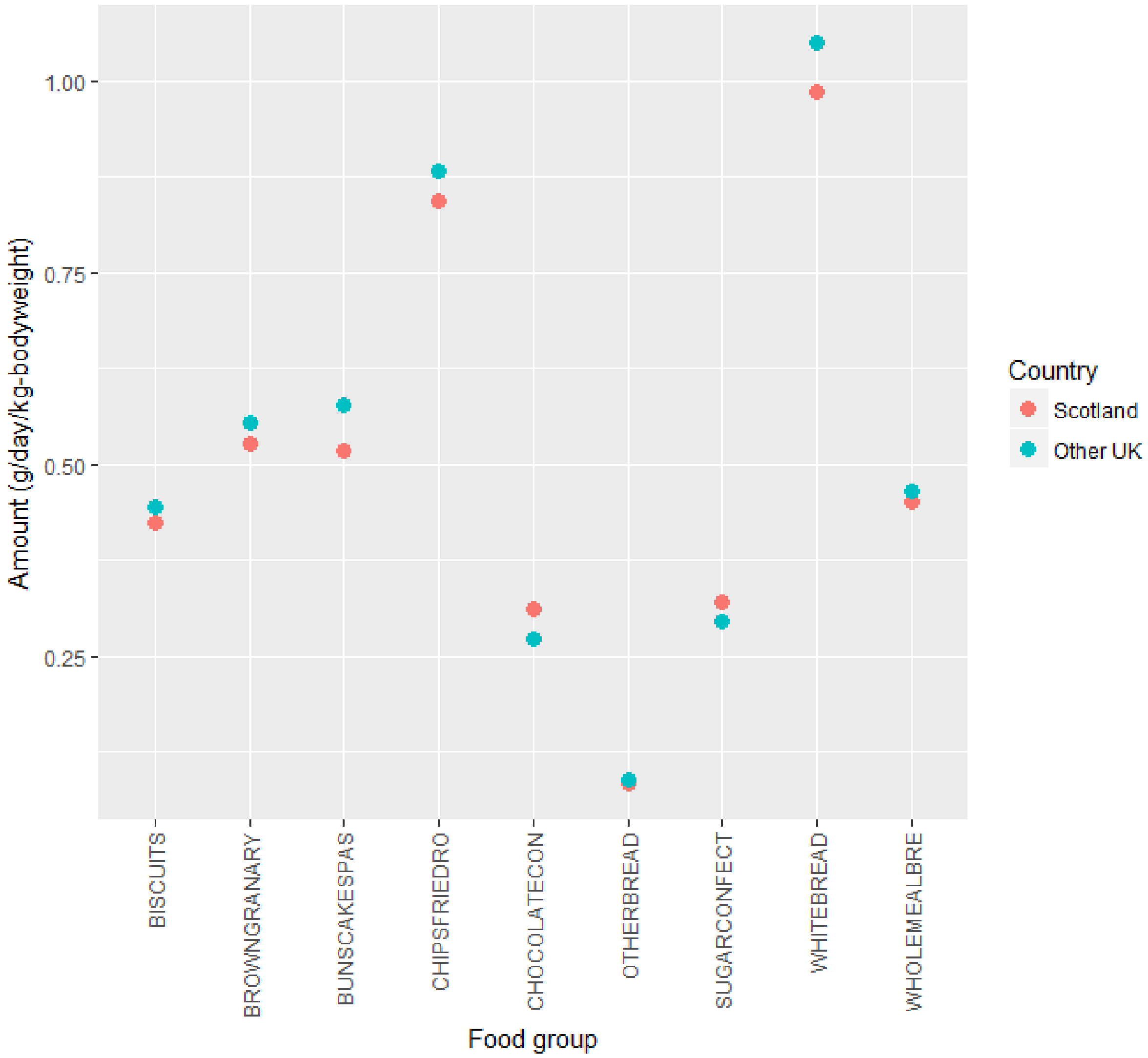

Figure 15. 95th percentile amounts of selected food groups consumed by under 18s. The food types considered are BISCUITS = Biscuits; BROWNGRANARY = Brown granary bread; CHIPSFRIEDRO = chips, fried or roasted potatoes; CHOCOLATECON = Chocolate confectionary; OTHERBREAD = other bread types; SUGARCONFECT = Sugar confectionary; WHITEBREAD = white bread; WHOLEMEALBRE = wholemeal bread.

Table 3. 95th percentile values for selected food types, as plotted in Figures 14-15

Drink type	Adult (g/day/kg-bw)		Child (g/day/kg-bw)	
	Scotland	**Other UK**	**Scotland**	**Other UK**
Chocolate	0.13	0.13	0.31	0.27
Sugar confectionary	0.03	0.04	0.32	0.30
Biscuits	0.18	0.17	0.42	0.44
Buns, cakes, pastries	0.24	0.28	0.52	0.58
Chips, fried, roast potatoes	0.43	0.42	0.84	0.88
White bread	0.45	0.47	0.98	1.05
Brown granary bread	0.24	0.25	0.53	0.55
Wholemeal bread	0.27	0.28	0.45	0.47
Other bread	0.07	0.08	0.08	0.09

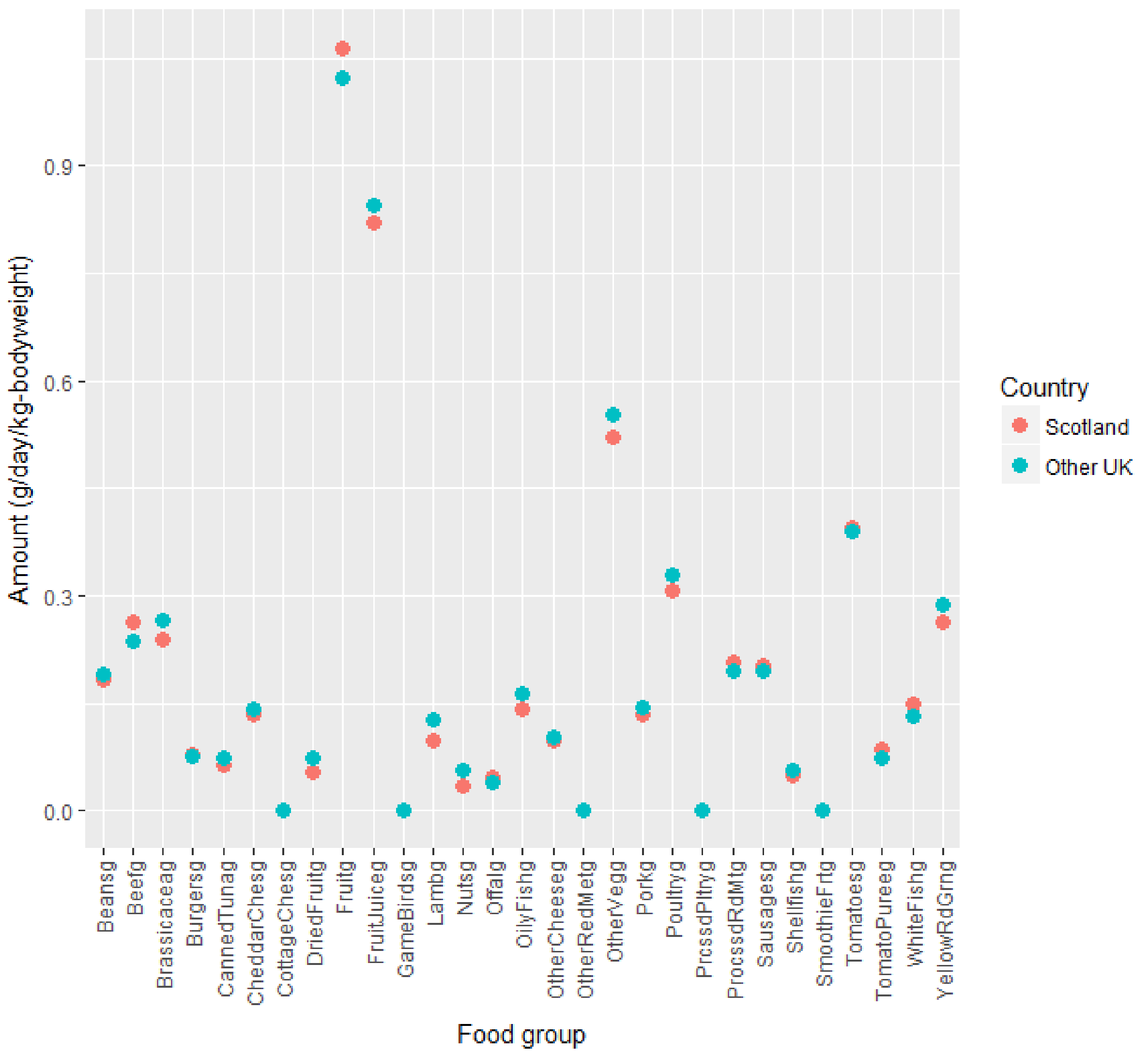

Figure 16. 95th percentile adult consumption amounts for the food types (disaggregation categories) as defined in the NDNS rolling program.

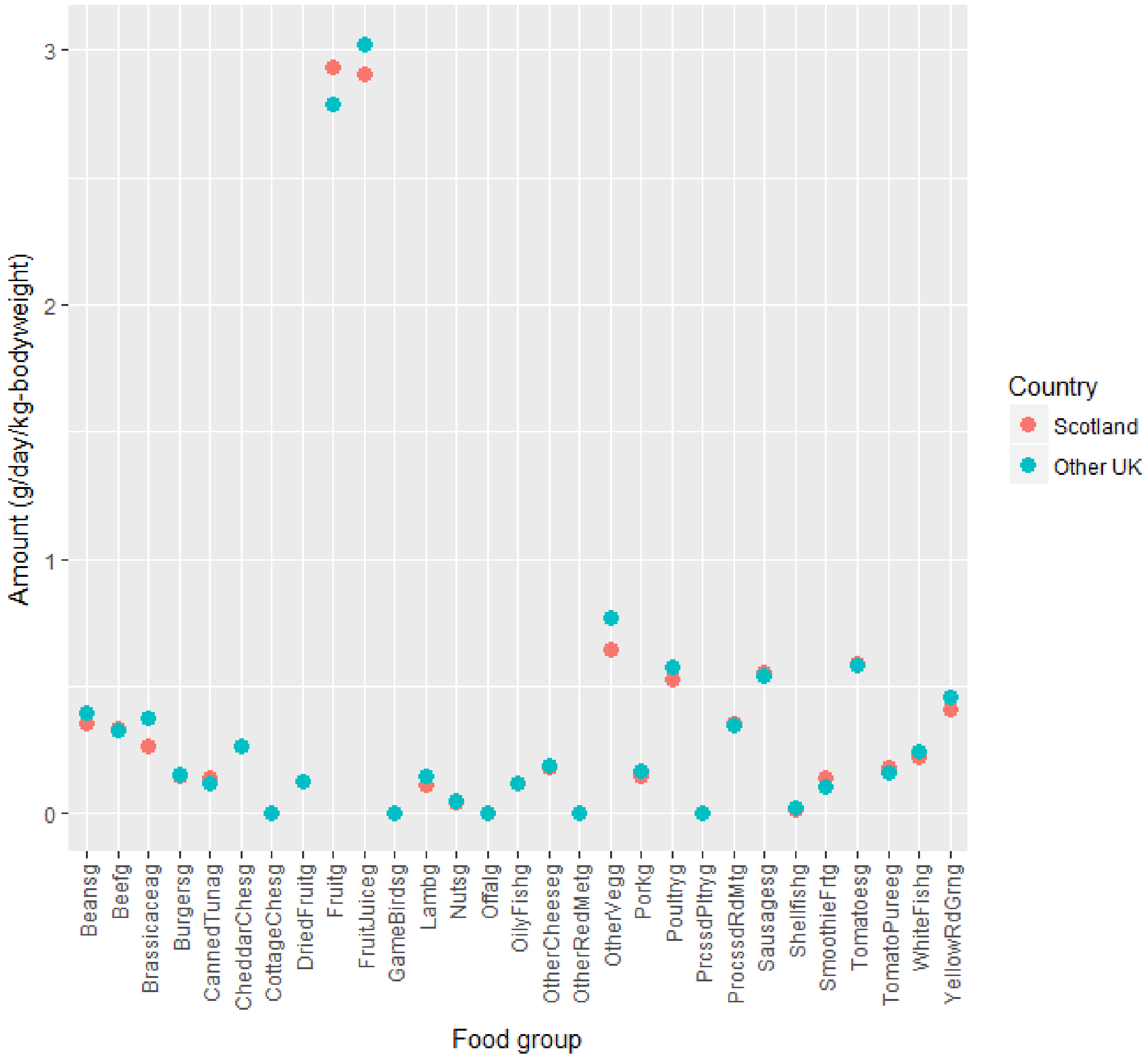

Figure 17. 95th percentile under 18s consumption amounts for the food types (disaggregation categories) as defined in the NDNS rolling program.

Table 4. 95th percentile values for the disaggregated food types defined in the NDNS, as plotted in Figures 16-17.

Drink type	Adult (g/day/kg-bw)		Child (g/day/kg-bw)	
	Scotland	Other UK	Scotland	Other UK
Fruit (fresh/canned)	1.06	1.02	2.93	2.79
Dried fruit	0.05	0.07	0.13	0.12
Fruit juice	0.82	0.84	2.90	3.02
Smoothie fruit	0	0	0.14	0.11
Tomatoes	0.40	0.39	0.59	0.59
Tomato puree	0.09	0.07	0.18	0.16
Brassicaceae	0.24	0.27	0.26	0.37
Yellow, red and green leafy vegetables	0.26	0.29	0.41	0.46
Other vegetables	0.52	0.55	0.65	0.77
Beans and pulses	0.18	0.19	0.35	0.40
Nuts	0.03	0.06	0.05	0.05
Beef	0.26	0.24	0.34	0.33
Lamb	0.10	0.13	0.11	0.14
Pork	0.13	0.14	0.15	0.17
Processed red meat	0.21	0.19	0.36	0.35
Other red meat	0	0	0	0
Burgers	0.08	0.08	0.15	0.16
Sausages	0.20	0.20	0.55	0.54
Offal	0.05	0.04	0	0
Poultry	0.31	0.33	0.53	0.58
Processed poultry	0	0	0	0
Game birds	0	0	0	0
White fish	0.15	0.13	0.22	0.25
Oily fish	0.14	0.16	0.12	0.12
Canned tuna	0.06	0.07	0.14	0.12
Shellfish	0.05	0.06	0.02	0.02
Cottage cheese	0	0	0	0
Cheddar cheese	0.14	0.14	0.27	0.26
Other cheese	0.10	0.10	0.18	0.19

In the results shown above, there is no evidence of substantial differences between the high percentile consumption amounts of Scotland consumers and others in the UK. We have restricted attention to the food groupings within the NDNS data, but these are known to be important food groups. The sample size was not sufficient to capture very localised dietary habits or rarely consumed items. It also does not consider cooking or processing effects.

For any of the values shown, multiplying by a concentration would generate an exposure level for the percentile consumer. However, note that this simple approach would only be the 95th percentile exposure quantile if the concentration is at a constant level. A more realistic analysis should account for the distribution of concentration levels and probabilistically combine them with randomly selected consumption amounts. Software and example analyses can be found at https://mcra8.rivm.nl

The choice of a 95th percentile consumer could be replaced by a higher level, which in theory would highlight differences seen in the more extreme tail of the population distribution. However, the NDNS sample size is not large and higher percentiles will be less representative of the true underlying population. This is especially true for food groups consumed by a small portion of the population (e.g. Offal or game birds). The NDNS included some food frequency questions related to a few categories of less commonly consumed types (e.g. offal, game, seaweed, shellfish) that could be missed within the short diary period. Figure 18**Error! Reference source not found.**, **Error! Reference source not found.** and Figure 20**Error! Reference source not found.** are examples.

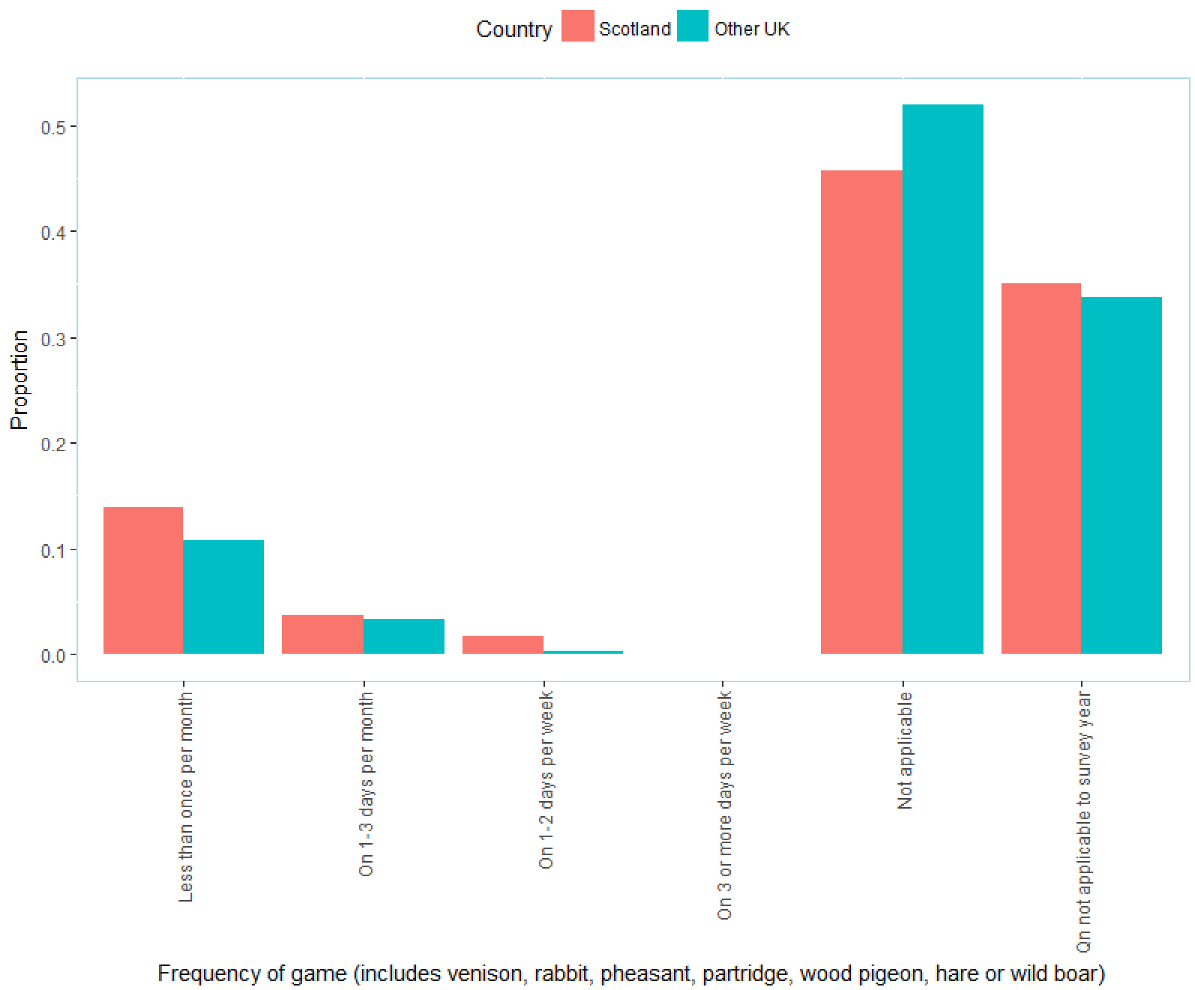

Figure 18. Summary of responses about frequency of consumption of game, in the NDNS. The 2 rightmost columns represent the non-consuming proportion of the population. Scotland has a higher proportion of consumers, especially for frequent (1-2 days per week) consumers.

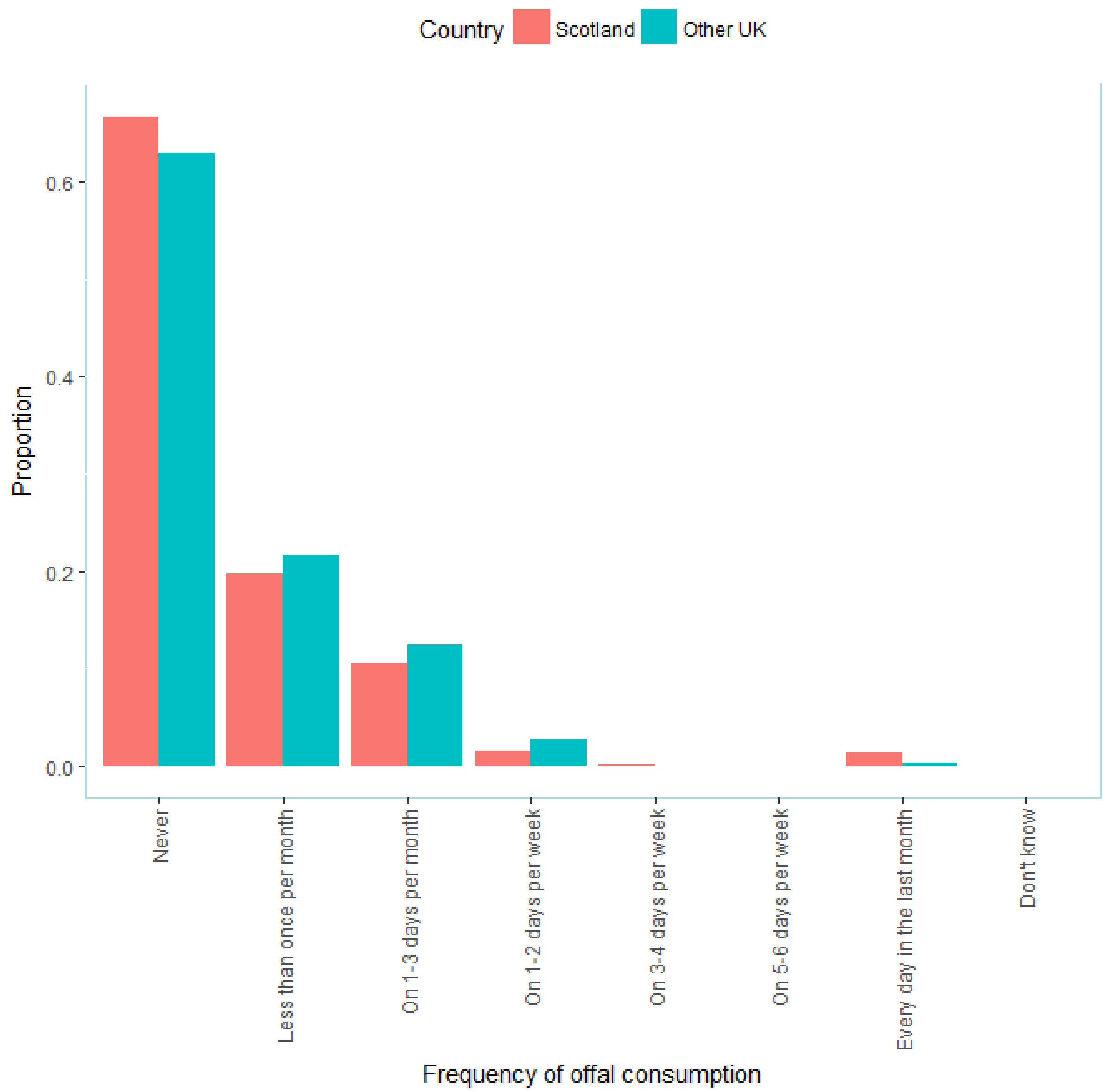

Figure 19. Summary of responses about frequency of consumption of offal, in the NDNS. The 2 rightmost columns represent the non-consuming proportion of the population. Scotland generally has a lower proportion of consumers, except for the most category (every day in the last month) consumers.

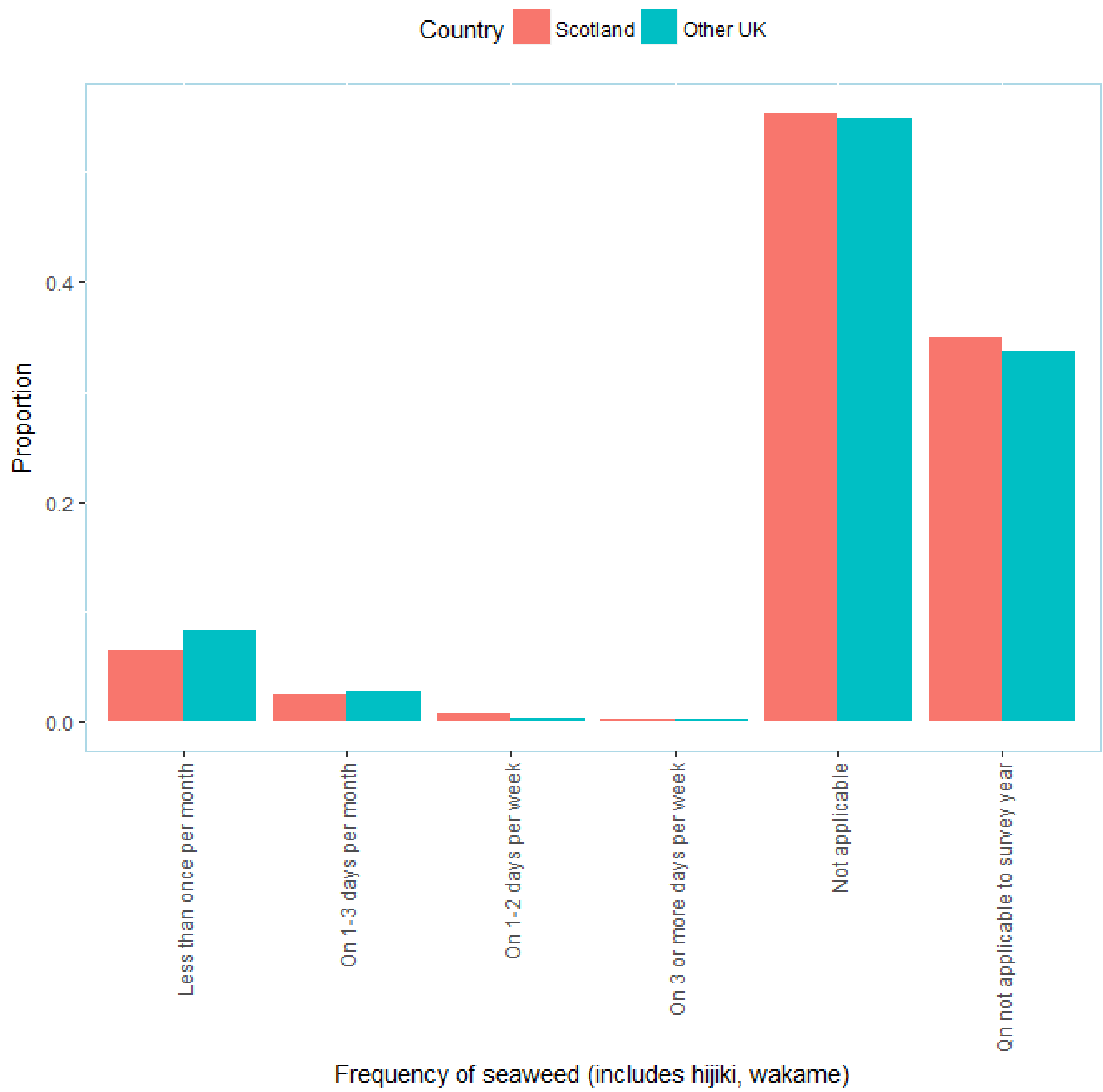

Figure 20. Summary of responses about frequency of consumption of seaweed, in the NDNS. The 2 rightmost columns represent the non-consuming proportion of the population. Scotland has a similar or lower proportion of consumers, compared to the rest of the UK

Often, due to the bodyweight scaling, children can be the most sensitive sub-population to consider in the risk assessment. However, dividing the data and separately displaying results for smaller sets of individuals can result in less accurate quantile estimates, particularly for high quantiles.

By using the aggregated consumption amounts per person, some day-to-day variation in consumed amounts has been averaged out. For acute health effects, the consumption per day (rather than the time-averaged daily consumption used here) should be considered. The corresponding exposure levels would be compared against acute reference dose levels. To take this into account would require recipe information to disaggregate the raw food items consumed on each day. This was not available within the current project and allowances for cooking are complex.

Frequency of takeaway and restaurant/café meal consumption

It was decided to include food eaten outside the home (at a restaurant or cafe) and takeaway food eaten in the home and compare the average Scottish consumption with the rest of the UK. The NDNS included separate questions about the frequency of takeaway meals (eaten at home) and meals eaten out at restaurants or cafes. The data were extracted and results summarised in Figure 21**Error! Reference source not found.** and (separated by age categories) in Figure 22**Error! Reference source not found.**, for the takeaway question, and Figure 23**Error! Reference source not found.** and Figure 24**Error! Reference source not found.** for the eating out question. Based on this survey a higher proportion the adult Scottish population (aged 19-64) consume takeaways at home or eat out; however this difference is generally small.

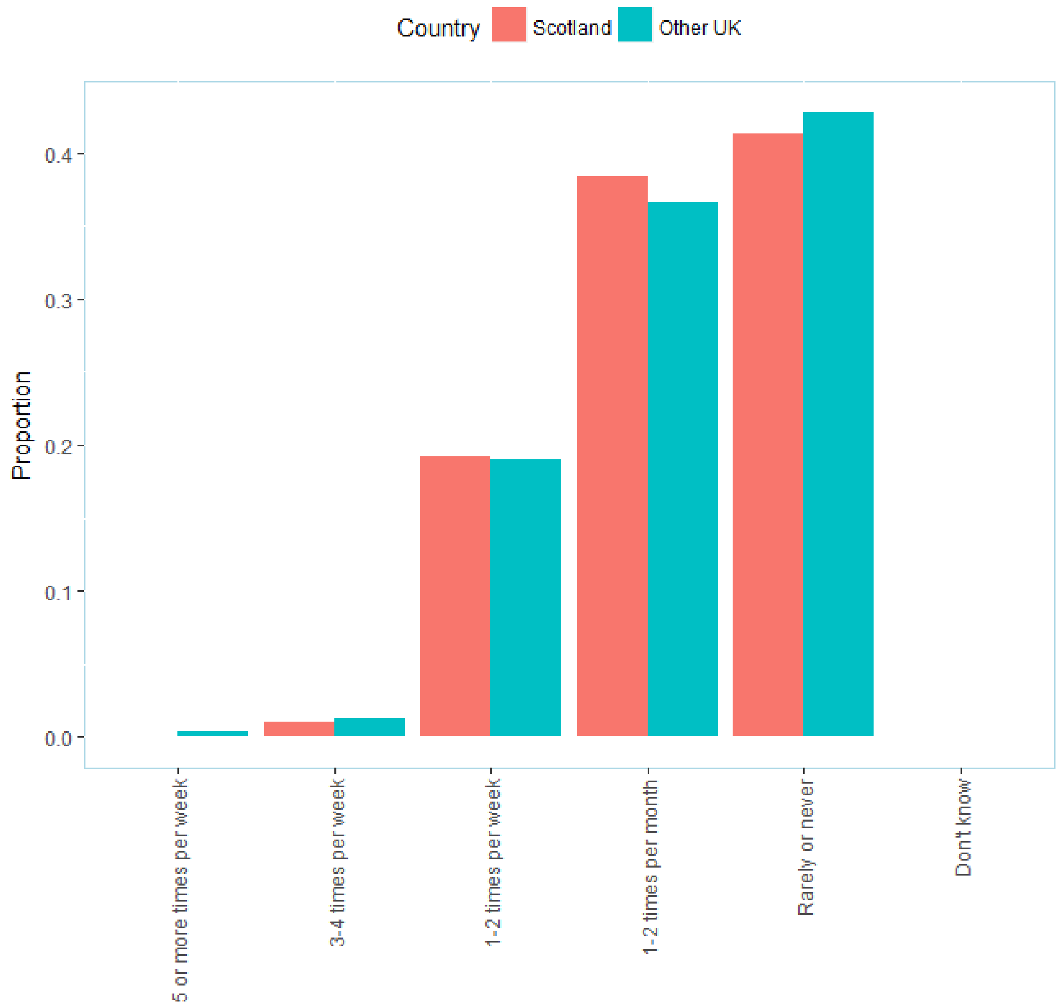

Figure 21. Summary of NDNS responses to the question of how often the individual consumes takeaway meals. The proportions are with respect to the relevant total subpopulation (Scotland or other UK).

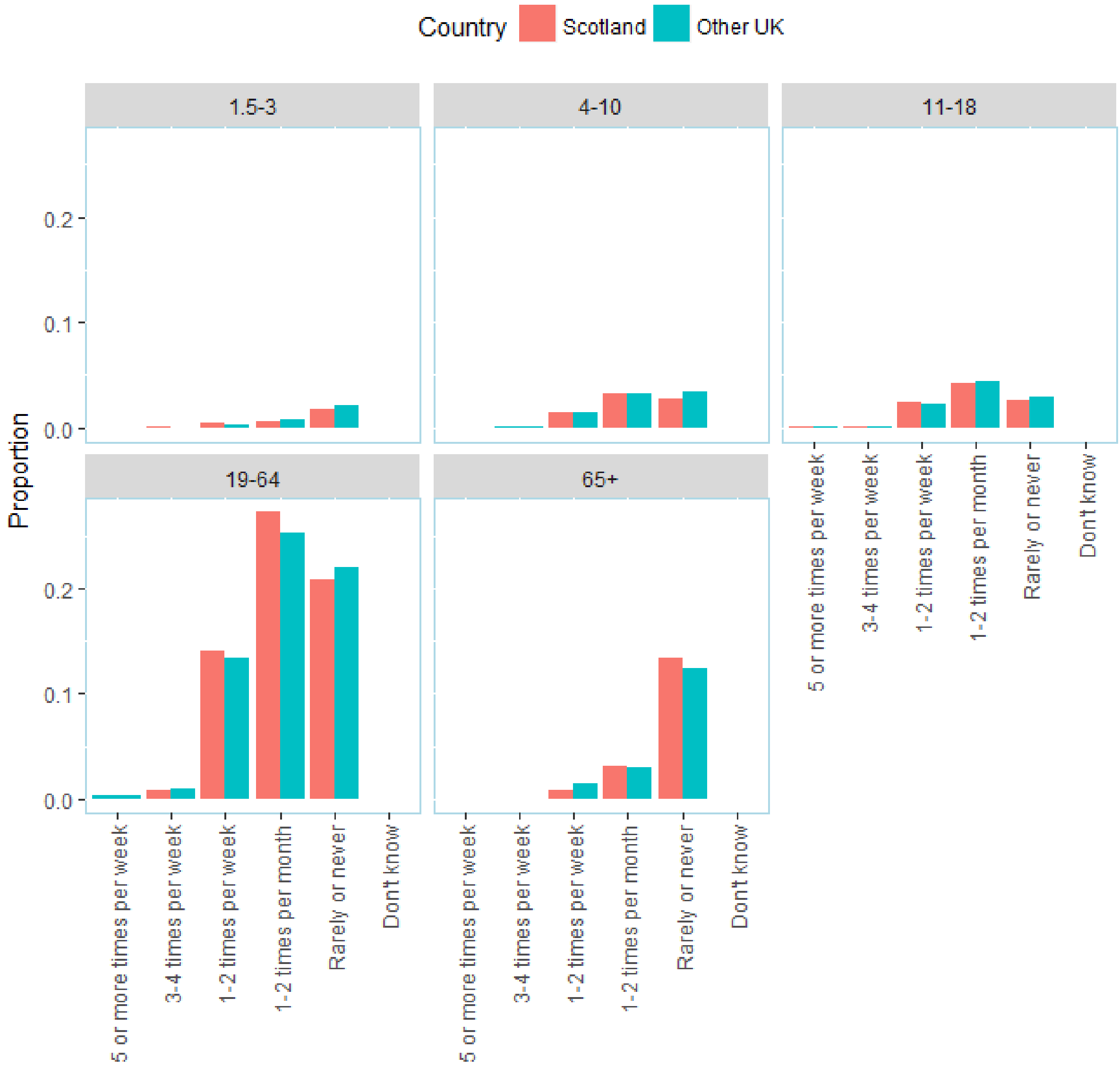

Figure 22. Summary of NDNS responses to the question of how often the individual consumes takeaway meals, by age category. The proportions are with respect to the relevant total subpopulation (Scotland or other UK).

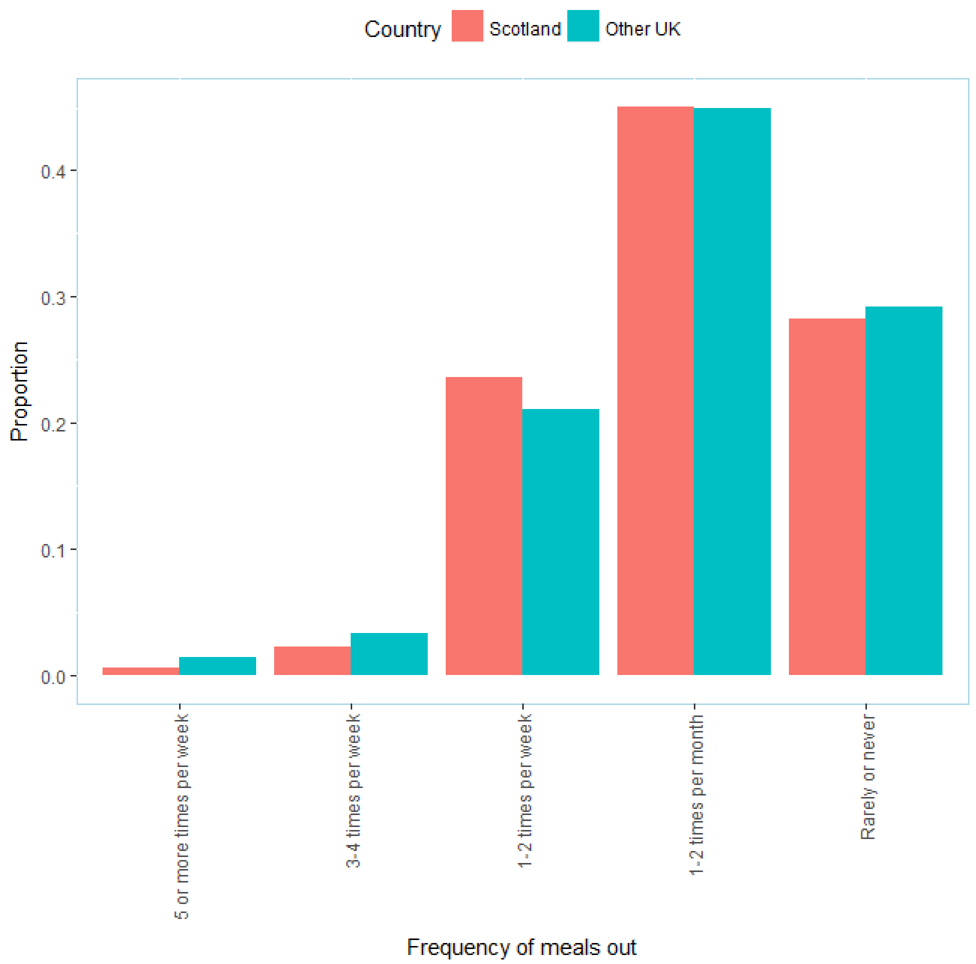

Figure 23. Summary of NDNS responses to the question of how often the individual consumes meals out. The proportions are with respect to the relevant total subpopulation (Scotland or other UK).

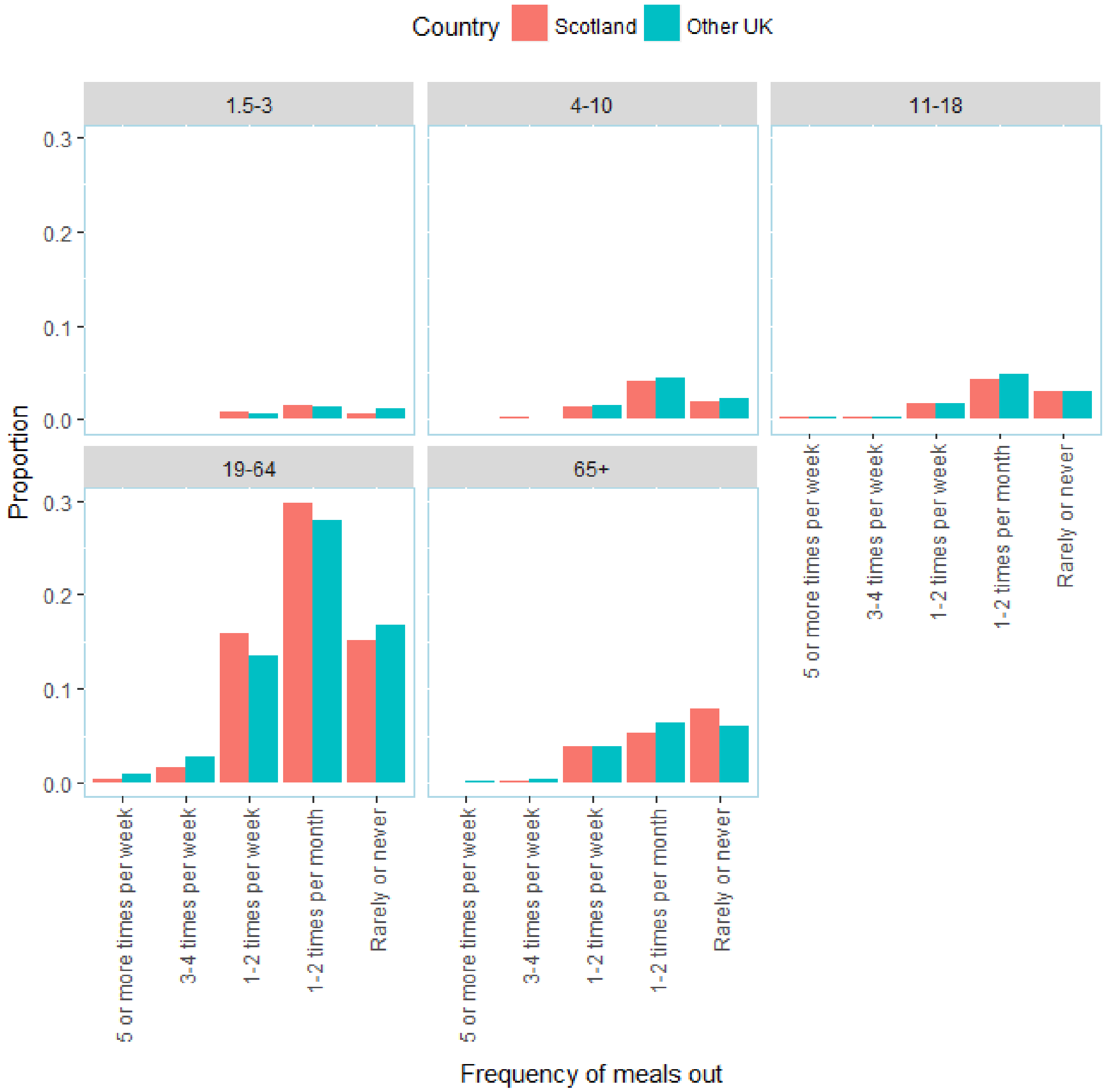

Figure 24. Summary of NDNS responses to the question of how often the individual consumes meals out, by age category. The proportions are with respect to the relevant total subpopulation (Scotland or other UK).

Appendix 4 – Results of literature and information sources review by contaminant

Metals

Lead

Background:

Food is one of the major sources of lead exposure in the UK, and offal tends to have the highest lead concentration of all foods. Since offal is not consumed in large quantities, the greatest contributions to the UK population dietary exposure for lead is from beverages, bread and other vegetables groups. EFSA stated that it was foods consumed in the greatest amount that had the biggest impact on dietary lead exposure; with grains and grain products (16.1%), milk and dairy products (10.4%), non-alcoholic beverages (10.2%) and vegetables and vegetable products (8.4%) contributing the greatest amount (EFSA, 2012). Results of the NDNS frequency question (Figure 9) suggests that Scottish consumers are less frequent consumers of offal in general. Lead accumulates in the body, and can cause various adverse health effects, the most important of which at low levels is impairment of intellectual and cognitive development in the foetus and child. Blood lead levels in children exposed pre- and post-natally are inversely associated with IQ, and there is no identified threshold for this effect.

In 2010, EFSA concluded that the previous provisional tolerable weekly intake PTWI of 25 µg/kg b.w. was no longer appropriate as there was no evidence for a threshold for critical lead-induced effects. In adults, children and infants the margins of exposures were such that the possibility of an effect from lead in some consumers, particularly in children from 1-7 years of age, could not be excluded. Protection of children against the potential risk of neurodevelopmental effects would be protective for all other adverse effects of lead, in all populations. Margins of Exposure (MOEs) for lead (lower bound – upper bound) ranged from 1.2 to 4.2 and from 0.51 to 1.81 for different population age groups. Hence, if exposure were closer to the upper bound estimates, there is a possibility that health effects could be observed in some consumers as a result of dietary exposure to lead (EFSA, 2010).

Literature search output:

There were 123 papers found in the global literature search; 27 papers when terms for Scotland were included; and 10 papers from the grey literature. This represents around 20% of all papers on industrial chemical contaminants.

One study looked at the correlation between blood lead and tissue lead concentrations in accidentally exposed cattle. The authors recommended that cattle with blood Pb > 25 g/L be withheld from slaughter and that liver, bone and kidney from all cattle with known lead exposure be withheld from the human food chain. (Bischoff et al. 2016). In the UK there are risk management procedures in place for lead incidents. For animals close to finishing weight a blood lead level of 0.15 - 0.48 µmol/L means the offal must be discarded by the abattoir; if over 0.48 µmol/L a risk assessment is also required to decide whether the carcase meat requires testing prior to release into the food chain (APHA, 2018). A review of childhood exposure to lead in Hong Kong concluded that even low levels of lead exposure can significantly impair learning, educational attainment, and neurodevelopment (Hon et al. 2017). Another study undertaken among mostly white, non-Hispanic men from a Veteran aging study in USA and Canada highlighted a higher lead body burden among middle aged to elderly men consuming a 'Western diet', typified by high intakes of processed meats, red meat, refined grains, high-fat dairy products, French fries, butter and eggs compared to those consuming a 'prudent dietary pattern', characterized by high intakes of fruit, legumes, vegetables, whole grains, poultry, and seafood, after other factors (smoking, weight, etc.) were taken into account (Wang et al. 2017). This 'Western diet' has strong similarities to the Scottish diet according to data published by Food Standards Scotland (Food Standards Scotland 2015a and 2016).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Lead shot used in game hunting can be a source of lead in some game meat products, and more game is produced in Scotland compared to other parts of the UK. Although the overall numbers are low, Scotland has a higher proportion of consumers, especially for frequent (1-2 days per week) consumers but the difference was not statistically significant. There are regular incidents where cattle are accidentally poisoned by lead. Between 2015 and 2017, 460 animals in Scotland were affected by lead poisoning, with 38 dying as a result. As well as not being able to sell the affected animal's produce, farmers can also face the costs involved in veterinary fees, stunted animal growth and loss of market value. FSS has published advice to farmers on measures to prevent this (Food Standards Scotland, 2017).

HorizonScan output

Total number of reports in the last 10 years: 356

A wide variety of products have been reported to contain high levels of lead. These include most recently durum wheat from Italy. There were also alerts about several types of herbs and spices, including turmeric, cinnamon and thyme; food supplements (zeolite and bentonite); fish; and seafood. Another major dietary source of lead could be from articles in contact with food, although not considered here there were a large number of reports of lead in ceramic and glass articles. There were also frequent reports of excessive levels of lead in animal feedingstuffs and feed additives (clays, minerals) for a range of species.

Summary of risk for lead to Scottish consumer and economy

Specific risks relating to lead for Scotland are related to lead shot used in game hunting which can be a source of lead in some game meat products, and any local sources as a result of regional geology, (historic) industrial activity or accident (e.g. discarded car batteries) that may lead to accidental poisoning of cattle. Although Scottish consumption of offal is not greater than the rest of UK, Scottish foods that contain offal, such as haggis, should be considered as a possible source of lead for Scottish consumers.

Cadmium

Background:

Cadmium has accumulated in the environment as a result of agricultural practices such as the use of cadmium-containing fertilizers and also from historic mining activities. A major use of cadmium is in nickel–cadmium dry-cell batteries; the metal also finds some use in the automobile industry. Exposure to cadmium can result in adverse health effects relating to kidney function (Rose, et al, 2010).

In 2009, EFSA established a tolerable weekly intake (TWI) for cadmium of 2.5 µg/kg b.w. (EFSA, 2009). The mean exposure for adults across Europe was close to, or slightly exceeded, the TWI. It was estimated that population subgroups such as vegetarians, children, smokers and people living in highly contaminated areas may exceed the TWI by about 2-fold. Although the risk for adverse health effects on kidney function at an individual level at dietary exposures across Europe was very low, the current exposure to Cd at the population level should be reduced. (EFSA, 2009).

Literature search output:

There were 81 papers identified in the global literature search, 22 when terms for Scotland were included and no papers identified in the grey literature.

A UK survey of brown crab meat reported cadmium levels in the range of 0.01 to 26 mg/kg. There is no legal limit for brown crab meat, but the mean concentrations found in the survey (3.4 mg/kg) exceeded the maximum limit of 0.5 mg/kg that applies to the white meat from the claw (Bolam et al. 2016).

Expert review of literature i.e. outside period or issues not picked up

Cadmium and lead were determined in fruit and vegetable produce in a field and market basket study of locally grown produce from the South-West of Britain (Devon and Cornwall). These were compared with similarly locally grown produce from the North-East of Britain (Aberdeenshire). The SW of Britain was chosen because of its history of mining, while the NE has limited, and localised, metal extraction industries. Growing produce on mine impacted soils can have an effect on the accumulation of heavy metals in the edible parts of the plants, leading to accumulation of toxic metals. For cadmium, 2 samples (0.2%) from NE Scotland exceeded the Maximum Limit, the produce with the highest concentrations categorised loosely as open leaf structure vegetables, i.e. produce that has a large surface area relative to its mass. Some produce (e.g. open leaf structure vegetables) are susceptible to contamination arising from soil/dust deposition, which may increase concentrations of the elements and may not be removed before cooking without adequate washing. In addition, cultivar, soil type and pH and use of inorganic fertilisers can all affect cadmium uptake in plants. The concentrations of cadmium and lead found in fruits and vegetables sampled during this study did not increase concern about risk to human health (Norton et al, 2015). A study funded by the Food Standards Agency (FSA, 2015) reported cadmium levels in brown crab meat ranged from 0.01 to 26 mg/kg wet weight (w.w.). The mean and median Cd concentrations were found to be 3.4 and 2.8 mg/kg w.w., respectively, compared to the ML of 0.50 mg/kg that applies to the white meat (EC, 2006). Samples for the study were taken all over the UK, but the results did not identify where the highest levels were found so it was not possible to determine whether there was an issue particular to Scotland. A follow up study to measure Cd levels in crab hepatopancreas and other edible organs found the mean Cd concentration was 4.0 mg/kg wet weight (w.w.), while the mean Cd concentration in other edible tissues from the cephalothorax was 0.27 mg/kg w.w. Samples were taken from 4 sites in the UK (2 in Scotland), but were combined and homogenised before analysis so there are no data specifically for Scotland (FSA, 2015).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Scotland is a major supplier of potatoes which can take up cadmium and other metals from the soil. However, no specific issues were identified for Scotland from the literature or from the UKFSS sampling for July 2016 to June 2017, where 95 samples were analysed for cadmium (information on sample type not known), and 100% were classified as satisfactory.

HorizonScan output

Total number of reports: 853

There were reports of cadmium in a range of foodstuffs including, fish and seafood (mainly cephalopods and squid); crustaceans; vegetables; cocoa; meat (mainly horse meat); poppy seeds and seaweed. Animal feedingstuffs were reported frequently. There were also large number of reports of Materials and Articles in Contact with Food that contained high levels of cadmium.

Summary of risk for cadmium to Scottish consumer and economy

No particular areas of concern for Scotland were identified. Products to be considered for monitoring would include crab and other shellfish, as well as potatoes and open leaf green vegetables.

Mercury

Background:

Sources of mercury contamination are environmental, industrial and agricultural. Exposure to mercury is mainly from the diet and dental amalgam. Mercury can exist in inorganic and organic forms in food, with the organic forms, such as methylmercury, being more toxic following ingestion. Adverse health effects include neuro-developmental effects in the embryo and foetus.

In 2012, EFSA established a TWI for methylmercury of 1.3 µg/kg b.w. expressed as mercury (EFSA, 2012a). The mean dietary exposure across age groups did not exceed the TWI for methylmercury, with the exception of toddlers and other children in some surveys. The medians of 95th percentile dietary exposures across surveys were close to or exceeded the TWI for all age groups. High consumers of fish meat may exceed the TWI by up to approximately six-fold. Unborn children constitute the most vulnerable group for developmental effects of methylmercury exposure, and pregnant women could be present in the group of high and frequent fish consumers.

There are recommendations for the maximum number of portions of different types of fish that should be consumed each week, these are different for different groups of people, e.g. children, pregnant women or women planning to become pregnant should not consume swordfish, marlin or shark as these contain more mercury than other fish, whereas other adults are advised to eat no more than one portion of these per week (NHS, 2018). At the same time in 2012, EFSA established a TWI for inorganic mercury of 4 µg/kg b.w., expressed as mercury. The estimated exposure to inorganic mercury in Europe from the diet alone did not exceed the TWI, but when additional sources of exposure such as inhaled mercury vapour from dental amalgam were considered, it was possible that the TWI could be exceeded (EFSA, 2012a).

Literature search output:

There were 64 papers identified for mercury from the global literature search, 29 when terms for Scotland were included and 2 papers in the grey literature.

There were several papers reporting the incidence of mercury in a range of foods including fish used in Sushi restaurants in Brazil ((Alves et al. 2017); methylmercury in rice based infant foods (Cui et al. 2017); and mercury in whey protein (de Aquino et al. 2017).

A study to assess mercury pollution in food crops grown near coal-fired power plants reported total mercury concentration in vegetables and grain crops collected from farms located near two coal-fired power plants. 79% of vegetable samples and 67% of grain samples exceeded the PTWIs. Mercury concentrations in soil samples were negatively correlated with distances from the studied coal-fired power plants, and the mercury contents in leafy vegetables, cowpea and rice samples correlated with the mercury contents in the soil samples, respectively. The mercury concentrations of vegetable leaves were much higher than in roots and the mercury content of vegetable leaves decreased significantly after water rinses (Li et al. 2017).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Mercury consumption is associated with fish, particularly predatory species such as shark and swordfish. Although no particular Scottish issues were identified, fish production is an important industry for Scotland and it is important to ensure that fish comply with regulatory limits as set out in Commission Regulation (EC) No 1881/2006 and amendments (European Commission, 2006). Crops, including vegetables, grown near industrial sites, including mines and smelting sites, sites may also show increased mercury (and other heavy metals) levels (Wuana and Okieimen, 2011).

HorizonScan output

Total number of reports: 1473

Most reports related to seafood and fish, with swordfish, shark, marlin and tuna as the main species reported, although some crustaceans were also reported. Food supplements and animal feedingstuffs were the other two main groups with a large number of notifications about mercury.

Summary of risk for mercury to Scottish consumer and economy

Mercury exposure is associated with fish consumption, particularly predatory species such as shark and swordfish. Although no particular Scottish issues were identified, fish production is an important industry for Scotland and it is important to ensure that fish comply with regulatory limits, and that consumption patterns in Scotland do not erode safety margins to an unacceptable level.

Arsenic

Background:

Arsenic is widely distributed in the Earth's crust and is present in the environment from natural sources, such as rocks and sediments and as a result of activities such as coal burning, copper smelting and the processing of mineral ores. It occurs in soil, waters (both marine and fresh), and in almost all plants and animal tissues, e.g. potatoes grown in lead arsenate contaminated soil (Codling et al. 2016). Levels of arsenic are higher in the aquatic environment than in most areas of land as it is fairly water soluble and may be washed out of arsenic bearing rocks. As a consequence, levels of arsenic in fish and seafood are usually high, because fish absorb arsenic from the water (Cott et al. 2016). The toxicity of arsenic is dependent on the chemical form in which it is present. Most arsenic in the diet is present in the less toxic, organic form, however a recent study has shown that organic arsenic from seafood can have an effect on thyroid hormones and function (Molin et al. 2017). The inorganic form is the more toxic species and is a known genotoxic carcinogen. Arsenic occurs in a wide range of foods and the majority of arsenic in the diet comes from fish and fish products; however, more than 97% of the total arsenic in fish is in the less toxic organic form.

Making a number of assumptions for the contribution of inorganic arsenic to total arsenic, the inorganic arsenic exposure from food and water across 19 European countries, using lower bound and upper bound concentrations, was estimated by EFSA to range from 0.13 to 0.56 µg/kg bodyweight (b.w.) per day for average consumers, and from 0.37 to 1.22 µg/kg b.w. per day for 95th percentile consumers (EFSA, 2009a). Dietary exposure to inorganic arsenic for children under three years of age was estimated to be from 2 to 3-fold higher than for adults. A range of benchmark dose lower confidence limit (BMDL01) values between 0.3 and 8 µg/kg b.w. per day was identified for cancers of the lung, skin and bladder, as well as skin lesions. The estimated dietary exposures to inorganic arsenic for average and high level consumers in Europe were stated to be within the range of the BMDL01 values identified, and therefore there was little or no margin of exposure and the possibility of adverse health effects in some consumers as a result of dietary exposure could not be excluded (EFSA, 2009a).

Literature search output:

There were 138 papers identified for arsenic from the global literature search, 39 when terms for Scotland were included and no papers from the grey literature were retrieved.

There are several reports in the historic literature (i.e. the period prior to that covered by the search performed for this report) of the presence of arsenic in seaweed. There are sheep in Orkney whose diet consists mainly of seaweed, and these have been studied to assess any health impact to the sheep and to consumers of the meat produced, as a result of the high arsenic contained in the seaweed (Feldmann et al, 2000). This sheep population and consequences for food production has been widely studied and reported in the literature. The arsenic concentration in the tissue and the wool was at least 2 orders of magnitude higher than for non-exposed sheep, but arsenic levels did not reach the UK guideline maximum allowed in foodstuffs (1 mg As per kg fresh weight). The arsenic speciation in the urine revealed that the arsenosugars were taken up by the sheep and excreted mainly as dimethylarsinic acid (DMAA) into the urine. It has been proposed this particular breed of sheep is resistant to large quantities of inorganic arsenic, since there is a several hundred year's tradition of having sheep on the beach and they have shown no adverse effects (Feldmann, 2001). Recent reports highlighted the presence of arsenic in commercial seaweed products and noted that due to the unique arsenic metabolites formed it may be possible to identify dietary intake of arsenic from seaweed from other exposure routes (Taylor and Jackson 2016, Taylor et al. 2017).

Consumption of rice sourced from regions where there is a problem with contaminated groundwater, such as some regions of Bangladesh, can be a major source of arsenic. This has been subject of many reports and is widely published in the scientific literature. This can be a particular problem to infants and small children because of the use of rice in infant-specific foods (Karagas et al. 2016, Rothenberg et al. 2017, Signes-Pastor et al. 2016).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Arsenic exposure is associated with fish consumption, and also with some species of seaweed. Although no particular Scottish issues were identified, fish production is an important industry for Scotland and it is important to ensure that fish comply with regulatory limits, and that consumption patterns in Scotland do not erode safety margins to an unacceptable level. The total amounts of arsenic in seaweed, and the arsenic species that are found, varies considerably between varieties of seaweed (Rose et al, 2007). Figure 10 shows seaweed consumption frequency to be lower in Scotland than the rest of the UK.

High consumers of rice, including infants and young children and some ethnic groups may also be at risk due to the presence of arsenic in rice, although this is not an issue specific to Scotland.

HorizonScan output

Total number of reports: 219

A broad range of products have been reported to contain high arsenic levels, including rice, and rice products and including infant foods; food ingredients such as salt and other chemicals used as food additives; fungi; seafood and beverages. Animal feedingstuffs and feed additives were also frequently reported, as well as articles in contact with food which can contain significant levels of arsenic and so would add to daily intake.

Summary of risk for arsenic to Scottish consumer and economy

With current increases in farming of seaweed for food use, arsenic may be of particular interest in these products from Scotland. Rice consumption may also be a concern for some groups of the population, particularly infants and young children.

Nickel

Background:

Nickel is another metal that is widely present in the Earth's crust. It has several industrial applications and is used in the manufacture of batteries, alloys and jewellery. Nickel is present in most foods. In a UK Total Diet Study, it was detected in most of the food groups except Carcass meat, Poultry, Oils and fats, Eggs and Milk. Concentrations of nickel in the other food groups varied from 0.02 mg/kg for the Offal group to 3.2 mg/kg for the Nuts group (Rose et al, 2010)

EFSA (EFSA, 2015) reported that reproductive and developmental toxicity in experimental animals was the critical effect for risk assessment of chronic effects of nickel and established a tolerable daily intake (TDI) of 2.8 µg Ni/kg body weight (b.w.) per day. The current dietary exposure to nickel as estimated by EFSA raised concern when considering the mean and 95th percentile chronic exposure levels for all different age groups. Systemic contact dermatitis (SCD) elicited in Ni-sensitive humans after oral exposure to nickel was selected as the critical effect for the risk assessment of acute effects of nickel. The Margins of Exposure (Moe) calculated considering the estimated mean and the 95th percentile acute exposure levels were considerably below 10 for all age groups, which was considered to be indicative of a low health concern. The Committee on Toxicity issued a statement on potential risks from nickel in infants and young children (COT, 2018). They concluded that all nickel exposures were below the TDI of 20 µg/kg bw for infants and young children. Although some exceedance of the ARfD was reported, it was stated that the effect from acute exposure in sensitised individuals could be a dermal reaction, which although unpleasant is not life-threatening.

Literature search output:

There were 40 papers identified for nickel from the global literature search, 8 papers when terms for Scotland were included and one paper from the grey literature.

Consumption / exposure / of Scottish population and Production / industry in Scotland

No specific issues of concern for Scotland over and above wider populations were identified.

HorizonScan output

There were 343 reports in HorizonScan, the reports all related to potential migration of nickel from articles in contact with foodstuffs, ranging from barbecue grills, vegetable peelers, hand blenders and stainless steel cookware.

Summary of risk for nickel to Scottish consumer and economy

There is no specific risk to Scottish consumers or the Scottish economy due to the occurrence of nickel and this should be viewed as a low priority.

Iodine

Background:

As with metals and other elements, the halogens (fluorine, chlorine, bromine, iodine, and astatine), are present naturally in food as a result of their presence in the environment, for example, in seawater, soils and rocks. They may also be present as a result of human activities. Iodine compounds are used in the dairy industry to sterilise cows' teats and milking tanks and may be added as nutritional supplements to animal feeds.

Iodine is an essential nutrient required for the synthesis of thyroid hormones. The most well-known iodine deficiency disorder (IDD) is enlargement of the thyroid gland (goitre). Iodine deficiency can also result in a wide range of mental, psychomotor and growth abnormalities as well as increased infant mortality. Although iodine deficiency is of concern, there are also health concerns associated with high levels of iodine in the diet. Excessive exposure to iodine can inhibit the function of the thyroid gland and produce symptoms including goitre and impaired brain function. Iodine concentrations were measured in seaweed eating sheep in Orkney during a feeding experiment. More than 66% of the total iodine ingested by the sheep was excreted within 24 h. Tissue samples from feral North Ronaldsay sheep taken directly from the beach showed elevated iodine levels, with iodine concentrations 17 times higher than those of non-exposed sheep. A trend of continuous accumulation of iodine in the liver and kidney throughout the life of the sheep was observed. No assessment of the impact of consuming these tissues was made (Lu et al, 2006).

EFSA assessed Dietary Reference Values for iodine in 2014 (EFSA, 2014). This report referred to the SCF (2002) report that adopted the value of 600 µg/day as a Tolerable Upper Intake Level (UL) for adults including pregnant and lactating women on the basis of dose-response studies of short duration (two weeks) and in a small number of subjects (n = 10 – 32).

Literature search output:

There were 7 papers identified for iodine from the global literature search, with 3 of these specifically related to seaweed.

There were no papers identified when terms for Scotland were included and only 1 paper grey literature that was on the topic of endocrine activity.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Interrogation of notifications identified on 'HorizonScan' showed 150 notifications related to high iodine in seaweed, alginate and carrageenan of levels up to 5000 mg/kg in some seaweed from China. The NHS recommends an adult needs 0.14 mg iodine per day, in 2006 the Scientific Committee for food established an upper limit for iodine intake of 600 µg/day (0.6 mg/day) for adults and 200 µg/day for children (Scientific Committee for Food, 2006). Therefore consumers of seaweed containing excessive levels (e.g. more than 20 mg iodine/kg dry matter, European Union, 2018) of iodine will be at risk, although there is no evidence that Scottish consumption of seaweed is higher than other parts of the UK (Figure 20).

HorizonScan output

Iodine is an essential element but can be of concern at high levels. Interrogation of notifications identified on ‘HorizonScan’ showed 187 notifications for iodine in total, and 150 related to high iodine in seaweed.

The main sources of the seaweed were Asia, predominantly China, The Republic of Korea and Japan. However there were also a significant number of reports from Europe, mainly Spain and Germany, although there were none from the UK.

Summary of risk for iodine to Scottish consumer and economy

Interrogation of notifications identified on ‘HorizonScan’ showed 150 notifications related to high iodine in seaweed. While none of the notifications referred to seaweed of Scottish or UK origin, although no monitoring was carried out during the UKFSS sampling so there are no data to evaluate the issue. This potential hazard should be borne in mind by seaweed producers and is an area that should be considered for future FSS surveillance, particularly in view of Commission Recommendation (EU) 2018/464.

Halogenated POPs

Dioxins and PCBs

Background:

Polychlorinated Dibenzo-p-dioxins/Dibenzofurans (PCDD/Fs; dioxins) and polychlorinated biphenyls (PCBs) bioaccumulate in the food web due to both their stability and lipophilicity, and they are listed as persistent organic pollutants (POPs) by the World Health Organization (WHO).

PCDD/Fs are formed by a variety of industrial and other processes. Due to their persistence and chemical stability these contaminants can be found ubiquitously in the environment, soil, sediments, and air (particle-bound). Due to their lipophilicity they accumulate in the food chain and ultimately enrich in human fatty tissue and liver. PCDD/Fs can be readily detected in all kinds of food, especially in fatty food of animal origin. The total PCDD/F content of a sample is usually given in TCDD equivalents (TEQ), a sum parameter, which takes into account the relative toxicities of the individual congeners, using the toxic equivalency factor (TEF) concept. PCBs were manufactured until the last half of the twentieth century, and some PCBs exhibit dioxin-like toxicity and are included in the TEF scheme. Other PCBs exhibit different toxicities.

EFSA compared different internationally recognised health-based guidance values (HBGVs) for dioxins and dioxin-like PCBs in 2015 (EFSA, 2015a). Those HBGVs considered are discussed below:

The Scientific Committee on Food (SCF) adopted on 30 May 2001 an Opinion on dioxins and dioxin-like PCBs in food, fixing a TWI of 14 picogrammes (pg) World Health Organisation toxic equivalent (WHO-TEQ)/kg body weight (b.w.) for dioxins and dioxin-like PCBs (SCF, 2001).

The Joint Expert Committee on Food Additives (JECFA) of the WHO and from the UN Food and Agriculture Organisation (FAO) established in June 2001 a provisional tolerable monthly intake (PTMI) at 70 pg/kg b.w. for dioxins and dioxin-like PCBs.

Converted to a tolerable daily intake, the SCF health-based guidance value of 2 pg/kg b.w. is in line with the JECFA value of 2.3 pg/kg b.w.

In 2008 EFSA used the TWI established by the SCF to estimate the risk for public health due to the presence of dioxins in pork from Ireland. In February 2012, the US Environment Protection Agency (US EPA) confirmed the oral reference dose (RfD) of 0.7 pg/kg b.w. per day for dioxins. In addition, the U.S. Agency for Toxic Substances and Disease Registry/Center for Disease Control and Prevention (ATSDR) has established a chronic-duration oral Minimal Risk Level (MRL) of 1.0 pg/kg b.w. per day for dioxins (EFSA, 2008).

Since population exposure estimates suggest that a proportion of the population exceeds these HBGVs, there is a potential dietary risk from dioxins and PCBs in food. EFSA is currently undertaking a new risk assessment for dioxins and PCBs and results should be published later in 2018.

Literature search output:

There were 21 papers identified for dioxins and PCBs from the global literature search, but none when search terms for Scotland were included and no papers from the grey literature.

EFSA is currently undertaking a risk assessment for PCDD/Fs and dioxin-like PCBs, and the implications of any changes to health based guidance values (HBGVs) need to be considered once this is finalised.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Due to their lipophilicity and bioaccumulation in the food chain, dioxins and PCBs can be found at high levels in fish and seafood (especially oily fish and fish oil products) and in meat and offal. Since fish and game are key industries in Scotland, and because oily fish and fish products, and game meat and offal can be of particular concern for dioxins and PCBs, these are important contaminants of concern for the Scottish consumer and industry. There are no recent data (last years) from the UKFSS sampling on dioxins and PCBs.

HorizonScan output

Total number of reports: 357

A diverse range of products were reported to contain dioxins and PCBs. These included meat (pork, lamb, chicken, offal); eggs; oils and fats (particularly fish oils); seafood; dried apple pomace; and cereals. Animal feedingstuffs, mineral feed additives and premixes were also frequently reported. The country of origin for the reports varied, there have been recent reports of dioxins in herbal mixtures for cattle from Germany, but Ukraine, The Netherlands, Spain, Poland, Brazil, India and China have all been the subject of reports in the last two years.

Summary of risk for dioxins and PCBs to Scottish consumer and economy

Since fish and game are key industries in Scotland, and because oily fish and fish products, and game meat and offal can be of particular concern for dioxins and PCBs, these are important contaminants of concern for the Scottish consumer and industry. Care should be taken with animal feeding products, especially minerals and feed additives, to ensure regulatory compliance including periodic testing to ensure levels of these contaminants do not exceed maximum permitted levels.

Brominated dioxins and biphenyls

Background:

Sources and health effects associated with this class of compounds are as for chlorinated dioxins and PCBs, discussed above.

There are very few papers in the scientific literature on this class of compounds, but this is more likely to reflect the complexity and cost of analysis, rather than their importance as a class of emerging contaminant. There are very few laboratories with the capability for measuring these compounds and consequently only few papers in the scientific literature. This class of compounds consists of brominated analogues (PBDD/Fs and Polybrominated Biphenyls (PBBs)) of the chlorinated dioxins discussed above. PBDD/Fs are formed in a similar manner to PCDD/Fs during combustion processes such as incineration. However, they can also occur as trace contaminants in BFRs such as PBDEs, and studies on formation chemistry show that the incineration of products containing BFRs as well as thermolysis of BFR materials such as PBDEs are important sources of PBDD/F emissions.

In general, foods contain lower levels of PBDD/Fs and PBBs (typically 20-40%) when compared to their chlorinated analogues, but whereas the chlorinated compounds are decreasing in the environment and in food, use of bromine compounds for example as flame retardants is increasing resulting in the potential for PBDD/Fs to be increasing.

The WHO have stated that the TEF values for chlorinated dioxins should be applied to their brominated analogues as an interim basis, but there are no internationally recognised HBGVs specifically for this class of compound (van Berg, et al, 2013).

Literature search output:

No papers were identified in the literature search for brominated dioxins and biphenyls.

Although this class of compounds is not currently regulated, they are known to have the same mode of toxic action as the chlorinated dioxins and PCBs. At its last review of toxic equivalency factors (van den Berg et al, 2006), the WHO stated that '…Based on mechanistic considerations, PCB 37, PBDDs, PBDFs, PXDDs, PXDFs, PCNs, PBNs, and PBBs undoubtedly belong in the TEF concept', and on this basis these classes of compounds could potentially at some point in the future be included in regulations.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Concerns for Scotland are as for the rest of the UK and are as for the chlorinated dioxins which are regulated.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Summary of risk for brominated dioxins and biphenyls to Scottish consumer and economy

Concerns for Scotland are as for the chlorinated dioxins.

Poly- and per- fluorinated alkyl substances (PFASs)

Background:

There are many substances that are included in this class of compounds, the most studied and the most prevalent being Perfluooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA).

The monomers and low-molecular-weight products are liquid surfactants, whereas the higher molecular weight oligomers, polymers, and esters are used for stationary surface treatments. PFASs are or have been used extensively in industrial polymers (Teflon, SilverStone); as waterproofing agents (Gore-Tex), stain repellents (ScotchGard, Stainmaster), and firefighting foams (AFFF); and in grease-proof food packaging materials (Zonyl). The carbon-fluorine covalent bond is strong and resistant to breakdown processes such as hydrolysis, photolysis, and microbial or mammalian metabolism. PFOS degrades only slowly, if at all, and persists in the environment. In biota it bioaccumulates, probably by covalent protein binding to the sulfhydryl groups in blood, liver, and other organs.

Drinking water can be a major source of PFASs where this has been contaminated around production plants or locations where these compounds are used on an industrial scale. Contaminated water can then result in contaminated foods that are produced in the same localities. No particular sites in Scotland were identified by the literature search, but it is prudent to be aware of potential contamination issues if industrial uses are identified in future.

In 2008, EFSA calculated an indicative dietary exposure of 60 ng/kg b.w. per day for PFOS which was below the TDI of 150 ng/kg b.w. (EFSA, 2008a). It was noted that the highest exposed people within the general population might slightly exceed this TDI. The same report gave an indicative human average and high level dietary exposure for PFOA of 2 and 6 ng/kg b.w. per day, respectively, which was well below the TDI of 1.5 µg/kg b.w. per day. Since that time, new studies about the health effects of PFOS and PFOA, and other PFASs have become available and EFSA are currently conducting a new risk assessment. The results of this work should be available soon for PFOS and PFOA, and later in 2018 for other PFASs.

Literature search output:

There were around 40 papers identified for PFASs from the global literature search, none when terms for Scotland were included and 4 papers from the grey literature.

Papers were found that reported PFAS in fish ((Babut et al. 2017, Bertin et al. 2016), breast milk (Lee et al. 2018), eggs (Zafeiraki et al. 2016) and milk and yoghurt (Xing et al. 2016).

Expert review of literature i.e. outside period or issues not picked up

Current estimates of exposure show that most consumers are well below recognised health based guidance values (HBGVs). There is a current scientific re-evaluation of PFASs underway by EFSA, and if this suggests that the HBGV should be lower, then the importance of this class of compounds would need to be re-considered.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that contain highest levels of PFOS and PFOA include fish and fish products, and meat offal. Due to the importance of these commodities to Scotland, both in terms of food production and to the consumer, this contaminant class should be seen as important.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Summary of risk for Poly- and per- fluorinated alkyl substances to Scottish consumer and economy

Food types that contain highest levels of PFOS and PFOA include fish and fish products, and meat offal. Due to the importance of these commodities to Scotland, both in terms of food production and to the consumer, this contaminant class should be seen as important. There is a current scientific re-evaluation of PFASs underway by EFSA, and if this suggests that the HBGV should be lower, then the importance of this class of compounds would need to be re-considered.

Polycyclic aromatic hydrocarbons (polyaromatic hydrocarbons; PAHs)

Background:

Polycyclic aromatic hydrocarbons (PAHs) are composed of hydrogen and carbon atoms placed in two or more benzene rings. More than a hundred different PAH compounds exist and almost always in mixtures. The term polycyclic aromatic compounds (PACs) covers PAHs with additional components such as nitrogen, sulphur or oxygen found in, for example, mineral oil. PAHs are found in environmental depositions, as a result of environmental pollution (e.g. oil spills), and can arise as a result of human activity (e.g. traffic, incineration, etc.) as well as during processing of food (e.g. smoking, drying, barbecuing, etc.). The major route of human exposure to PAHs for non-smokers is from food. Some PAHs are recognised as genotoxic carcinogens, and exposure should therefore be as low as reasonably practicable (ALARP principle).

EFSA evaluated PAHs in 2008 (EFSA, 2008b) which resulted in the identification of the 4 marker PAH (PAH4) compounds (benzo[a]pyrene, chrysene, benz[a]anthracene and benzo[b]fluoranthene) which were later to become the focus of regulation. EFSA also considered using PAH2, PAH4, PAH8 and PAH15 models for exposure. The EFSA assessment presented resulting MOEs for average consumers of 17,900 for benzo[a]pyrene, 15,900 for PAH2, 17,500 for PAH4 and 17,000 for PAH8. For high level consumers, the respective MOEs were 10,800, 9,500, 9,900 and 9,600. These MOEs indicated a low concern for consumer health at the average estimated dietary exposures.

Literature search output:

There were 46 papers identified for PAHs from the global literature search, none when terms for Scotland were included and 4 papers from the grey literature search.

A Chinese study showed vegetable oils contained PAHs, these increased with increased frying times or repeated use for the oils, and they recommended that repeated use of cooking oils should be avoided (Hao et al. 2016). PAHs were reported in other foods such as fish, traditional infusions (mate) and vegetable oils. The effects of time, cooking method, pH and marinades on PAH formation were also reported in the literature (Park et al. 2017, Wongmaneepratip and Vangnai 2017).

Consumption / exposure / of Scottish population and Production / industry in Scotland

No particular areas of concern were identified for Scotland from the literature search, but local speciality smoked foods such as smoked fish products are likely to be sources of PAHs.

HorizonScan output

Total number of reports: 312

PAHs have recently been reported in bay leaves, sunflower oil, cocoa cake, coconut oil, almond oil, dried garlic, black pepper, meat products and food supplements.

Summary of risk for polycyclic aromatic hydrocarbons to Scottish consumer and economy

No particular areas of concern were identified for Scotland from the literature search, but local speciality smoked foods such as smoked fish products are likely to be sources of PAHs and there is the potential for incidents in the Scottish oil industry to affect the food chain, e.g. from industrial accidents, spills or leakages from pipes.

Polychlorinated Naphthalenes (PCNs)

Background:

Chlorinated polycyclic aromatic hydrocarbons consist of a vast group of little studied environmental contaminants of anthropogenic origin. PCNs are the subset of 75 congeners of this group that contain a fused 2 benzene ring structure, and are the most studied subgroup of these compounds. They have recognized toxic, bio-accumulative, and persistence properties, which coupled with the similarity in structural planar configuration to some PCBs and dioxins, can bestow a dioxin-like mode of toxic action. PCNs are an industrial chemical, produced over most of the 20th century, although their manufacture is currently banned in some countries. They were sold as technical mixtures (e.g., Halowax in the United States, Nibren in Germany, Seekay in the United Kingdom, etc.) of the commercial PCN product in mineral oil. The mixtures differed in the percentage of chlorine present on the naphthalene molecule, ranging from monochloro - to octachlorosubstituted naphthalene.

Like the brominated dioxins, there is little reported of this class of contaminant in the literature, but this probably reflects that low number of laboratories with the capability for measuring them, and the high cost of analysis, rather than their importance in terms of risk to the consumer.

EFSA have not evaluated PCNs and these compounds are not regulated in food in Europe.

Literature search output:

There was 1 paper identified for PCNs from the global literature search, none when terms for Scotland were included and 1 paper (the same paper) from the grey literature search.

Although this class of compounds is not currently regulated, they are known to have the same mode of toxic action as the chlorinated dioxins and PCBs. At its last review of toxic equivalency factors (van den Berg et al, 2006), the WHO stated that '…Based on mechanistic considerations, PCB 37, PBDDs, PBDFs, PXCDDs, PXCDFs, PCNs, PBNs, and PBBs undoubtedly belong in the TEF concept', and on this basis this class of compounds could potentially at some point in the future be included in regulations.

Consumption / exposure / of Scottish population and Production / industry in Scotland

No particular areas of concern were identified for Scotland from the literature search, but there is generally very little information about this class of contaminant in the literature, and like other POPs, they are found at highest concentrations in oily fish products and some meat products that are important for Scotland.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Summary of risk for polychlorinated naphthalenes to Scottish consumer and economy

No particular areas of concern were identified for Scotland from the literature search, but there is generally very little information about this class of contaminant in the literature, and like other POPs, they are found at highest concentrations in oily fish products and some meat products that are important for Scotland.

Brominated Flame Retardants (BFRs)

Background:

The most widely studied BFRs in terms of environmental and food contamination are the PBDEs. However, there are many other BFRs in use, and in recent years, there has been an increasing amount of data relating to dietary exposure to HBCD. As replacement flame retardants are found and used, these newer compounds gain attention. Some of these emerging BFRs include hexabromobenzene, 1,2- bis(2,4,6-tribromophenoxy)ethane, 5,6-dibromo-1,10,11,12,13,13-(hexachloro-11-tricyclo[8.2.1.02,9]tridecene), 1,2,3,4,7,7-hexachloro-5-(2,3,4,5-tetrabromophenyl)-bicyclo[2.2.1]hept-2-ene, pentabromotoluene, pentabromobenzyl acrylate, pentabromoethylbenzene 1,2,4,5-tetrabromo-3,6-dimethylbenzene, decabromodiphenyl ethane, and octabromotrimethylphenyl indane.

The BFRs were subject of a series of Opinions produced by EFSA in 2011 – 2012, resulting in a request for more data on occurrence of these compounds (EFSA 2012b, EFSA, 2012c). The Opinions are due for an update now that more data are available on occurrence for these contaminants.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Polybrominated Diphenyl Ethers (PBDEs)

Background:

PBDEs were mass-produced as BFRs and were used as additives in a variety of plastics, textiles, surface coatings, foams, and man-made fibres before their production and use was restricted in the early 2000s. PBDEs are thought to cause liver and neurodevelopmental toxicities, and to affect thyroid hormone levels. They are also implicated in DNA damage through the induction of reactive oxygen species.

There has been some discussion about limits for PBDEs and these are likely to be set in EU regulation in the near future.

PBDEs are lipophilic and bioaccumulate in the food chain. Like dioxins and PCBs, they are found at highest levels in oily fish and fish products, and in some meat and game products such as offal.

EFSA published a Scientific Opinion on PBDEs in 2011 (EFSA, 2011a), which concluded that it was inappropriate to use the derived BMDLs to establish health based guidance values, and instead used a margin of exposure (MOE) approach for the health risk assessment. Since elimination characteristics of PBDE congeners in animals and humans differ considerably, the Panel used the body burden as a starting point for the MOE approach. It was concluded that for BDE-47, -153 and -209 current dietary exposure in the EU did not raise a health concern. For BDE-99 there was a potential health concern with respect to dietary exposure.

Literature search output:

There were 12 papers identified for PBDEs from the global literature search, 1 when terms for Scotland were included and 0 papers in the grey literature.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Although no particular Scottish issues were identified, fish meat and game production are important industries for Scotland and it is important to ensure that any future regulatory limits are met.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Hexabromocyclododecane (HBCDD or HBCD)

Background:

HBCDD is a BFR and is used to inhibit the ignition of combustible materials and hinder the spread of fire. It is a lipophilic chemical that has a high adsorption affinity to particles and a low water solubility, and is considered to be a POP. Like dioxins and PCBs, they are found at highest levels in oily fish and fish products, and in some meat and game products such as offal. There is little known on the toxicity of HBCDD, but it has been associated with reproductive effects and is acutely toxic to some aquatic organisms. It is also associated with endocrine activity.

EFSA evaluated HBCDD in 2011 (EFSA, 2011c) and concluded that it was inappropriate to use a BMDL to establish a health based guidance value, and instead used a margin of exposure (MOE) approach for the health risk assessment. Since elimination characteristics of HBCDDs in animals and humans differ, the body burden was used as starting point for the MOE approach. It was concluded that dietary exposure to HBCDDs in the European Union did not raise a health concern.

Literature search output:

There were 8 papers identified for HBCDD from the global literature search, 2 when terms for Scotland were included and 1 paper from the search of grey literature.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Although no particular Scottish issues were identified, fish meat and game production are important industries for Scotland and it is important to ensure that any future regulatory limits are met.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established.

Chlorinated paraffins

Background:

Chlorinated paraffins (CPs), are used in a wide range of applications such as extreme pressure additives in metal working fluids, and flame retardants or plasticizers in rubbers, plastics, paints, coatings, sealants and adhesives (UNEP, 2012). They are also known as polychlorinated n-alkanes. They have been used for many years, but recent concerns about persistence and toxicity make them a class of (re-)emerging persistent pollutants. CPs exist as complex mixtures of various carbon chain lengths and chlorine atoms. Based on these carbon lengths, CPs are divided into three groups: short (C10–C13), medium (C14–C17) and long (C18–C28) chained. The number of congeners in each class makes analysis of CPs an extremely challenging task.

Depending on their concentration, CPs can be responsible for an array of health concerns such as immunotoxic, carcinogenic and endocrine disrupting effects.

EFSA have not previously evaluated chlorinated paraffins and there are no regulatory limits for these compounds in foods in Europe. An evaluation is currently underway by EFSA, and should be published in 2019.

Literature search output:

There were 2 papers identified for CPs from the global literature search, none specifically related to Scotland, and 1 paper from the search of grey literature.

There are very few papers in the literature with reliable data for CPs at low but significant levels in foods. This is partly due to the complexity of analysis and also because this class of compounds has not featured as a priority due to a lack of robust data on health effects. In recent years as more data on exposure and environmental persistence have been generated, and since they have been classified as a POP under the Stockholm Convention (www.pops.int), they are becoming a greater focus of international and national attention. EFSA has recently formed a working group on CPs which should report in 2019.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Although no particular Scottish issues were identified, CPs are found at higher levels in the same types of foods as other POPs, and since fish, meat and game production are important industries for Scotland it is important to ensure that any risk of exposure to the Scottish consumer, and concerns for Scottish industry are considered.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Organo-phosphorous Flame Retardants

Background:

The importance of organo-phosphorus flame retardants (OPFRs) in recent years has increased due to restrictions and reduced use of BFRs (see above). They have been used for several decades in many industries, including the production of dyes, varnishes, adhesives, synthetic resins, polyvinyl chloride, hydraulic fluids, plastics and textiles. They have been associated with neurotoxic, fertility, reproductive and carcinogenic effects.

EFSA have not evaluated this class of chemicals and there are no regulatory limits for these compounds in foods in Europe.

Literature search output:

There were 8 papers identified for OPFRs from the global literature search, 1 specifically related to Scotland, and nothing was retrieved from the search of grey literature.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Although no particular Scottish issues were identified, OPFRs are found at higher levels in the same types of foods as the POPs, and since fish, meat and game production are important industries for Scotland and it is important to ensure that any risk of exposure to the Scottish consumer, and concerns for Scottish industry are considered.

HorizonScan output

HorizonScan does not currently monitor this class of contaminant since regulatory limits have not been established

Summary of risk for brominated flame retardants to Scottish consumer and economy

Although no particular Scottish issues were identified, fish, meat and game production are important industries for Scotland and it is important to ensure that any risk of exposure to the Scottish consumer, and concerns for Scottish industry are considered and that any future regulatory limits are met.

Natural Toxins

Mycotoxins – Multi-mycotoxins and Co-occurrence

Background:

Mycotoxins are produced by moulds and can be found in a range of foodstuffs and animal feeds. *Fusarium, Aspergillus* and *Penicillium* species are probably the most commonly found producers of mycotoxins, but *Alternaria* species and *Claviceps* also produce mycotoxins that may be considered significant from a toxicological or production perspective.

Improvements in analytical methods have made it possible to measure different classes of mycotoxins in the same sample, which has led to increased reports and interest in co-occurrence of multiple mycotoxins in food and feed materials. This raises a question about the possible 'cocktail effect' of exposure to these mixtures, as generally toxicity testing and risk assessments consider each mycotoxin in isolation. During the literature searches a significant number of publications were found that discussed co-occurrence of mycotoxins, or that simply mentioned 'Mycotoxins' in the title. These reports and the issue of multi-mycotoxin contamination are considered in this section.

Literature search output:

There were 134 papers identified for 'mycotoxins' from the global literature search, one when terms for Scotland were included and 5 papers from the grey literature.

There were several review papers; one looked at food and feed levels in Portugal and Probable Daily Intakes (Abrunhosa et al. 2016); one reviewed mycotoxins in bovine milk and dairy products (Becker-Algeri et al. 2016); and one reviewed the use of mycotoxin detoxifying agents for animals (Wielogorska et al. 2016). Two reviews on mycotoxins impact or consequences in aquaculture may be of particular interest for Scottish aquaculture (Anater et al. 2016, Matejova et al. 2017b), as well as a report of mycotoxin occurrence in aquaculture feed ingredients (Goncalves et al. 2017). There were many reports of co-occurrence of mycotoxins in a variety of foods and feedstuffs from all the world, including countries from Europe (Saladino et al. 2017), the US (Al-Taher et al. 2017), South America (Granados-Chinchilla et al. 2017) Africa (Abdallah et al. 2017) and Asia (Wei et al. 2017). Total diet studies were reported for The Netherlands (Lopez et al. 2016) and Hong Kong (Yau et al. 2016).

The issue of climate change is also important for mycotoxins, two studies applied models for cereals grown in Europe (Van der Fels-Klerx et al. 2016). Results showed DON contamination in wheat is likely to rise, however there is a large degree of variability associated with this. Research gaps were identified related to the limited number of models for climate change and their validation. However it seems likely that climate change will have an impact on the frequency and concentrations of mycotoxins.

Expert review of literature i.e. outside period or issues not picked up

EFSA have had a large programme of work, carrying out surveys, and exposure and risk assessments for a range of mycotoxins. These will be referred to in the individual mycotoxin sections below. The FSA funded a Total Diet Study in 2014 -2015 to measure mycotoxin concentrations in UK food samples (MacDonald et al 2015). No unexpectedly high levels were found, however the exposure assessment has still to be completed and published. The CoT has published statements of ochratoxin A and T-2 toxin, HT-2 toxin and neosolaniol in the diet of infants and young children (Committee on Toxicity, 2018 & 2018a). Co-occurrence of multiple mycotoxins was reported in a study funded by AHDB (Agriculture and Horticulture Development Board) to analyse 300 Dried Distillers Grains with Solubles (DDGS) samples for 77 mycotoxins (AHDB, 2017). All DDGS samples analysed were contaminated with 13−34 different mycotoxins, although levels were all well below Guidance Values for feed. 42 UK wheat based DDGS were included in the survey.

The European Commission are considering Climate Change in their ‘Comprehensive Strategy’ for mycotoxin measures, where they include prevention, mitigation, detoxification and regulation as part of a combined approach to control mycotoxins going forward (Frans Verstraete, presentation 2017). There is an acceptance that mycotoxins may increase, and strategies are required on how to deal with this, whether it is trying to find more resistant crops (prevention), use of mycotoxin binders and other products or alternative uses for contaminated crops (mitigation), or the development of detoxification processes, in which case these must be defined and acceptability criteria developed.

There are also several on-line sources of mycotoxin co-occurrence data, although these are targeted to animal feed ingredients they give a useful insight to the global occurrence of mycotoxins. Data are regularly published by companies such as Biomin, Alltech, Engormix and Nutriad:

http://news.trilogylab.com/mycotoxin-pre-harvest-outlook-2017

https://info.biomin.net/acton/fs/blocks/showLandingPage/a/14109/p/p-004e/t/page/fm/17

https://nutriad.com/page/2/?s=mycotoxin+survey&x=0&y=0

https://en.engormix.com/mycotoxins/articles/mycotoxin-survey-feed-2017-t41353.htm

These surveys can give snapshot of mycotoxin occurrence and could inform of potential issues that might be developing, such as a bad crop from a particular country or region.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Many important food commodities and ingredients are at risk from mycotoxin contamination, both home grown and imported products. The possible effects of mixtures or the ‘cocktail effect’ of exposure to lower levels of multiple mycotoxins is currently not well understood and will be an area of future research. In the meantime, high risk commodities should be monitored to ensure compliance with maximum levels to protect Scotland, both in terms of food production and the consumer. This contaminant class should be seen as important and measures taken to ensure that regulatory limits are met.

HorizonScan output

There were 996 results from HorizonScan when 'mycotoxin' was used as the search term. Most reports were for aflatoxins in different types of nuts, dried figs, maize products and spices.

Summary of risk for mycotoxins to Scottish consumer and economy

As above, mycotoxins are a risk for imported products and ingredients, e.g. spices, dried fruit, but also home-grown crops such as oats and barley and are of importance to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met.

Masked or modified mycotoxins

EFSA published an Opinion in 2014 on the risks to human and animal health related to the presence of modified forms of mycotoxins. The term 'modified' was applied for masked and bound mycotoxins and mycotoxin metabolites (EFSA, 2014a).

A book was published in 2015 giving a thorough overview of the topic (Dall'Asta and Berthiller, eds. 2015). EFSA have conducted further assessments of the individual (groups of) toxins and these are dealt with separately under the mycotoxin headings below.

Masked ('modified') mycotoxins e.g. DON and ZON have been highlighted in the FSS Chemical Contaminants Strategy as an area that is a potential risk and has a requirement for more evidence.

Aflatoxins B_1, B_2, G_1 and G_2

Background:

Aflatoxin B_1 is classified as a Group 1 carcinogen by IARC (carcinogenic to humans), the other related compounds have similar, although lesser toxicity. These compounds occur in a range of food commodities as a result of either pre- or post-harvest infection by Aspergillus species, the most common being *Aspergillus flavus* and *Aspergillus parasiticus*. They commonly occur on crops such as peanuts, and other nuts, maize, spices and dried fruit, but have been reported on a wide range of other products. The maximum limits set by the EU are very low due to application of the ALARA principle for carcinogens, particularly for infants and young children (from 0.1 µg/kg AFB_1 in infant food).

Literature search output:

There were 25 papers identified for from the global literature search, none when terms for Scotland were included and 2 papers from the grey literature.

The majority of the papers identified related to aflatoxin occurrence or exposure in countries outside the EU from products grown and consumed within those countries, e.g. Iran, Tanzania and China. However 2 papers highlighted exposure within Europe, one in Portugal as a result of working in a poultry slaughterhouse (Viegas et al 2016) and one in Serbia from consumption of breakfast cereals (Torovic et al 2017). The issue of climate change is also important for mycotoxins and a predictive model has been published that suggests aflatoxin B_1 is likely to become a food safety issue in maize within Europe, if the likely predicted scenario of a +2ºC increase in temperature occurs (Battilani et al, 2016).

Expert review of literature i.e. outside period or issues not picked up

In 2013 there was a European wide issue of aflatoxin contaminated maize that originated in Serbia. There were also reports of up to 72% of maize from certain regions containing levels of aflatoxin that made it unsuitable for human consumption as a result of dry weather in 2015 (Hajnal et al. 2017)). In view that higher aflatoxin levels are allowed in peanuts in some countries (a likely consequence of climate change), EFSA was asked to carry out a risk evaluation of the effect of increasing the maximum level of aflatoxins in peanut from 4µg/kg to 10 µg/kg. They concluded there would be an increased cancer risk for some groups, but that a full risk assessment should be undertaken as the last one was completed in 2007 (EFSA, 2018c).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Many important food commodities and ingredients are at risk from aflatoxin contamination, these will be mainly imported products, but evidence shows that aflatoxin occurrence is increasing within Europe. Commodities, such as spices, nuts and dried fruit should be monitored to ensure compliance with maximum levels to protect Scotland, both in terms of food production and the consumer. Recent monitoring has not found an issue, with 1 sample out of 104 not satisfactory for aflatoxin B_1 (UKFSS, 2017). This contaminant class should be seen as important and measures taken to ensure that the ALARA principle is applied and that regulatory limits are met.

HorizonScan output

Total number of reports: 11394

There were multiple reports of international surveys of cereal products carried out by commercial companies. Various commodities including nuts, maize, animal feed, dried fruit, spices are regularly reported to contain aflatoxins.

Summary of risk for aflatoxins B_1, B_2, G_1 and G_2 to Scottish consumer and economy

As above, imported products and ingredients, e.g. spices are of importance to Scotland, both in terms of food production and the consumer. This contaminant class should be seen as important and measures taken to ensure that regulatory limits are met. Maize as an animal feed ingredient could be a high risk commodity in bad harvest years.

Aflatoxin M_1

Background:

Aflatoxin M_1 is hydroxymetabolite of aflatoxin B_1 that is excreted in mammalian milk after consumption of aflatoxin B_1. It is carcinogenic, and for this reason there are strict maximum limits for aflatoxin B_1 in animal feed intended for dairy cows, and for aflatoxin M_1 in milk and infant formula.

Literature search output:

There were 41 papers identified for aflatoxin M_1 from the global literature search, none when terms for Scotland were included and one paper from the grey literature.

Expert review of literature i.e. outside period or issues not picked up

The major issue resulting from the Serbian incident in 2013 was that much of the maize was used as animal feed and this led to aflatoxin M_1 contaminated milk being produced all over Europe, with reports from Serbia, Romania, Germany and The Netherlands. The incident was reported to have caused cost the Serbian government hundreds of millions of Euros.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Aflatoxin M_1 occurrence is rare in the UK as a result of the controls of aflatoxin B_1 in feed, but due to toxicity of aflatoxin M_1 and the vulnerable groups that are more likely to consume large amounts of milk and dairy products (i.e. infants and young children) this contaminant class should be seen as important and measures taken to ensure that regulatory limits continue to be met.

HorizonScan output

Total number of reports: 12

There were reports in 2013 of a significant increase (4 x annual average) in interceptions of milk from Hungary contaminated with aflatoxins, as well as reports from Italy, Serbia, and Germany as a result of aflatoxin contaminated maize being used for animal feed.

Summary of risk for aflatoxin M_1 to Scottish consumer and economy

Food types that are likely to be contaminated with aflatoxin M_1 include milk and milk products and infant formula. As above for aflatoxin, the role of climate change is likely to result in aflatoxin occurrence more frequently in European grown maize, so levels should be assessed if this grain is used for animal feed to avoid a problem similar to that caused by the Serbian maize in 2013 and 2015. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be considered important with the ALARA principle and regulatory limits applied preferably at the feed stage to minimise carry over into milk.

Ochratoxin A

Background:

OTA is produced by *Aspergillus species*, and can be found in crops from temperate regions, e.g. UK produced cereals, as well products from warmer climates, e.g. dried vine fruits, coffee, spices. It is teratogenic (harms the unborn foetus) and possibly carcinogenic. It is a fairly ubiquitous mycotoxin and has been reported in a wide range of foodstuffs including meat products (fresh and preserved), cereals, cocoa, and liquorice. It is very stable and survives processing and fermentation and therefore is found in processed products made from contaminated ingredients, so it also occurs in baked goods, breakfast cereals, beer, and wine as examples.

Literature search output:

There were 69 papers identified for OTA from the global literature search, eleven when terms for Scotland were included and one paper from the grey literature.

UK cereal samples taken in each of the years 2012 to 2015 (stored milling wheat and malting barley and malt as matched pairs) were analysed for OTA. Only four samples exceeded the maximum limit across four years of sampling, (AHDB, 2017). A follow on project started in 2016 and showed a similar pattern of results. The highest incidence of detectable levels (91%) was in wheat feed, but the highest level found was 2.1 µg/kg, well below Guidance Levels for animal feed (EC, 2006a). One sample of oats was just above the ML of 5 µg/kg (AHDB, 2017a).

Expert review of literature i.e. outside period or issues not picked up

On closer review the papers that were found using the 'Scot' search string did not relate to Scotland. There were a number of exposure assessments for populations in the US, Croatia and Canada, ((Kolakowski et al. 2016, Mitchell et al. 2017, Vulic et al. 2016). They all concluded there was tolerable exposure and therefore low risk for the populations studied, although both the US and Canadian studies noted that infant cereals containing oats could be a significant source of OTA for infants and young children. Another study assessed the impact of feeding Atlantic salmon with feed containing OTA and DON (Bernhoft et al. 2017). Analysis showed OTA was eliminated faster than DON from various tissues, and using Norwegian food consumption data it was found that consumption of salmon that had been fed diets containing the maximum recommended level of these mycotoxins posed a negligible risk.

Consumption / exposure / of Scottish population and Production / industry in Scotland

OTA can occur in UK and Scottish cereals as a result of poor post handling drying and storage, so could be a problem for any producer using cereals (bakers, brewers etc.). However this is a well-known issue and there is good knowledge and understanding within industry, Codes of Practice and advice are available and the problem has largely been eradicated. The data from the recent AHDB surveys and Scottish LA monitoring support this (AHDB, 2017; AHBB, 2017a; UKFSS, 2016; UKFSS, 2017). Based on the exposure assessments above it seems unlikely that OTA is likely to be of major concern, although measures should continue to ensure that regulatory limits continue to be met.

HorizonScan output

Total number of reports: 675

Recent reports have included widespread reports from all over Europe of OTA in raisins from Turkey. There have also been reports of OTA in nutmeg, black pepper, dried figs, wheat, peanuts, pistachios, dried apricots, liquorice, rice, spices and dried garlic powder.

Summary of risk for ochratoxin A to Scottish consumer and economy

Cereal crops could be a source of OTA, however recent UK data shows the risk from home grown cereals is small due to good agricultural practice in place. Other food types that are likely to be contaminated with OTA include many imported products such as spices and dried fruit. Therefore, measures should be taken to ensure that regulatory limits are met, but it is not a major concern.

Trichothecenes (focus on DON , Nivalenol (NIV) and 'modified' forms)

Background:

DON is a mycotoxin primarily produced by *Fusarium* fungi, occurring predominantly in cereal grains. It is associated with Fusarium Head Blight (FHB) infection, and co-occurs with other mycotoxins from the trichothecene group related to DON; 3-acetyl-DON (3-Ac-DON), 15-acetyl-DON (15-Ac-DON) and DON-3-glucoside (DON-3-Glc) (Payros et al. 2016), as well as other type B trichothecenes such as NIV. DON-3-Glc is also known as a 'masked' or 'modified' mycotoxin and is formed as part of a plants natural defence to *Fusarium* infection.

A TDI of 1 µg/kg bw per day was established for DON by EFSA in 2013 (EFSA, 2013). However recent evidence has shown that DON is released from modified forms during digestion, so EFSA were asked to carry out a risk and exposure assessment to address co-occurrence. The TDI for DON was used as a group-TDI for the sum of DON, 3-Ac-DON, 15-Ac-DON and DON-3-Glc. The estimated mean chronic dietary exposure was above the group-TDI in infants, toddlers and other children, and at high exposure also in adolescents and adults, indicating a potential health concern. It was noted that at the high concentrations in feed, there is a potential risk for chronic adverse effects in pigs and fish (EFSA, 2017b). A risk assessment for Norwegian consumers came to a similar conclusion, i.e. exceeding the TDI for infants and children is of concern, but other groups were below the TDI (Sundheim et al. 2017). Regulation (EC) No 1881/2006 includes MLs for DON in a range of cereal based foods, but currently the acetylated and glucoside forms are not included. There are also Guidance limits for animal feed in Commission Recommendation 2006/576/EC.

NIV was also recently reviewed by the EFSA CONTAM Panel (Jan Alexander 2017), but as no new relevant data were identified the TDI for NIV of 1.2 µg/kg bw was retained. Nivalenol-3-glucoside (NIV-3-Glc) can also occur in cereals at up to ~50% of NIV, recent results show it is hydrolysed to NIV in the intestinal tract (Gratz et al, 2017), therefore it should be included in a group TDI and in a group Acute Reference Dose (ARfD) with NIV. NIV is not included in any Regulations for food or feed.

Literature search output:

There were 51 papers identified for DON and NIV from the global literature search, 96 when the term 'trichothecene' was included, and 1 when terms for Scotland were included and 8 papers from the grey literature.

There were several toxicity studies, and surveys from several countries. One study assessed the severity of DON contamination in oats from East Canada. They found some relatively resistant cultivars, and some that are more susceptible. Using a more resistant cultivar can reduce the risk of a crop not meeting the EU limit for infant food from 16% to 10%, and they recommended breeding for FHB resistance should be included in regional breeding programmes (Yan et al. 2017). A review of literature to assess if breeding for enhanced FHB resistance in wheat concluded that breeding for resistance reduced DON content and with it DON-3-glucoside content, although the relative proportion of the DON-3-Glc level was higher than in less resistant varieties (Lemmens et al, 2016).

A review of DON in malting and brewing showed that the industry largely has this issue under control, however it noted the growing craft ale sector may present some potential challenges (Schwarz 2017).

Expert review of literature i.e. outside period or issues not picked up

Trichothecenes are included in the AHDB Contaminant Monitoring projects, results from 2012 to 2015 showed a decline in incidence and levels found in milling wheat over the four year period. Levels in malting barley were lower than in milling wheat, all samples were below the MLs (AHDB, 2017). Similar results were observed for the 2016 harvest, none of the samples exceeded the maximum limit for DON (AHDB, 2017a). DON-3-Glc was also measured in the samples. No DON-3-Glc was detected in barley (malting or feed), feed oats or oatfeed. The highest level found was 176 µg/kg in a sample of food oats. Wheat samples were more likely to contain DON-3-Glc than other cereals, over 40% of all wheat types contained DON-3-Glc above the LOD, but the highest mean level was 31 µg/kg in wheatfeed.

An FSA funded survey of UK retail foods was carried out for masked mycotoxins and published in 2016. UK retails foods (184 in total), comprising cereal products, breakfast cereals, infant foods, beer and spices were analysed for trichothecenes and ZON and their masked forms (3 and 15 ACDON, DON-3-Glc, α and β zearalenol, α and β zearalenol glucoside, zearalenone glucoside and zearalenone sulphate). Masked mycotoxins were detected in 19% of samples, but at very low levels. DON-3-Glc was found at the highest level (121 µg/kg in a sample of breakfast cereal. Beer was the product most frequently found to contain DON-3-Glc.

Fusarium toxin levels found are highly influenced by weather conditions, extended periods of wet weather at certain times in the growth cycle can lead to increased mycotoxin concentrations. There are warning systems in place e.g. CropMonitor (http://www.cropmonitor.co.uk/) that provide advice on optimum times to use fungicides to protect crops that can help reduce fungal disease and prevent mycotoxin formation.

Consumption / exposure / of Scottish population and Production / industry in Scotland

There are no specific risks for Scottish consumers or producers that are different to the rest of the UK. All 108 samples taken as part of the UKFSS sampling in 2016-2017 were found to be satisfactory for DON (UKFSS, 2017). Cereal growers will be aware of this issue and take appropriate measures. According to EFSA intake calculations, infants and young children, as high consumers of cereal products, may be at risk of exceeding the TDI if maximum levels in infant foods are exceeded therefore controls to ensure Regulations are complied with should be maintained. Potential industries relevant to this issue are cereal growers, the brewing and whisky industries, animal feed manufacturers (including Dried Distillers Grains with Solubles (DDGS)) and aquaculture. Grain quality could impact the quality of the final product in malting and brewing as DON and DON-3-Glc can be found in beer, and there is some evidence that DON-3-Glc levels increase during brewing ((Bauer et al. 2016, Jan Alexander 11 September 2017). A study into the fate of 13 mycotoxins during distillation of a grain based fermented beverage found none of the mycotoxins carried over into the distilled alcoholic beverage (Nagatomi et al, 2012). Also DDGS produced from these industries could be at risk, as mycotoxins tend to be concentrated in DDGS compared to the starting grain, by up to a factor of three (AHDB, 2017).

HorizonScan output

Total number of reports: 82

Several reports include survey results from commercial companies about occurrence and levels of these mycotoxins in animal feed ingredients. There are also reports of DON, commonly co-occurring with ZON, in cereals and cereal products, such as maize, wheat, corn meal and polenta.

Summary of risk for trichothecenes to Scottish consumer and economy

Cereals are at risk from contamination with DON and its modified forms in years of wet weather if appropriate measures are not taken. Food types that are likely to be at risk are cereals and products made from cereals, including animal feeds. The use of DON contaminated feed could have an adverse effect on aquaculture. Infants and young children are the group most likely to be at risk of exceeding the TDI for these toxins. Recent survey data of UK grown cereals shows levels are generally below the ML, and the contribution from modified forms is low, however due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met.

T-2 and HT-2 toxin

Background:

T-2 and HT-2 toxin are *Fusarium* mycotoxins that form part of the trichothecenes group of toxins. They are classed as Type A trichothecenes (i.e. higher toxicity). EFSA published a Scientific Opinion on them in 2011. Using collected occurrence data and toxicity data; a benchmark dose analysis was carried out by the CONTAM panel. They established a group TDI of 100 ng/kg bw for the sum of T-2 and HT-2 toxins. They stated at that time that estimates for chronic human exposure were below the TDI and this was not a health concern (EFSA, 2011d). In 2016, a new lower TDI of 0.02 µg/kg (20ng/kg) bw day for T-2 and HT-2 was established by the CONTAM panel based on new toxicity data (EFSA, 2011d). They also considered modified forms, and although there were few data, established a group TDI for T-2 and HT-2 and its modified forms. The modified forms were assigned relative potency factors. As the modified forms are cleaved during digestion releasing the parent forms the potency factors were all either 1 or less than 1. A further exposure assessment was published in 2017 using the new TDI values (EFSA, 2017a). The highest levels are found in oats and oat products. Toddlers and infants were found to have the highest mean chronic dietary exposure, with upper bound values of 64.8 and 62.9 ng/kg bw respectively (three times the TDI). Other sources of exposure were; cereal flakes, fine bakery wares, bread and rolls and some dietary supplements.

Literature search output:

There were 19 papers identified for T-2 and/or HT-2 toxins from the global literature search, none when terms for Scotland were included and two papers from the grey literature.

From the literature study there were three papers on the effect of T-2 toxin on common carp. Two studies also assessed DON, and concluded that trichothecenes have some effect on free radical formation and anti-oxidant defence but this depended on the duration of exposure and the dose (Bocsai et al. 2016, Pelyhe et al. 2016). The other study reported that T-2 toxin is able to induce anaemia and oxidative stress and cause changes in the immune response of the common carp ((Matejova et al. 2017a)). It is not known if this will be the same in other fish species, but care should be taken to ensure the quality and mycotoxin levels in fish feed for aquaculture.

Expert review of literature i.e. outside period or issues not picked up

Following reports in 2014 of high levels of T-2 and HT-2 toxins in unprocessed oat cereal crops, the FSA carried out a UK retail survey for T-2 and HT-2 toxins in oat based retail products, to determine if the toxins transferred into finished retail products. Two hundred samples were analysed, and levels were found to be low and below the Indicative Levels set in Commission Recommendation 2013/165/EU. Dietary exposures were calculated and estimated to be well below the TDI in effect at that time of 100 ng/kg bw, including high level consumers (FSA, 2017).

An additional study to investigate the effect of farming practices and weather on T-2 and HT-2 toxins levels was also conducted. Details of oat consignments that had been analysed for T-2 and HT-2 were evaluated. This included information on grower's location, oat variety and further agronomic data were also obtained. Statistically significant higher levels were found for Scottish grown oats, and this was highly significant for northern Scotland. There were higher mean concentrations in winter oats compared to spring varieties. In this study rainfall in the 2 week period at the predicted time of panicle (where the seeds develop) emergence was the only significant correlation found, however the lack of other correlations may have been due to a lack of accurate agronomic data. Heavy rainfall can also encourage splash dispersal of spores at a critical susceptible growth stage, although it is not fully understood what stage that is. The authors suggested several mitigation strategies including crop rotation and change of variety but noted that there are large economic barriers to growers to adopt the suggested strategies (Edwards and Jennings 2016).

Recent survey data for UK cereals shows no occurrence of T-2 and HT-2 toxins in milling wheat, but it was found in barley and oats. The highest level for human food was 1093 µg/kg in food oats. Levels in feed materials followed a similar pattern; the highest level was in oatfeed, where a maximum of 5787 µg/kg was found. For the first time T-2-3-glucoside (modified T-2) was also analysed. It was only detected in oat samples where the highest level was 389 µg/kg in oatfeed, less than 10% of the T-2 toxin concentration.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Oats are the cereal crop most likely to be contaminated with T-2 and HT-2 toxins. This is an important crop, and production is increasing due to increased demand for oats because of its perceived health benefits. While it seems that the cleaning and processing carried out during the production of finished oats products significantly reduces T-2 and HT-2 toxins, it must be borne in mind that the TDI has been reduced, and some population groups are at risk of exceeding the TDI. The most vulnerable groups are infants, toddler and elderly people. Due to the importance of these commodities to Scotland, both in terms of food production and to the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met. Weather appears to be the key risk parameter and change of agronomic practices, such as growing spring oats instead of winter oats and growing oats in rotation with non-cereal crops suggested by Edwards and Jennings, 2016, can only reduce the risk not eliminate it. As highlighted above aquaculture may be impacted by mycotoxins and feed quality should be monitored.

HorizonScan output

Total number of reports: 2

There was a report from the Canadian Food Inspection Agency (CFIA) warning the public not to consume certain baby cereal products from Russia because they may contain mycotoxin HT-2. There was at least one reported illness associated with the consumption of these products (http://www.inspection.gc.ca/about-the-cfia/newsroom/food-recall-warnings/complete-listing/2013-06-27/eng/1372379805536/137237981).

Summary of risk for T-2 and HT-2 toxin to Scottish consumer and economy

Oats and oat products are the main sources of T-2 and HT-2 toxins (and their modified forms) in the diet. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that the ALARA principle is applied and Indicative Levels are not exceeded. In the UKFSS data from 2016-17, of 91 samples reported for T-2 toxin (85 samples) or T-2/HT-2 toxins combined (6 samples), all were satisfactory although it did not state sample type. The contamination is weather dependant so will vary year on year, so surveys should be carried out in years that high rainfall increases the risk of T-2 and HT-2 toxin occurrence.

Zearalenone

Background:

ZON is a *Fusarium* mycotoxin that typically occurs in cereals after a late wet harvest. It is found in wheat, barley, rye, sorghum and commonly in maize. It has oestrogenic activity. A TDI of 0.25µg/kg bw was established in 2011 based on oestrogenicity in pigs (EFSA, 2011b). In 2016 EFSA reviewed data on the occurrence of modified forms that indicated that several modified forms may be present in cereal foods, with varying amounts of up 100% of ZON. It was assumed that the oestrogenic effects of these compounds would be additive. EFSA assigned relative potency factors relative to ZON, and set the previous TDI as a group TDI expressed as ZON equivalents for ZON and its modified forms (EFSA, 2016c).

ZON can also occur in pasture grass and residues of its metabolites are found in the urine of cattle. These metabolites have higher oestrogenic activity than ZON, and due to this EFSA have issued a call to collect data on their occurrence in food and feed of both plant and animal origin.

Literature search output:

There were 22 papers identified for ZON (and metabolites) from the global literature search, none when terms for Scotland were included and 4 papers from the grey literature.

There were reports of ZON occurrence in food and feed from several countries (e.g. Iran, Pakistan, Brazil, Croatia and China) (Bahrami-Samani et al. 2017) (Iqbal et al. 2016), (Mallmann et al. 2017), (Pleadin et al. 2017a, Pleadin et al. 2017b), (Liu et al. 2016). There was a review that looked at possible options for bio-monitoring for ZON and whether this could be a useful strategy to determine exposure. The authors stated that ZON and its metabolites may present suitable biomarkers of ZON exposure (Mally et al. 2016). There was also a survey in Italy of ZON in human breast milk, the results indicated breast milk was contaminated with ZON but no assessment was made of the levels found (Massart et al. 2016).

The effects on animals were also noted, ZON in combination with aflatoxin B1 affected laying performance, egg quality and toxins residues in eggs (Jia et al. 2016). Another study confirmed that ZON transferred from the alimentary tract in rainbow trout to the ovaries, however it only transferred to muscle to a limited extent. The results indicated the health risk from dietary intake of ZON from fish roe is negligible, however the potential of ZON to transfer to fish ovaries may be of concern for aquaculture (Wozny et al. 2017).

Expert review of literature i.e. outside period or issues not picked up

The FSA survey of masked mycotoxins found few residues of ZON or it modified forms in range of foods (FSA, 2016). The AHDB Contaminants monitoring project for samples from 2012 to 2015 included ZON. Levels declined across the four year period and the highest level found in milling wheat was 234 µ/kg in 2012, exceeding the maximum limit of 100 µg/kg. Levels in milling wheat were generally higher than malting barley in the same season. Wheatfeed contained the highest levels in animal feed materials, again levels dropped from 2010 through to 2015. (AHDB, 2017a). Results for 2016 were very similar with a low incidence of low levels founds for all cereals analysed. Modified ZON compounds were also included in 2016, however none were detected above the LOD (AHDB, 2017b).

After a delayed wet harvest in the UK in 2008, 29% of wheat exceeded the maximum European limit for unprocessed cereals. The led to difficulties in sourcing bran to produce high fibre breakfast cereal that would meet the EU limit. A temporary derogation of the limit was allowed for high fibre breakfast cereal to overcome this shortage. Data from 10 years for rainfall and ZON concentrations were used to predict the occurrence of high ZON in wheat. High ZON was predicted to occur as a one in five year event for northern Europe (Edwards, 2011).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Cereal products and cereal based animal feeds are at risk, but grass pasture can also be a source for grazing animals. ZON metabolites are highly oestrogenic and could be transferred into animal products and positive results are routinely found for ZON exposure in animals during statutory monitoring for veterinary medicines residues. Pigs are very sensitive to this mycotoxin and exposure can result in productivity and welfare issues in this species. More data are needed to assess the occurrence and also take into consideration the oestrogenic effect, as there are several other sources of endocrine disrupting chemicals in the diet. EFSA have requested data on the occurrence of ZON and modified forms in products of plant and animal origin.

ZON and modified forms are predicted to occur during late wet harvest and this has been predicted to occur as a one in year in five year event. Recent data have not shown a problem, but climate change will have a possible impact as more extreme rainfall events happen. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met.

HorizonScan output

Total number of reports: 22

ZON was reported in compound feed from China at 22265 µg/kg. Other animal feed, feed additives, maize and maize products have been reported to have levels of ZON, co-occurring with DON.

Summary of risk for zearalenone to Scottish consumer and economy

Food types that are likely to be contaminated with ZON and its modified forms include cereals, cereal products, animal feeds and foods of animal origin. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met. EFSA have requested data on the occurrence of ZON and its modified forms in foods of plant and animal origin. One sample was reported to be unsatisfactory in 2016-17 UKFSS data.

Ergot alkaloids

Background:

Ergot alkaloids occur in cereals as a result of infection by *Claviceps* spp.. Currently the presence of ergot alkaloids is controlled by Commission Regulation (EC) No 1881/2006, by controlling the amount of ergot sclerotia in cereals. However even after removal of sclerotia, ergot alkaloids can still be detected and discussions are underway to set maximum levels for the sum of the main 12 (EFSA) ergot alkaloids. The incidence of ergot alkaloids has increased in recent years due to changes in farming practices, including minimum tillage and changes to crop rotation. Ergot alkaloids can exhibit a range of effects and vasoconstrictive effects were considered for setting a group TDI of 0.6 µg/kg bw. The EFSA CONTAM panel concluded that available data were not a cause for concern but there could be possible unknown contributions from other foods (EFSA, 2012d). When a more recent exposure assessment to estimate chronic and acute dietary exposure to ergot alkaloids in humans and animals was carried out, more data was available for more foods, including processed foods. This wider range of products probably resulted in higher chronic dietary exposure estimates in comparison to those from 2012, although it was noted that the overall ergot alkaloid content seemed to be slightly higher than in the previous assessment. Highest acute dietary exposure estimates were similar to those reported in 2012. EFSA recommended that efforts should continue to be made to collect data, in particular in processed foods (EFSA, 2017c).

Literature search output:

There were 11 papers identified for ergot alkaloids from the global literature search, none when terms for Scotland were included and two papers from the grey literature.

There were 7 papers about analysis of ergot alkaloids and/or ergot sclerotia. One paper of note by Grusie et al. (2017) compared ergot sclerotia weight and count with total ergot alkaloids concentrations in grain. They found that below 350 µg/kg total ergot alkaloids, ergot sclerotia weight and count were not correlated to the alkaloid concentration. During sampling and analysis, sample heterogeneity is an issue, analysis of small samples has been shown to produce highly variable and potentially variable results. This is an important issue that should be borne in mind when regulations and therefore controls come into place.

Expert review of literature i.e. outside period or issues not picked up

The AHDB survey included ergot alkaloids from 2012 to 2015. The highest level found, 78679 µg/kg, was in a sample of German milling wheat. Wheatfeed and oatfeed were the most frequently contaminated samples (AHDB, 2017a). The results from 2016 found the highest level in milling wheat (1435 µg/kg), although the highest mean level was found for wheatfeed (404 µg/kg) (AHDB, 2017b).

In 2016, experts at the SRUC issued a warning to Scottish farmers about the increased risk of ergot in grain. There had been reports of increased ergot levels from farms in the Lothians and Borders and they noted that ergot poisoning is seen more frequently in cattle than sheep (www.sruc.ac.uk/news/article/1727/farmers_warned_of_increased_risk_of_ergot_fungus_in_grain). SRUC also has information about a Scottish Government Campaign on ergot on its website (www.sruc.ac.uk/info/120118/crop_clinin/503?scottish_government_campaigns/3).

The UK TDS survey included ergot alkaloids. They were detected in most of the cereal food groups, albeit at low levels (Stratton, et al, 2015).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Ergot alkaloids can have a significant negative impact on livestock and measures should be taken to reduce their occurrence in animal feed in line with the ALARA principle. Although maximum levels have not been set, EFSA's risk assessment indicated no cause for concern for health based on current data. Discussions on maximum levels are underway and it may be pertinent to carry out some monitoring once these are agreed. A high number (60%) of oats samples were found to contain ergot alkaloids in the AHDB survey in 2016, this is a significant crop for Scotland and should be reviewed when maximum limits are known. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure compliance with regulatory limits when they are set.

HorizonScan output

Total number of reports: 18

There were reports of ergot (sclerotia or alkaloids) in rye, wheat, spelt, and triticale and in animal feedstuffs.

Summary of risk for ergot alkaloids to Scottish consumer and economy

Cereals, particularly oats may be a concern in view of new regulations under discussion, but there are no recent data on ergot alkaloids for Scotland. This contaminant class should be seen as important and measures taken to ensure compliance with regulatory limits when they are set. Limits are still under discussion at an EU level, although no final levels have been agreed yet (FSA, 2018)

Fumonisins

Background:

Fumonisins are mycotoxin produced by predominantly *Fusarium* species, and are found in maize. They have been implicated in several disease outbreaks in different animal species including pigs and horses, and were shown to cause liver cancer in mice during a chronic study. A TDI of 1 µg/kg fumonisin B_1 was set by EFSA and this was recently reviewed to consider if a group TDI could be set to include modified forms of fumonisins. The CONTAM panel concluded that it was not appropriate to include modified fumonisins in the group TDI although it did include the structurally related compounds FB_2, FB_3 and FB_4 in the group TDI (EFSA, 2018d). They stated more data on occurrence, toxicokinetics and toxicity of the fumonisins B_{2}-$_{6}$ and modified forms would help reduce the uncertainty of the assessment (EFSA 2018d).

Literature search output:

There were 18 papers identified for fumonisins from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

The papers mainly dealt with analytical methods or analysis of foods from countries with maize as a staple food, e.g. Brazil, Tanzania, rural South Africa, and Vietnam (Petrarca et al. 2016), (Magoha et al. 2016) (Rheeder et al. 2016), (Huong et al. 2016a, Huong et al. 2016b), and so are not relevant for the dietary habits of the Scottish consumers.

Expert review of literature i.e. outside period or issues not picked up

Research has shown that parent fumonisins may be altered or bound to food matrices during food processing.

A report from February 2018 stated that fumonisins showed the highest increase in global occurrence among the main agriculturally relevant mycotoxins. A survey of products from 2017 showed that 695 of the samples analysed were positive for fumonisins, from all regions sampled (North America, South America, Asia Pacific and Europe) (Biomin, 2018). Within Europe this will be an issue confined to southern countries, e.g. Spain.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Maize based products, food and animal feed are most at risk from fumonisin contamination. Therefore this is mainly an issue for imported products as maize for cereal grain is not grown in Scotland. This will also include any spent grains from the brewing and distilling industries where maize is used. Highest levels in foodstuffs are usually found in polenta, which is not a common food in Scotland. There is no current cause for concern with exposure relating to Scottish consumers.

HorizonScan output

Total number of reports: 105

Reports of fumonisins in maize and maize products from France and Italy.

Summary of risk for fumonisins to Scottish consumer and economy

Maize based products, food and animal feed are most at risk from fumonisin contamination, therefore this is mainly an issue for imported products. Care should be taken to monitor maize materials to ensure that regulatory limits are met, however it is not deemed a high risk contaminant for Scotland. Results from the UKFSS survey in 2016-17 showed no cause for concern, all samples analysed for either fumonisin B_1 or fumonisins B_1 and B_2 were found to be satisfactory.

Patulin

Background:

Patulin is produced by a number of moulds growing on fruit, especially *Penicillium, Aspergillus*, and *Byssochlamys*. Apples are prone to patulin contamination as a result of *Penicillium expansum* infection, but patulin can also occur in range of other fruits including pears, peaches, banana, pineapple, cherries and grapes. Patulin can also occur in badly maintained silage and may be the toxin associated with neurological problems in cattle ingesting malting by-products and sprouting grains.

There are maximum limits for patulin in fruits juices, apple products and infant food laid down in Commission Regulation (EC) No 1881/2006. There a number of industry guides and codes of practice to help producers ensure that their products comply with these limits.

Literature search output:

There were 17 papers identified for patulin from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

The papers found were mainly reports of occurrence of patulin in different foods, mostly apple products. A method was reported to analyse for patulin in strawberries, but all test samples were below the limit of detection (Sadok et al. 2018).

Expert review of literature i.e. outside period or issues not picked up

No issues detected. This is quite a well-established issue, and industry are aware of the need to follow the appropriate Codes of Practice to comply with the EU maximum limits.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to contain patulin are fruits, especially apples and pears but also other fruit. There is no significant risk to Scotland, in terms of food production and the consumer. Measures should continue to be taken to ensure that regulatory limits are met, but it is not considered a major concern for Scotland.

HorizonScan output

Total number of reports: 36

High levels of patulin detected in apple juice from Australia and Germany, as well as in apple and strawberry juice and fresh and wild cranberries.

Summary of risk for patulin to Scottish consumer and economy

Food types that are likely to contain patulin are fruits, especially apples and pears but also other fruit. There is no significant risk to Scotland, in terms of food production and to the consumer. Measures should continue to be taken to ensure that regulatory limits are met, but it is not considered a major concern for Scotland.

Plant Toxins

Pyrrolizidine Alkaloids

Background:

Pyrrolizidine Alkaloids (PAs) are toxins produced by several genera of plants which cause liver damage in humans and are potential carcinogens with liver as the target organ. To date, approximately 600 PAs are known. The PAs occur in plants that can be weeds in crops and high levels are found in pollen so PAs can occur in honey. EFSA has published several documents on PAs, in 2011 they concluded that there is a possible health concern for toddlers and children that are high consumers of honey. EFSA commissioned a European wide survey for PAs in foods, and this included herbal teas and infusions, honey, dietary supplements and meat and milk products and was reported in 2015 (Mulder et al, 2015). A dietary exposure assessment published in 2016 concluded tea and herbal infusions were the main contributors to exposure to PAs, the highest estimates of exposure were calculated for 'Toddlers'. A Scientific Opinion on PAs was delivered by EFSA in 2017 (EFSA, 2017). Based on data limited to honey, the CONTAM Panel concluded that there was a possible health concern for children and toddlers that are high consumers of honey. They also concluded that there is a possible health concern for high and frequent consumers of tea and herbal infusions. The Panel also noted that herbal supplements could result in exposure levels causing acute and short term toxicity. A list of 17 PAs was given for monitoring food and feed and the panel recommended continuing monitoring, improving methods of analysis and generation of data to identify the toxicity and carcinogenicity potency for the common PAs (EFSA 2017). There are no maximum limits for PAs, but this is currently under discussion within the EU.

Literature search output:

There were 14 papers identified for pyrrolizidine alkaloids from the global literature search, none when terms for Scotland were included and two papers from the grey literature.

There were two papers reporting PAs in honey, *Jacobaea vulgaris* (Tansy ragwort) was reported as the source of the PAs in one paper (Neumann and Huckauf 2016) and nectar from *Echium vulgare* (Viper's bugloss) was the source in the other report (Lucchetti et al. 2016). Both of these plants occur in the UK. Teas have been reported to contain high levels of PAs and Rooibos tea has been shown to be contaminated with *Senecio angustifolius*, a common weed where the tea is grown, resulting in PA contamination (Van Wyk et al. 2017).

A survey from Hong Kong analysed 48 different food items for PAs (234 samples). PAs were not detected in barley, beef, cattle liver, pork, chicken, milk and non-fermented tea. The highest levels (up 11000 µg/kg) were found in cumin seed, oregano, tarragon and herbs de Provence. Herbs and spices had not been considered in the EFSA survey or dietary intake assessment.

There is some evidence of transfer of PAs into eggs and meat of laying hens exposed to PAs in their diet (Mulder et al. 2016).

Expert review of literature i.e. outside period or issues not picked up

A UK survey of PAs found PAs in UK honey, in herbal teas and dietary supplements. A workshop on PAs was held and a risk assessment presented. Levels of up to 52000µg/kg were found in herbal teas, although the highest levels were in borage and comfrey that are known to have high levels of PAs. A maximum level of 1170 µg/kg was found in black, green and Earl Grey teas. Fifty-four samples of honey were analysed, 33 contained residues of PAs, the highest level was 250 µg/kg, and borage honeys contained the highest levels (FSA, 2016b). The FSA risk assessment concluded that efforts should be made to minimise PA content in teas and honey.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to contain PAs are honey, herbal teas and infusions, herbal supplements and herbs and spices. Honey is the main product of concern for Scotland and, although it is not possible to control where bees forage, care should be taken during the siting of hives, or weed management should be considered. There are no specific dietary concerns for Scotland, however due to the high toxicity measures should be taken to encourage Good Agricultural (and apiaricultural) Practice to reduce adventitious contamination and to monitor PA occurrence in Scottish foods in preparation for the introduction of maximum legal limits.

HorizonScan output

Total number of reports: 22

High levels of PAs (1031 µg/kg) in organic spearmint tea from Iran were reported by Germany. Bee pollen was reported to contain high levels of PAs in Germany. Extremely high levels of PAs (58441 µg/kg) were found in herbal tea from France, reported by Belgium.

Summary of risk for pyrrolizidine alkaloids to Scottish consumer and economy

Food types that are likely to contain PAs are honey, herbal teas and supplements and herbs and spices. There is not a significant risk to Scotland, in terms of food production and the consumer, however measures should be taken to monitor occurrence before limits are set.

Tropane Alkaloids

Background:

Tropane Alkaloids (TAs) are toxins produced by several plant families which can cause acute narcosis and paralysis. More than 200 TAs have been identified, however toxicity data are limited to a few compounds. EFSA published a Scientific Opinion on Tropane Alkaloids in food and feed in 2013. They could only perform the risk assessment on atropine and scopolamine and concluded that it was appropriate to establish an ARfD, and established a group ARfD of 0.016µg/kg bw for the sum of atropine and scopolamine (EFSA, 2013). Commission Regulation (EU) 2016/239 published in February 2016, introduced limits for atropine and scopolamine in infant foods. There was insufficient data to carry out an accurate exposure assessment and so EFSA commissioned a Europe-wide survey. The survey results were published in 2016 and included over 200 UK samples. A total of 1709 samples were analysed for 24 TAs. The highest mean concentrations were found in cereal-based meals for children (130.7 µg/kg), and the maximum TA concentrations were found in herbal teas, the highest level was 4358 µg/kg in dry herbal tea. Atropine and scopolamine were the most frequently detected TAs (Mulder et al, 2016a). An exposure assessment was published in 2018 using data from the survey and other data reported by 13 European countries. The mean and 95th percentile acute dietary exposures were highest in infants, toddlers and other children. Among processed foods, the main contributors to exposure of atropine and scopolamine were, at the UB, bread and cereal-based foods and at the LB, tea and herbal infusions for all age classes (EFSA, 2018d).

Literature search output:

There were 3 papers identified for tropane alkaloids from the global literature search, none when terms for Scotland were included and two papers from the grey literature.

Papers from the search described analytical methods.

Expert review of literature i.e. outside period or issues not picked up

The UK part of the EFSA survey was co-funded by the FSA. TAs were found in cereal products, particularly those containing millet, cereal-based infant foods and herbal teas. Peppermint tea contained high levels of TA (MacDonald et al, 2016).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to contain TAs are cereals, particularly containing millet, herbal teas and cereal-based infant food. There are no specific concerns for Scotland either for diet or production, however given the toxicity and that the most at risk groups are infants and young children, measures should be taken to monitor TA occurrence in Scottish foods to ensure they comply with regulatory limits.

HorizonScan output

Tropane alkaloids (atropine; scopolamine)

Total number of reports: 99

A RASFF report was issued for organic burdock tea from Germany (with raw materials coming from Croatia) following the detection of the tropane alkaloid atropine. There have also been reports of belladonna in infant homeopathic teething products for infants. Atropine and scopolamine have been reported in cereals, including millet.

Summary of risk for tropane alkaloids to Scottish consumer and economy

Food types that are likely to contain TAs are cereals, particularly containing millet, herbal teas and cereal-based infant food. There are no specific concerns for Scotland (millet is not a home grown cereal), however measures should be taken to monitor TA occurrence in Scottish foods to ensure they comply with regulatory limits.

Hydrocyanic acid (Cyanogenic glycoside, amygdalin)

Background:

Raw apricot kernels contain a naturally occurring substance called amygdalin, this is a cyanogenic glycoside which when ingested results in the release of cyanide in the human gut. Cyanide can cause nausea, fever, headaches, insomnia, muscle and joint pain and in extreme cases death. EFSA have evaluated the risks to human health and concluded that an adult consuming less than half a large apricot kernel could exceed the safe level for cyanide. EFSA advised that it is not possible to distinguish between the bitter varieties that contain the highest levels and the sweet varieties and therefore there is risk to human health. A maximum limit of 20 mg/kg has been set out in Commission Regulation (EU) 2017/1237 of 7 July 2017 amending Regulation (EC) No 1881/2006 as regards a maximum level of hydrocyanic acid in unprocessed whole, ground, milled, cracked or chopped apricot kernels placed on the market for the final consumer and limits for marzipan and similar products are also set in Regulation (EC) 1334/2008 on flavourings. Bitter almonds are also known to contain high levels of cyanide compounds but these are not included in the Regulation. There are also reports of high levels of hydrocyanic acid in cassava. WHO/JECFA have evaluated cyanogenic glycosides and derived an acute reference dose (ARfD) and a PMTDI of 0.09 mg/kg bw of cyanide equivalents and 20 µg/kg bw/d, respectively.

Literature search output:

There was 1 paper identified for cyanogenic glycosides from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

The paper reported the presence of cyanogenic glycosides in gluten free bread fortified with flaxseed meal (Shim, et al. 2016).

Expert review of literature i.e. outside period or issues not picked up

Australian food safety authorities have reported several incidents of poisoning from consumption of apricot kernels, particularly from consumers using apricot kernels as a health food, ostensibly to prevent or cure cancer, and in 2015 approved a code to prohibit the retail sale of raw apricot kernels (https://ris.pmc.gov.au/2015/12/22/hydrocyanic-acid-apricot-kernels).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with cyanogenic glycosides are raw apricot kernels, bitter almonds, some spirit drinks, marzipan and nougat and cassava based snack foods. These commodities are unlikely to have a large impact on Scotland, both in terms of food production and the consumer. However due to the severe toxic effects, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met. This may be difficult as some of these foods (apricot kernels) may be purchased via the internet.

HorizonScan output

Hydrocyanic acid; cyanogenic glycoside

Total number of reports: 176

A RASFF alert was released by Germany which informed the country of origin (Pakistan). The kernels were distributed to; Austria, Belgium, Croatia, Czech Republic, France, Germany, Italy, Netherlands, Poland, Slovakia, Switzerland, and the United Kingdom. Other recalls have been issued by several companies within the Netherlands, Belgium and Slovenia; the country of origin is not clear at this time.

Summary of risk for hydrocyanic acid to Scottish consumer and economy

Food types that are likely to contain cyanogenic glycosides are raw apricot kernels, bitter almonds, some spirit drinks, marzipan and nougat and cassava based snack foods. These commodities are unlikely to have a large impact on Scotland, both in terms of food production and the consumer. However due to the severe toxic effects, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met.

Erucic acid

Background:

Erucic acid is a fatty acid that occurs naturally in rapeseed, and other plants such as mustard which may cause heart disease. Low and high erucic acid varieties are grown for human consumption and industrial uses respectively. EFSA published a Scientific Opinion in 2016 that stated due to the high use of rapeseed oil in processed food products, some consumers, particularly infants and small children, could be at risk from chronic exposure to erucic acid. There are maximum limits for erucic acid in Regulation (EC) No 1881/2006 and the legislation requires that oil for food use contains no more than 5% erucic acid, but trade use a limit of 2% (the Codex level) to ensure a safety margin and compliance.

Literature search output:

There were no papers identified for erucic acid from the global literature search, none when terms for Scotland were included and one paper from the grey literature.

Expert review of literature i.e. outside period or issues not picked up

In recent years seed crushers have been reporting high levels of erucic acid in rapeseed, with levels as high as 30% erucic acid, resulting in some batches being diverted into non-food use, with subsequent loss of value for that batch (Farmers Weekly, 2016). The cause of the issue is unknown, however AHDB have just commissioned a research project to study this problem. (AHDB website).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Erucic acid is present in rapeseed, and so will be found in processed foods produced using this as an ingredient. High consumption of pastries and baked goods may put children at extra risk from chronic exposure to erucic acid. There is also a risk to Scottish growers of rapeseed from higher than expected levels of erucic acid leading to rejection of crop or diversion to non-food use at crushing facilities.

HorizonScan output

Total number of reports: 51

In 2016, EFSA released a new Scientific Opinion in regard to the presence of naturally occurring erucic acid in food and feed (EFSA, 2016b). They have concluded that while it is not a safety concern for most consumers, it may be a long-term health risk for children up to 10 years of age who consume high amounts of foods containing this substance. It may also be a health risk for chickens that are exposed to it through their feed.

Summary of risk for erucic acid to Scottish consumer and economy

Rapeseed crops and foods produced using rapeseed oil are most at risk from erucic acid. There is a risk to consumers and producers and although this contaminant is not a major issue, measures should still be taken to ensure that regulatory limits are met.

Processing Contaminants

Acrylamide

Background:

Acrylamide was classified as probably carcinogenic to humans in 1994 (group 2A) by the International Agency for Research on Cancer. The carcinogenicity of acrylamide to humans through food is however debated. Epidemiological studies are mainly negative but acrylamide is known to be a neurotoxin. Acrylamide is a contaminant naturally generated when sugars and asparagine (an amino acid) react during the heat treatment of carbohydrate rich foods. Exposure to acrylamide is largely through ingestion of foods although smoking may also contribute. In 2015 EFSA confirmed that acrylamide is a cause for concern for human health (EFSA, 2015b), with young children the most vulnerable group. In April 2018, Commission Regulation (EU) 2017/2158 established Benchmark Levels (BMLs) to prompt FBOs to introduce mitigation measures to try to reduce consumer exposure to acrylamide.

Literature search output:

There were 41 papers identified for acrylamide from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

A survey from Italy highlighted coffee and potato crisps as major dietary sources of acrylamide and stated that acrylamide exposure was significant and should be decreased (Bertuzzi et al. 2017). A study of intake by infants in Estonia also reported that acrylamide exposure among infant should be reduced (Elias et al. 2017). A further study to reassess acrylamide risk using Belgium as a case study also found low Margin of Exposure (MoE) values that indicate that acrylamide remains an issue for public concern (Claeys et al. 2016). However, EFSA's Scientific Opinion on acrylamide (EFSA 2015b) indicates that it would be difficult to lower exposure sufficiently to significantly increase the MoE.

Expert review of literature i.e. outside period or issues not picked up

Regulation (EU) 2017/2158 established best practice, mitigation measures and BMLs for the reduction of the presence of acrylamide in food.

Food Business Operators are expected to:

- Be aware of acrylamide as a food safety hazard and have a general understanding of how acrylamide is formed in the food they produce;
- Take the necessary steps to mitigate acrylamide formation in the food they produce; adopting the relevant measures as part of their food safety management procedures;
- Undertake representative sampling and analysis where appropriate, to monitor the levels of acrylamide in their products as part of their assessment of the mitigation measures;
- Keep appropriate records of the mitigation measures undertaken, together with sampling plans and results of any testing

The measures are proportionate to the nature and size of the business, to ensure that small and micro-businesses are not burdened. The new legislation applies to all FBOs that produce or place on the market the foods listed below:

- French fries, other cut (deep fried) products and sliced potato crisps from fresh potatoes
- Potato crisps, snacks, crackers and other potato products from potato dough
- Bread
- Breakfast cereals (excluding porridge)
- Fine bakery wares: cookies, biscuits, rusks, cereal bars, scones, cornets, wafers, crumpets and gingerbread, as well as crackers, crisp breads and bread substitutes
- Coffee: (i) roast coffee; (ii) instant (soluble) coffee
- Coffee substitutes
- Baby food and processed cereal-based food intended for infants and young children

Different requirements apply to local and independent FBOs selling food directly to the consumer or directly into local retail. For example, independent cafes, fish and chip shops and restaurants.

For larger centrally controlled and supplied chains with standardised menus and operating procedures, the legislation reflects that the controls of acrylamide can be managed from the centre. This would apply to, for example, large restaurants, hotels and café chains.

There have been recent studies on the presence of acrylamide in UK foods. The most recent FSA results were published in March 2017 (www.food.gov.uk/sites/default/files/fs102075report2016.pdf). These showed the highest levels were found in potato products and some biscuits, the FSA said the results did not increase their concern about risk to human health, but they did note that the nature of the survey and the data were limited. A total diet study that included acrylamide was also published by the FSA (www.food.gov.uk/science/chemical-safety-research-/env-cont/fs102081). Again they noted that potato products were the main dietary source of acrylamide. They stated dietary acrylamide exposure levels for all age classes are of possible concern for an increased lifetime risk of cancer. However they also stated that the survey results did not increase concern but reinforced the FSA advice to consumers and the FSA's efforts to support the food industry in reducing acrylamide. A further independent survey of 92 snack products was undertaken by Changing Markets at the end of 2016 and published in 2017. This found 16 samples exceeded the EU recommended Indicative Value of 1000 µg/kg acrylamide. The highest levels were found in sweet potato crisps, with a level of nearly 2.5 times the Indicative Value found in one sample (2483 µg/kg). (Changing Markets, 2017). Other vegetable crisp samples have also been found to contain high levels, but these products are specifically covered by the new Regulation. The UKFSS Annual Report for 2015-16, reported that 14.2% of samples tested exceeded the recommended values. Results for 2016-17 showed an increase of unsatisfactory results as 26.5% were reported as unsatisfactory.

Consumption / exposure / of Scottish population and Production / industry in Scotland

The wide range of food types that are likely to contain acrylamide are all commonly eaten and produced in Scotland. In addition there may be some foods specific to Scotland, such as well fired rolls, that may contain higher acrylamide levels. Monitoring has shown an increase in the percentage of samples exceeding the Indicative Value in Scotland over the last 2 years (UKFSS, 2016 and 2017). The highest percentage of samples in the 2016-207 was found for acrylamide with 27% of samples found to exceed the Indicative Value, although it should be noted that this was targeted sampling. The introduction of legislation, and the continued concern among researchers about the high exposure, resulting in low MOE levels, means that this contaminant should be seen as important. Specific checks may need to be made on local and speciality foods in Scotland to check for compliance and help the FBOs reduce acrylamide levels, and in line with the ALARA principle in order to protect public health.

HorizonScan output

Total number of reports: 29

High levels of acrylamide (944 µg/kg) were reported in cookies from Bosnia and Herzegovina. Biscuits with apple concentrate were found to have high levels of acrylamide, with reports received from Poland, Croatia, and Belgium. Acrylamide (2803 µg/kg) was reported in biscuits with apple flavour from Belgium.

Summary of risk for acrylamide to Scottish consumer and economy

The wide range of food types that are likely to contain acrylamide, all commonly eaten and produced in Scotland and the introduction of legislation means that this contaminant should be seen as important, and monitoring of specific foods should be continued to compare with the BMLs introduced in 2018.

Furan, Methyl furan

Background:

Although the presence of furan in foods has been known for years, interest in this compound increased after the International Agency for Research on Cancer (IARC) classified furan as a possible human carcinogen (Group 2B) following extensive research in animals. Furan is hepatotoxic in rats and mice with cholangiofibrosis in rats and hepatocellular adenomas/carcinomas in mice being the most prominent effects. EFSA published a Scientific Opinion in October 2017 that concluded that the level of exposure to furans in food indicates a potential human health concern (EFSA, 2017d). They concluded that based on animal studies, liver damage and liver cancer were the most critical health effects. They noted that the Joint FAO/WHO Expert Committee on Food Additives (JECFA) had also concluded that the level of exposure to furan in food indicates a human health concern.

Furan and related compounds 2- and 3- methyl furan are formed in foods during thermal processing and can co-occur. Furans are produced from several precursors such as ascorbic acid, amino acids, carbohydrates, unsaturated fatty acids and carotenoids, and are found in a variety of foods including coffee and canned and jarred foods.

Literature search output:

There were 16 papers identified for furans from the global literature search, none when terms for Scotland were included and 1 paper from the grey literature.

A study from Spain showed high levels in deep fried foods, e.g. ham croquettes, onion rings, fish fingers. Levels of furan were between 12 and 172 µg/kg, levels increased when the frying oil was re-used (Juaniz et al. 2016). A risk assessment showed the MOEs were below 10000 for the population, but there could be a possible health concern from furan for high consumers of fried food alone. A second Spanish study concluded there was no health concern from furan for infants from infant formula and cereal baby foods, but there could be a potential risk from meat and fished based food (Altaki et al. 2017).

Expert review of literature i.e. outside period or issues not picked up

The FSA have published surveys for furan in food in 2012 and 2017. In the most recent survey 120 samples were analysed for furans. The highest mean and maximum levels of 3347 and 5009 µg/kg were found in roasted coffee. The FSA noted that the results give a snapshot of the range of levels in foods, but these will vary depending on raw materials, and processing conditions used, so they can only give an indication of occurrence. More sampling and analysis is planned until December 2018.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with furan and methyl furan include heat treated foods in cans and jars (e.g. baby food, soups). Health risks may appear above a certain daily dose of furan consumption. Toddlers (12 to 36 months) and adults (18 to 65 years) are the groups of most concern for furan exposure. Coffee (roast and instant) are significant sources of furans, although due to the volatility of furan the levels will decrease in hot beverages in open containers. Furan may be of relevance for speciality cereals and baked goods (e.g. well fired rolls) as biscuits, crackers crispbreads were the group with the second highest concentrations after coffee. Scottish consumers are not different to the rest of the UK for these commodities, however they are higher consumers of takeaway and food eaten outside the home which is more likely to be deep fried. Given the EFSA conclusion that furans are of potential health concern, this contaminant class should be seen as important both in terms of food production and to the consumer. No data have been collected during Local Authority surveys in the last 2 years and this should be considered in light of the recent EFSA Opinion.

HorizonScan output

Total number of reports: 0

No reports of levels in foods yet, but in October 2017 EFSA published an assessment of the risks posed by furan in food (EFSA, 2017d). They concluded that exposure to furan and methyl furans in food could lead to possible long-term liver damage. The most exposed group of consumers are infants through consumption of ready-to-eat jarred and canned foods. Exposure in other population groups is mainly from consumption of grain-based foods and coffee, depending on age and consumer habits.

Summary of risk for furan, methyl furan to Scottish consumer and economy

Food types that are likely to be contaminated with furan and methyl furan include heat treated foods in cans and jars (e.g. baby food, soups), fried foods and coffee. Due to the importance of these commodities to Scotland, both in terms of food production and to the consumer, this contaminant class should be seen as important, and some monitoring should be considered. These compounds are included in an EFSA call for data that opened on 15 May 2018 (EFSA, 2018).

2-MCPD, 3-MCPD, Glycidol, 2-MCPD Esters, 3-MCPD Esters, Glycidyl Esters

Background:

3-MCPD has been found in a wide range of foods. These foodstuffs include soy sauce, bread, noodles, biscuits; malt based food ingredients, coffee and certain meats, cheeses, salted fish and smoked foods.

Main contributors of 3-MCPD to dietary intake were found to be soy sauce and soy-sauce based products, and bread and noodles. The latter two due to high consumption rather than the high levels of 3-MCPD present in these foods.

3-MCPD may be formed as a result of a reaction between a source of chlorine (e.g. chlorinated water or salt) in the food or a food contact material and a lipid source.

This reaction is encouraged during the heat processing of foods, including the roasting of cereals and malts used for brewing. It is also known to occur in acid-hydrolysed vegetable protein (HVP) when produced using hydrochloric acid.

During the production of fats and oils, fatty acid esters may be formed from 2-MCPD, 3-MCPD and glycidol when the fats and oils are heated to high temperatures in the presence of chloride ions.

The International Agency for Research on Cancer (IARC) classified glycidol as probably carcinogenic to humans (group 2A) and 3-MCPD as a possible human carcinogen (group 2B). The concern with the fatty acid esters of these compounds is that the parent MCPD/glycidol moiety is released in the human intestine. A comprehensive review of 3- and 2-MCPD and their fatty acid esters and glycidyl fatty acid esters was undertaken by EFSA. The EFSA opinion stated that the estimated exposure to 3-MCPD of infants receiving formula only was 2.4 µg/kg bw per day using mean occurrence and 3.2 µg/kg bw per day using P95 of occurrence; both values are above the group TDI, which for the high consumers was exceeded up to fourfold (EFSA, 2016).

Literature search output:

There were 19 papers identified for 2-MCPD, 3-MCPD, glycidol, 2-MCPD esters, 3-MCPD esters, glycidyl esters from the global literature search, none when terms for Scotland were included and 3 papers from the grey literature.

A study to examine possible formation of 3 MCPD fatty esters (bound 3-MCPD) during frying found that using corn oil with no endogenous bound 3-MCPD did not result in an increase in levels in food, but using a palm oil that contained bound 3-MCPD did result in an increase in the fried food (Arisseto et al. 2017).

Expert review of literature i.e. outside period or issues not picked up

An amendment to Regulation (EC) No 1881/2006 as regards maximum levels of glycidyl fatty acid esters in certain foods was published on 27 February 2018 and came into force on 19th March 2018. The new Regulation covers edible oils and infant formula as well as soy sauce and hydrolysed vegetable protein. Limits for glycidyl esters have been set for infant formula (powder and liquid) at 75µg/kg and 10µg/kg respectively, but these will be reduced to 50µg/kg and 6µg/kg from 1st July 2019.

Consumption / exposure / of Scottish population and Production / industry in Scotland

There is concern that infants receiving only formula could consume levels of MCPD esters that are a potential health risk (Arisseto et al. (2017), Jedrkiewicz, et al., (2016) and Wang, et al (2016), and could exceed the TDI for 3-MCPD by up to four fold (EFSA, 2016). Foods produced using palm oil as an ingredient, or that are fried in palm oil could have significant levels of bound 3-MCPD and GE. Due to the importance of these commodities to Scotland, both in terms of food production and to the consumer, this contaminant class should be seen as important and measures taken to ensure that current and upcoming regulatory limits are met. There are no recent data on the occurrence of these compounds in the UKFSS results and in view of the new regulation some monitoring should be considered. Given that the legislation applies to oils as an ingredient, these should be targeted rather than finished products.

HorizonScan output

Total number of reports: 128

EFSA released an update (EFSA, 2018b) of the risk assessment on 3-MCPD in vegetable oils and food to reassess the possible long-term adverse effects on the kidney and male fertility. It was noted that the TDI of 2 µg/kg per day established by EFSA in 2017 is not exceeded in the adult population, though a slight exceedance of the TDI was observed in high consumers of younger age groups, particularly infants receiving formula only.

Summary of risk for 2-MCPD, 3-MCPD, glycidol, 2-MCPD esters, 3-MCPD esters, glycidyl esters to Scottish consumer and economy

Food types that are likely to contain 3-MCPD and glycidyl esters include ingredients commonly used in the production of a lot of products, particularly oils and fats as these are used in a large range of commodities. There is concern that infants only receiving formula could exceed the TDI. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important and measures taken to ensure that regulatory limits are met, including some monitoring to check compliance with the new legislation.

Ethyl Carbamate

Background:

Ethyl carbamate (EC), also referred to as urethane, is an ethyl ester of carbamic acid. EC has been found in many fermented food products and alcoholic beverages such as cheese, bread, yoghurt, wine, whisky and soy sauce.

EC has been classified as a probable carcinogen (Group 2A) by the International Agency for Research on Cancer (IARC). EC has been linked to lung cancer, and mutations in organs such as liver, mammary glands, heart, ovary and forestomach. EC exposure during pregnancy can cause damage to developing brains.

Literature search output:

There were 5 papers identified for ethyl carbamate from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

A recent review highlighted that as well as being classified as a Group 2A carcinogen by IARC, there is new evidence that long-term exposure to EC may cause neurological disorders (Gowd et al. 2018). An exposure assessment for Korea found the major foods contributing to EC exposure were soy sauce, plum liqueur and whisky (Choi et al. 2017), however EC was low concern for the Korean general population.

Expert review of literature i.e. outside period or issues not picked up

EFSA have requested data on levels of EC compounds in foods and beverages. This is in response to the FAO and WHO conclusion in 2016 that EC is genotoxic and is a multisite carcinogen in all animal species tested. The submitted data will be used by EFSA to carry out a risk assessment and may lead to regulations or pressure on industry to change production methods to reduce levels.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with EC include spirit drinks and fermented foods. Spirit drinks are important to Scotland, particularly whisky, but there were very few reports of EC in HorizonScan. The industry worked on this issue many years ago to minimise EC in whisky. This is not an issue particular to Scotland, but in view of the toxicological reclassification, EFSA's request for data, and the lack of recent data on the presence of EC in other foods, this contaminant class should be seen as important and monitoring should be considered.

HorizonScan output

Total number of reports: 6

Ethyl carbamate (4.7mg/kg) reported in plum brandy from Germany. Kirsch was recalled due to content of high levels of EC.

Summary of risk for ethyl carbamate to Scottish consumer and economy

Food types that are likely to be contaminated with EC include spirit drinks and fermented foods. This is not an issue particular to Scotland, but in view of the toxicological reclassification, EFSA's request for data, and the lack of recent data on the presence of EC in other foods, this contaminant class should be seen as important and monitoring should be considered.

4-methylimidazole, 2-methylimidazole, MeIQ, 2-amino-3,4-dimethylimidazo[4,5-f]quinoline

Background:

The presence of substituted imidazoles 4-methylimidazole (4-MEI), 2-methylimidazole (2-MEI) in foods may result from addition of ammonia caramel colourings E150c (Class III) and E150d (Class IV). Class III ammonia caramels are commonly added to a wide range of foods, such as bakery products, soy and brown sauces, gravies, soups, vinegars and beers, whilst Class IV sulphite ammonia caramels are added to soft drinks, pet foods and soups. In the manufacturing process of such caramel colours, imidazoles are formed as by-products, typically when ammonia or ammonium salts react with reducing sugars.

In 2012, the International Agency for Research on Cancer (IARC) classified both 4-MEI and 2-MEI as "possibly carcinogenic to humans" (group 2B).

Heterocyclic aromatic amines (HCAs) such as MeIQ and 2-amino-3,4-dimethylimidazo[4,5-f]quinoline are mutagenic and/or carcinogenic compounds formed naturally during cooking of proteinaceous food such as meat and fish. EFSA reviewed caramel colours in 2011, and concluded that the highest exposure that could come from consumption of foods containing colours E150c and E150 did not give cause for concern. However they also stated that to minimise exposure it would be prudent to keep levels in caramel colours as low as technologically feasible and recommended further research into the relationship between production of caramel colours and the formation and nature of their constituents (EFSA, 2011).

Literature search output:

There were 13 papers identified for imidazoles and HCAs from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

4-MEI was reported in several types of coffee and coffee substitutes in Portugal (Cunha et al. 2016), while Mottier et al. 2017 reported the presence of 4-MEI in products known not to contain caramel, i.e. roasted barley, roasted malt, cocoa powders. Low levels were found in cereal based foods, including toasted bread. The authors highlighted that measurement of 4-MEI is not a reliable indicator of the use of additives E150c and E150d.

Expert review of literature i.e. outside period or issues not picked up

The Centre for Food Safety issued a notice in September 2016 to state that although some soy sauce samples had been found to contain 4-MEI the levels found did not give rise to health concern (www.cfs.gov.hk/english/multimedia_pub/multimedia_pub_fsf_122_04.html). However they advised the manufacturers of caramel colour to maintain 4-MEI levels as low as technically possible, and food manufacturers to use food colours with the lowest possible level required for the intended function. This mirrors the advice from EFSA and is appropriate for all manufacturers.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with imidazoles and HCA are widely eaten and produced in Scotland. Although not statistically significant there was an indication that some groups of the Scottish consume more soft drinks than other parts of the UK. This class of contaminant, while important, is probably one of the lower risk groups considered in this review.

HorizonScan output

Total number of reports: 1

More than a quarter of the brands of soy sauce tested in Hong Kong were found to contain 4-methylimidazole (4-MEI).

Summary of risk for 4-methylimidazole, 2-methylimidazole, MeIQ, 2-amino-3,4-dimethylimidazo[4,5-f]quinolone to Scottish consumer and economy

Food types that are likely to be contaminated with imidazoles and HCA are widely eaten and produced. This class of contaminant, while important, is probably one of the lower risk groups considered in this review.

Hydroxymethylfurfural, Furfural

Background:

5-Hydroxymethylfurfural (5-HMF) and furfural are cyclic aldehydes, commonly occurring in food, formed in the process of non-enzymatic browning. These compounds, especially HMF, are widely used as a quality indicator of the intensity of thermal changes in products; on the other hand, they are food contaminants with potential carcinogenic and genotoxic properties. Several studies report that high concentrations of these contaminants may have cytotoxic effects in the respiratory tract and may cause irritation of the eyes, skin and mucous membranes. Furthermore, HMF can be converted into 5-sulfoxymethyllfurfural (SMF), which showed activity in mouse skin tumours and mutagenic action in bacterial and mammalian cells. HMF may also give rise to 5-chloromethyllfurfural, which can be more mutagenic than SMF.

In carbonated soft drinks, the sources of 5-HMF are both sweeteners and sulphite ammonia caramel, added as a food colouring. The levels of this compound depend on the type of drink and sweetener: sucrose or glucose–fructose syrup. A German risk assessment concluded no relevance for humans regarding carcinogenic and genotoxic effects could be derived (Abraham et al 2011).

In bakery products, cookies, candies, chewing gums and alcoholic beverages HMF may be present due to the use of corn syrups. HMF may also be present in fruit juices, dried fruits, crackers, vinegars, baby food, honey and coffee.

Literature search output:

There were 27 papers identified for hydroxymethylfurfural and furfural from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

There were reports of HMF in non-alcoholic drinks (Czerwonka, 2018), Brazilian corn syrup (de Andrade, 2016), raisins and dried milk (Sun, 2017).

Expert review of literature i.e. outside period or issues not picked up

In 2017 the EU issued a public consultation for proposed modifications to Annex III to Regulation 1223/2009: Restrict the use of furfural at the concentration up to 0.001% in cosmetic products. The Department of Food Safety, Federal Institute for Risk Assessment, Germany carried out a risk assessment on 5-HMF in food. The foods they noted that could lead to exposure were dried fruits, cereals and bread and coffee. It was noted exposure data were incomplete as coffee, a major source of HMF, was missing from the data set. They also noted there is a need to analyse HMF content in food containing caramel colours (Abraham, 2011).

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with HMF and furfural are widely eaten and produced. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important.

HorizonScan output

Total number of reports: 0

Summary of risk for hydroxymethylfurfural, furfural to Scottish consumer and economy

Food types that are likely to be contaminated with HMF and furfural are widely eaten and produced in Scotland. Honey production is one industry that is affected by HMF levels, as there are regulations that set criteria for the maximum amount of HMF permitted (Scottish Statutory Instruments, 2015). High levels of HMF in honey can be an indication of poor quality or adulteration in honey, and may provide evidence of fraudulent labelling of honey as Scottish. Due to the importance of this commodity to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important.

Nitrosamines

Background:

Nitrosamines are formed by reaction of secondary or tertiary amines with a nitrosating agent. In foods, the nitrosating agent is usually nitrous anhydride, formed from nitrite in acidic, aqueous solution. Food constituents and the physical make-up of the food can affect nitrosamine formation. Foods which have been shown to contain volatile nitrosamines include cured meats, primarily cooked bacon; beer; some cheeses; non-fat dry milk; and sometimes fish.

N-nitrosodimethylamine (NDMA) is one of the most frequently occurring nitrosamines in our dietary foods. NDMA is a potent carcinogen, capable of inducing malignant tumours in various animal species in a variety of tissues, including liver, lung, and stomach.

Literature search output:

There were 3 papers identified for nitrosamines from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be contaminated with nitrosamines are widely eaten and produced in Scotland, such as salted and smoked fish and bacon. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important.

HorizonScan output

There were 4 reports in HorizonScan, 3 on beer and one on an article in contact with foodstuffs (baby's dummy).

Summary of risk for nitrosamines to Scottish consumer and economy

Food types that are likely to be contaminated with nitrosamines are widely eaten and produced. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant class should be seen as important.

Semicarbazide

Background:

Semicarbazide (SEM) is determined in food as a marker to detect the illegal use of the banned antibiotic nitrofurazone. SEM also forms naturally in certain shellfish, seaweed, eggs, and whey. Certain nitrogenous compounds, principally the amino acid arginine, have been proposed as precursors of SEM in these foods, and arginine has been reported to be present at a high level in some shellfish. However, SEM is also present in certain foods packed in glass jars and bottles closed with metal lids sealed with plastic gaskets that are foamed using the chemical blowing agent azodicarbonamide (ADC). The products concerned included fruit juices, jams, conserves, honey, baby food, pickles and sterilised vegetables, mayonnaise, mustard, sauces and ketchup. ADC is also used as a flour additive in some countries such as Canada, USA and Brazil owing to its dough-improving properties; however, this practice is banned in the European Union.

The main concern about SEM from the toxicological point of view relates to its potential genotoxicity and/or carcinogenicity. Some studies indicate that SEM is both a weakly genotoxic and carcinogenic agent.

Literature search output:

There were no papers identified for SEM from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

Expert review of literature i.e. outside period or issues not picked up

SEM was reported in several heather honey samples tested in Scotland and northern England in 2009, and also in two samples of wild forest honey from New Zealand in 2011. The hives from which these samples were taken were strongly considered to have been free from nitrofurazone treatment, and therefore a natural source of SEM was suspected. A literature study to investigate possible sources of SEM in heather honey was carried out for FSAS (now FSS) in 2012. One conclusion was that natural SEM precursors, such as arginine were present in heather honey through transfer from Calluna plants (Crews, 2012). The natural formation of SEM has been demonstrated in certain shellfish, seaweed, eggs, and whey, with arginine and creatinine proposed as its precursors.

Consumption / exposure / of Scottish population and Production / industry in Scotland

With current increases in farming of seaweed for food use, SEM may be of particular interest in these products from Scotland along with the possibility of SEM presence in heather honey. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant should be seen as important.

HorizonScan output

Total number of reports: 24

Summary of risk for semicarbazide to Scottish consumer and economy

With current increases in farming of seaweed for food use, SEM may be of particular interest in these products from Scotland along with the possibility of SEM presence in heather honey. Due to the importance of these commodities to Scotland, both in terms of food production and the consumer, this contaminant should be seen as important.

Processing Contaminants (fraudulent/illegal)

Melamine

Background:

Melamine is a nitrogen rich organic compound which has been added to food and feed to fraudulently increase the apparent protein content and may also be leached out of non-compliant food contact materials. Dietary long term exposure to high levels of melamine may lead to kidney and bladder diseases. EFSA published a Scientific Opinion on melamine and related compounds (cyanuric acid, ammeline and ammedlide) in food and feed in 2010 (EFSA, 2010b). They concluded that the exposure from background levels from approved sources, e.g. food contact materials does not represent a risk, however the Opinion did not consider the potential exposure from adulteration. A TDI of 0.2 mg/kg bw was established by EFSA for melamine after the Chinese milk scandal and the European Commission introduced a maximum limit of 2.5 mg/kg in food.

Literature search output:

There were 44 papers identified for melamine from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

The majority of the papers related to analytical methods to detect melamine. One paper discussed the impact of children affected by the scandal in 2008, and possible as yet unknown effects (Wen et al. 2016).

Expert review of literature i.e. outside period or issues not picked up

US NGO The Endocrine Disruption Exchange has stated that melamine could have health impacts beyond kidney function. Following a review of 43 studies on melamine, they have highlighted effects on memory and learning as areas for focus for research.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be adulterated with melamine include milk and milk products and animal feeds. Scottish milk is unlikely to be contaminated with melamine, but imported feed commodities may be a risk to Scotland, however there is no specific additional risk for Scotland, so while measures should be taken to ensure that regulatory limits are met it is not a high priority.

HorizonScan output

Total number of reports: 111 (related to fraud), 538 in total when migration from food contact materials included.

Thai authorities found cyanuric acid in feed after testing 60 tons of dried squid meal imported from a Vietnamese firm. Chinese police seized almost 12 tonnes of yoghurt candy tainted with melamine.

Summary of risk for melamine to Scottish consumer and economy

Food types that are likely to be adulterated with melamine include milk and milk products and animal feeds however there is no specific additional risk for Scotland, so while measures should be taken to ensure that regulatory limits are met it is not a high priority.

Sudan Dyes

Background:

Sudan dyes I-IV are synthetic azo dyes. The EU does not permit the use of these colourants as food additives because their degradation products are considered to be carcinogens and teratogens. Sudan dyes themselves may also cause skin irritation. These dyes are still sometimes fraudulently used in spices such as paprika to enhance the colour and so the apparent ‘freshness’ of the product.

Literature search output:

There were 6 papers identified for Sudan dyes from the global literature search, none when terms for Scotland were included and no papers from the grey literature.

Expert review of literature i.e. outside period or issues not picked up

There have been frequent recent reports of Sudan dyes in palm oil from Ghana. This product is included in the list of products under increased official controls under Regulation 669/2009 as amended.

Consumption / exposure / of Scottish population and Production / industry in Scotland

Food types that are likely to be adulterated with Sudan dyes include spices and products from these spices, as well as palm oil. This contaminant class is not of major significance for Scotland, however measures should be taken to ensure that regulatory limits are met.

HorizonScan output

Total number of reports: 15

The Swiss government released a warning following the discovery of Sudan IV (Scarlet Red) in palm oil originating from Ghana. This is the latest in a number of warnings and recalls involving palm oil from Ghana contaminated with Sudan dyes. Reports have also been received of Sudan dyes in palm oil from Senegal.

Summary of risk for Sudan dyes to Scottish consumer and economy

Food types that are likely to be adulterated with Sudan dyes include spices and palm oil and products made from these. This contaminant class is not of major significance for Scotland, however measures should be taken to ensure that regulatory limits are met.

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