RISK ANALYSIS

Honey Risk Profile

Andrew Hudson, Andy Axon, Amelia Stoneley, Catherine Kane, Emma French, Lauren Adams, Lucy Smythe, Pamela Iheozor-Ejiofor

Keywords: Foodborne Disease and AMR, Foodborne disease, Trade, Products of animal origin

https://doi.org/10.46756/sci.fsa.fjl846

FSA Research and Evidence

This risk profile on imported honey was produced by Food Standards Agency (FSA) and Food Standards Scotland (FSS) at the request of Defra UK Office for Sanitary and Phytosanitary Trade Assurance (UK Office). The risk profile will be used by UK Office to inform of the potential public health risks associated with honey imported into GB and to assist in the assessment of market access requests.

This risk profile is not a risk assessment and therefore does not assess the public health risks of honey. The risk profile identifies and characterises the main hazards that may be present in imported honey, at the point(s) at which the commodity enters the food chain. It describes the nature and the evidence informing on levels of hazard in the commodity, the potential human health effects of the hazards, as well as key mitigations, regulations and controls, data gaps and uncertainties.

1. Executive Summary

Honey consists of what is essentially partially dehydrated plant nectar or honeydew that has undergone an enzymatic transformation to convert the disaccharide sucrose to the monosaccharides glucose and fructose. It has physicochemical properties that make it inhibitory to microbial spoilage, a necessary property since honey is stored by bees to provide food for the winter (non-flowering) months.

The very nature of the way in which nectar, honeydew, pollen and water are harvested by bees explains the way in which contaminants are introduced into the honey. Bees can fly up to 12 km (usually 1.5 km) to collect nectar or honeydew and so they “sample” the surrounding environment, bringing contaminants back to the colony on their bodies or in the collected pollen and liquids. This means that any contaminants in the surrounding area can be present in honey and consequently this has led to bees being used as bio-monitors of the surrounding environment.

Other contaminants can be introduced from bee keeping activities such as smoking and treating *Varroa* (a parasitic mite) infestations. Treatment of bacterial infections of bees using antibiotics has resulted in detections of antibiotics, notably chloramphenicol, and regulatory actions to prevent importation of such contaminated honey.

Essentially, therefore, contaminants of honey are derived predominantly from either from the environment or bee keeping activities with some potential for contamination during processing.

The list of potential contaminants is consequently long: pathogenic bacteria, pesticides, metals, veterinary medicines including antibiotics, allergens, persistent organic pollutants, microplastics, and radionuclides. While many of these can often be detected (e.g. pesticides) they are seldom present at concerning concentrations or there is no current clear understanding of the risk posed (e.g. microplastics).

The perennial honey hazard of note is *Clostridium botulinum* which can cause infant botulism and, rarely (<1% of cases), fatalities. Honey can be contaminated usually in the order of up to 10% of samples, but also as much as 20%, albeit at low spore concentrations. However, the disease is infrequent (for example, data from Canada reports a few cases per million live births) as the risk is recognised and public health information advising parents/carers not to give honey to children less than one year old is the primary form of control.

Pesticides are used under control to prevent crop losses and residues have been detected even in organic honey. Metals may be present naturally in the environment or as the result of human activity, and persistent organic pollutants (POPs) are also anthropogenic. These hazards may be controlled by risk management actions such as control of use of pesticides to minimise exposure to bees, for example by application when plants are not flowering. Siting of colonies can affect presence of contaminants such as metals and POPs associated with industrial/transport activity.

Veterinary medicines, which include antibiotics, can be introduced though bee keeping activities aimed at controlling bee pests and/or pathogens. These are managed through appropriate and targeted use of the chemicals applied or the use of alternative non-allotropic chemicals.

Microplastics/nanoplastics have also been detected in honey but their significance is unknown since the risks to human health are unclear. Natural toxins such as tutin can be brought back to the colony from particular plants or honeydew-producing insects. Contamination of honey can be controlled by preventing honey being produced close to the plants/ insects of concern or by temporal interventions.

Radionuclides derived from human activity can be detected, and honey has been the focus of testing following incidents such as the Chernobyl emergency to monitor the environment. Mechanisms are in place to declare such emergencies and there is enabling legislation to implement testing of foods from areas likely to be affected by deposition. In the absence of localised contamination resulting from accidents, the consensus of published data is that honey is not a source of concerning radioactivity.

The Codex standard for honey (as amended in 2022) is focused on the composition and definitions of honey, and there are few specific prohibitions of hazards other than general statements that it should be free from heavy metals in amounts which may represent a hazard to human health, should have residues of pesticides and veterinary drugs that conform to Maximum Residue Limits (MRLs) produced by Codex Alimentarius Commission (CAC), be produced according to accepted general principles of food hygiene, and adhere to any applicable CAC microbiological criteria. Some of the compositional criteria are of relevance to microbiological food safety, including minimum glucose and fructose concentrations and maximum water concentrations which in combination provide conditions unsuitable for the growth of pathogenic bacteria.

Imports of honey to the UK have increased over time and 51,400 tonnes were imported in 2022. Most UK imports come from China, with 68% of those imports (as measured by weight) originating there, with the next highest being Mexico at 6.3%. China, Turkiye, Iran and Argentina are the four largest producers, while China and Argentina are the largest exporters to the world.

The maximum mean mass consumed over time in any one UK age group consuming honey other than as an ingredient in another food is 7.8 g per person per day (97.5th percentile=24g), and consumption in the UK increased from 2016 to 2022. Almost 80% of consumers spread honey on bread, usually at breakfast time, but there is a growing tendency to use honey as a beverage and yoghurt sweetener. A significant form of exposure is in the form of breakfast cereals.

Hazards can be detected at low concentrations/activities quite routinely, but it is uncommon for them to be present at a level exceeding a MRL. There are few technological remediation processes that can be applied to honey once harvested and so prevention of contamination and surveillance programmes constitute the main means of control.

Overall, the primary health concern associated with honey, infant botulism, is well controlled by public health messaging, with the advice to parents/ care givers being consistent. Plant toxins have caused disease following honey consumption. One is tutin which is confined to New Zealand and for which there are mitigations and standards in force. Another, grayanotoxin, causes “mad honey” disease when the toxin is introduced into honey from a few species of *Rhododendron*. The source of this honey is primarily restricted to parts of Turkiye and Nepal. At least one more, gelsedine alkaloids, is known but little information is available.

2. Background

2.1. Introduction and Scope

This Risk Profile identifies and characterises the main hazards associated with imported honey that may be a concern for public health. Key controls, mitigation measures and relevant regulations are summarised along with general UK consumption patterns and information on global production and trade. This information will be used by Defra UK Office for SPS Trade Assurance (UK Office) and the FSA Imports Market Access Assurance (IMAA) Team. It will provide background information on potential food safety concerns relating to imported honey to contribute to the overall evidence package used for assessment of specific third country market access requests to export honey to the UK and to support related audit and assurance activities.

This Risk Profile will not assess risk and is not a Risk Assessment, since exposure assessment and risk characterisation are not performed. This risk profile is not an exhaustive assessment of all potential hazards in honey; it describes the main hazards that may need to be considered in relation to control of imported honey. This Risk Profile does not make public health recommendations or otherwise constitute public health advice. It intended to inform on the hazards potentially associated with honey, to guide market access audit and assurance activities relating to imported honey. Identification of hazards in this profile does not necessarily indicate a present concern for public health from honey. However, further investigation such as risk assessment or review of controls or other specific audit activities may be required on the identified hazards before approving market access for honey. This Risk Profile will not address issues concerning fraud or authenticity unless there is an identified food safety consequence.

“Honey” is taken to mean products trade under the HS code 0409 “natural honey” and as defined under assimilated Council Directive 2001/110/EC (Council of the European Union, 2001) as below. Wax is included since it may be present in commercial honeys, whereas other honey products such as royal jelly or foods containing honey as an ingredient are excluded from the risk profile.

2.2. Commodity Description

Honey is the natural sweet substance produced by *Apis mellifera* and, potentially, other species of bee from the nectar of plants or “honeydew” produced by some plant-sucking insects. Honey consists of what is essentially partially dehydrated plant nectar or honeydew that has undergone an enzymatic transformation to convert sucrose to glucose and fructose.

Bees forage for nectar (for the carbohydrate) and/or pollen (primarily for the protein) from flowers or honeydew (Douglas, 2009). It is then brought back to the hive where the nectar is stored in honeycomb and dehydrated by the action of bees' wings and a warm environment to produce the viscous sweet product. Honey is produced to allow the colony to survive the winter by storing excess nectar in a form that is resistant to microbial degradation because of the very high sugar content. Bee colonies will naturally produce a surplus, but apiculturists manipulate hives in such a manner that a larger harvestable excess is stored than would occur naturally. A hive can produce in excess of 22 kg, but a more normal weight would be 11 kg (British Beekeepers Association, 2017).

By observing and decoding bee waggle dances, (a behaviour in which bees communicate to other hive members the location of resources) (Dong et al., 2023), it was concluded that 10% of bees foraged >9.5 km from the hive and the rest at shorter ranges, but only when ample heather was available in August (Beekman & Ratnieks, 2000), and under the particular geographical situation of the colony. Typical flight ranges are 1 – 1.5 km.

When returning to the hive the nectar is transferred to food-storer bees who then regurgitate the nectar into the waxy hexagonal cells known as the comb. Water is removed from the nectar by evaporation such that the final moisture content is <20% and the remaining mass is mostly glucose (about 31%) and fructose (about 38%). Honeydew honeys also contain melezitose. Other components include organic acids which lower the pH and provide flavour, pollen, minerals, nitrogenous compounds including enzymes, B vitamins and vitamin C (Bellik & Iguer-ouada, 2013). The high sugar concentration, low pH (3.2 – 5.7) (Lage et al., 2012) and presence of hydrogen peroxide and gluconic acid act to prevent microbial spoilage (McHugh, 2017).

In the collection of honey, extraction is a process in which the liquid honey is separated from insoluble wax and pollen. A general scheme is shown in Figure 1. Essentially honey is obtained from filled frames using a mixture of methods such as straining, pressure filtration, or low speed centrifugation, with limited heating of the honey to speed up the process (Subramanian et al., 2007). With centrifuged honey the whole frame is placed into a specialised centrifuge to separate the honey from previously uncapped (wax removed from one side) cells. Honey may be heated to eliminate yeasts capable of causing spoilage (and hence vegetative pathogens that may also be present). With raw honey, no heating is applied and filtration is restricted to microfiltration to remove particles larger than 10 μm (McHugh, 2017).

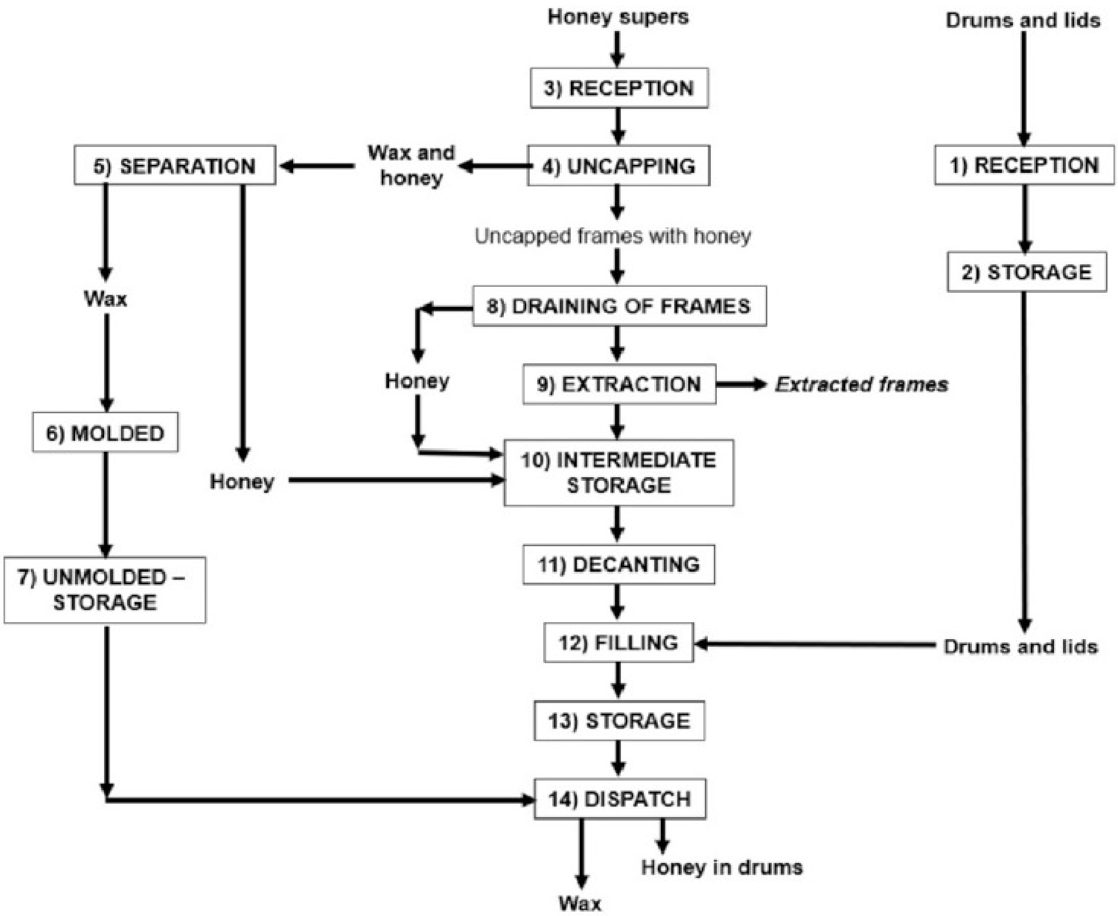

Figure 1. Flow diagram of the honey extraction process (Civit et al., 2023).

Honey "supers" are the boxes in which the frames are placed and the honey collected.

Hazards that contaminate honey come from two main sources, the environment and beekeepers' husbandry of colonies (Bogdanov, 2006). Any hazard present within the zone from which bees forage may potentially be brought back to the hive either within the nectar, honeydew or on dust/pollen located on the bee's body. Beekeepers may use veterinary medicines to control parasites/pathogens of bees which may introduce hazards intentionally. Contamination could also be introduced during harvesting/processing but there is relatively little information on this.

The main types of honey are as follows from the Codex standard (Codex Alimentarius Commission, 2022):

- Blossom honey or nectar honey is honey obtained from the nectar of plants.
- Honeydew honey is obtained mainly from excretions of plant sucking insects (Hemiptera) on the living part of plants or secretions of living parts of plants.

- Comb honey is honey stored by bees in the cells of freshly built broodless combs or thin comb foundation sheets made solely of beeswax and sold in sealed whole combs or sections of such combs.
- Chunk honey or cut comb in honey is honey which contains one or more pieces of comb honey.
- Drained honey is honey obtained by draining decapped broodless combs.
- Extracted honey is honey obtained by centrifuging decapped broodless combs.
- Pressed honey is honey obtained by pressing broodless combs with or without the application of moderate heat not exceeding 45°C.
- Filtered honey is honey obtained by removing foreign inorganic or organic matter in such a way as to result in the significant removal of pollen.
- Baker's honey is honey which is suitable for industrial uses or as an ingredient in other foodstuffs which are then processed and may have a foreign taste or odour, have begun to ferment, have fermented or have been overheated.

2.3. Regulations

Regulations relating to honey mainly concern compositional criteria such as minimum concentrations of glucose and fructose, and a maximum concentration for water. A Codex Standard for honey exists (Codex Alimentarius Commission, 2022), and national legislation (e.g. UK and EU) is generally aligned with it with few exceptions. One such exception is in reference to the kind of bee that honey can be produced by, for assimilated EU legislation it is restricted to *Apis mellifera* (Council of the European Union, 2001) but Codex do not specify a species or range of species. Regulations also cover definitions around the different kinds of honey, e.g. creamed honey (produced by controlled crystallisation) and chunk honey as listed in section 2.2. Other regulations cover consumer-relevant issues such as country of origin labelling.

Some aspects are important to food safety, for example the definitions for sugar and water content characterise a food product that is not capable of supporting the growth of bacterial pathogens. In respect to contaminants, "Honey shall be free from heavy metals in amounts which may represent a hazard to human health" and should comply with the maximum defined by the CAC. Similarly, the MRLs for pesticides set by the CAC should be adhered to. Hygiene standards should be those of the General Principles of Food Hygiene (CXC 1-1969) and should comply with "any microbiological criteria established in accordance with the Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods (CXG 21-1997)"

Further details are given in section 5.2.2.

2.4. Consumption

2.4.1. Consumption estimates of honey in the UK from survey data

Chronic consumption estimates for honey were obtained using data from the Diet and Nutrition Survey for Infants and Young Children (DNSIYC) and National Diet and Nutrition Survey (NDNS) for all age groups between 4 months and 95 years (Government of the United Kingdom, 2013; Public Health England & the Food Standards Agency, 2019). The DNSIYC includes infants and children between 4 and 18 months and was carried out in 2011. The NDNS includes participants from 18 months – 95 years, and data used here are from years 1 to 11 of the NDNS. The NDNS rolling programme is a continuous, cross-sectional survey designed to collect detailed, quantitative information on food consumption, nutrient intake and nutritional status of the general population in UK private households. The survey covers a representative sample of around 1000 people per year. Appendix I presents detailed chronic and acute consumption data for honey (without recipes), foods containing ≥ 5% honey and foods containing ≥1% honey.

NDNS and DNSIYC food codes (and their definitions) used to estimate consumption are listed Appendix I. Children (4-10 years) are the highest chronic consumers of honey on a per kg bodyweight per day basis and they consume 0.99 g/kg bw/d (97.5 percentile, without recipes). Chronic consumption in adults (19-64 years) is 0.38 g/kg bw/d (97.5th percentile, without recipes). Regarding acute consumption, the highest consumers are infants (12-18 months) who consume 2.5 g/kg bw/d (97.5th percentile, without recipes). Acute consumption in adults (19-64 years) is 0.69 g/kg bw/d (97.5 percentile, without recipes). It is important to note that UK consumption data from DNSIYC shows that babies (<12 months) do consume honey, in contradiction to public health advice.

The Food and You survey is a consumer survey commissioned by the FSA to provide evidence on consumers' self-reported food-related activities and attitudes. The survey has been running on a biennial basis since 2010 and provides data for England, Wales and Northern Ireland (Food Standards Agency, 2019). The report was searched for data on honey, but it contained no results.

2.4.2. Consumer behaviour

The Defra Family Food Dataset for UK Household Purchases in 2021 – 2022, shows that only an average of 8g of honey was purchased per person (Government of the United Kingdom, 2023). Furthermore, according to the Defra Family Food Dataset for UK Eating Out Purchases in 2021-2022, no honey (defined as fats, preserves, sugar and custard (including jam, marmalade and honey)) was purchased on average while eating out (Government of the United Kingdom, 2023), as was recorded in previous years.

However, the Defra Family Food Dataset for UK Household Purchases in 2021 – 2022, shows that an average of 29 g of sweetened breakfast cereals were purchased per person. The NDNS survey, for Years 7 and 8 (2014/15-2015/16), found that the main source of free sugars in children aged 1.5 to 3 years and 4 to 10 years was 'cereal and cereal products' (31% and 33% respectively) (Public Health England & the Food Standards Agency, 2018). 'Cereal and cereal products' was the second main contributor of free sugars for children aged 11 to 18 years (29%) and adults aged 19 to 64 years (24%) (Public Health England & the Food Standards Agency, 2018). Across all NDNS survey age groups, breakfast cereals contributed 7-14% of sugar honey intake (Amoutzopoulos et al., 2020). When looking at consumers only, for most individuals in the NDNS population sample, 26% of consumers' sugar consumption was derived from honey (Amoutzopoulos et al., 2020).

Honey consumption in the UK has been increasing continuously since 2009, amounting to more than 42,000 tonnes in 2013 (CBI Ministry of Foreign Affiars, 2015). Similarly, a 2024 study analysing the trends in honey consumption and purchasing habits in some European countries (Hungary, Poland, Slovakia, the Czech Republic, Romania, Italy and Serbia) found that honey consumption has increased in recent years and that the respondents are becoming more conscious of their honey consumption and purchases (Vida & Ferenczi, 2023).

As reported by Emerald Group Publishing in 2002, one honey supplier in the UK has seen an increase in demand mainly due to consumers using honey as a cooking ingredient and as a perceived healthier alternative to sugar, as well as honey in squeezable bottles being introduced to the market. The same company has also seen an increase in sales of Manuka honey (a New Zealand monofloral premium honey) due to claims relating to its health benefits. Almost 80% of UK honey consumers spread honey on bread, usually at breakfast time, but there is a growing tendency to use honey as a beverage and yoghurt sweetener (Anonymous, Databank, 2002). A study carried out in Poland found that 89.1% of people surveyed "declared honey consumption" and that the most common types of honey consumption were in hot drinks, desserts, cakes, spread on sandwiches, and direct consumption (Kowalczuk et al., 2023).

2.5. Trade

2.5.1. UK Exports

UK honey export data were extracted from the UN Comtrade database. The UK exports honey to over 80 countries with most (11,933 t from 2016 to 2022) going to Ireland, representing approximately 59% of the total export volume of the UK's largest volume export markets measured between 2016 and 2022. With a total volume of 937 t (4.61% of total volume of top 15 exports) Spain ranked second, followed by France (905 t; 4.45%).

The 15 highest recipients of UK honey exports are summarised in Appendix II.

2.5.2. UK Imports

Honey is traded under the import code 0409 as 'Natural Honey'. Import data from His Majesty's Revenue and Customs (HMRC) extracted from the FSA Trade Visualisation Dashboard (Food Standards Agency, 2023) shows that between 2016 and 2022 the UK imported a total of 335,902 t and an average of approximately 48,000 t of honey per year. There was an increase in imports of honey to the UK of approximately 25% during this period, with approximately 41,200 t in 2016 and 51,400 t in 2022, although volumes varied by year considerably.

The countries that the UK imported most honey from were China (68%), Mexico (6.3%), Poland (4.4%), New Zealand (3.4%), Vietnam (3.1%), Germany (2.4%), Spain (1.5%), Argentina (1.2%), Brazil (1.2%), Ireland (1.0%), Belgium (0.9%), Romania (0.9%), Italy (0.9%), Hungary (0.8%), Ukraine (0.8%), France (0.6%), Australia (0.5%), Netherlands (0.4%), Greece (0.3%), Uruguay (0.2%), and Bulgaria (0.1%) (Appendix II).

2.5.3. Global Trade

Global export data was extracted from the UN Comtrade global database (UN Comtrade) using the commodity code 0409 for the period 2016-2022 as this was the most complete dataset.

The top five countries exporting honey globally between 2016 and 2022 in the order of the highest trade volume were Argentina (~1,100,000 t), China (873,000 t), India (424,000 t), Ukraine (420,000 t) and Brazil (240,000 t). Data are presented in Appendix II.

3. Hazard identification

Hazards may be introduced into honey predominantly through contamination from the environment in the area foraged by honey producing bees, and through beekeeping activities (Bogdanov, 2006). It is known that honey can contain a wide range of contaminants, including chemical, microbiological, radiological and physical hazards. Contaminants of air, water, soil or plants may be introduced into honey through the nectar, pollen, water and honeydew collecting activities of bees, an observation which has prompted the suggested use of bees as environmental monitors (Bargańska et al., 2016; Porrini et al., 2003). In addition to environmental contamination, beekeeping entails the use of chemicals to control bee pests such as the mite *Varroa* and the bacterial disease American Foul Brood, and so contaminants may exist as residues of substances intentionally and directly applied into the hive.

3.1. Identification and refinement of hazards

The identification of hazards in honey belonging to different categories is expanded upon in the sections below, along with a summary as to why some were taken forward for characterisation while some were not. This decision was made on a hazard-by-hazard basis and some expert judgement was applied on a case-by-case basis.

Following identification of hazards, the list of identified hazards was further refined for characterisation (section 4) based on the relevance of the hazard in honey with respect to public health. A hazard was included where the evidence of occurrence supported it as being a relevant consideration, for example, a hazard may be excluded where only identified in a single study or paper and where not identified elsewhere, and has not been associated with consumer risks, on a case-by-case basis.

Hazards were then assessed against the following criteria and were taken forward for characterisation where at least one criterion was met:

- There is evidence of the hazard causing illness in consumers and this being associated with the consumption of honey,
- The identified hazard in honey is controlled (e.g. through specific regulation, MRLs, MLs etc), either in honey or in other commodities, or
- Available knowledge and/or evidence suggests the hazard is a potential risk to consumers (whether or not in honey) and this potential risk could not be readily dismissed for honey.

3.2. Food Safety Alerts

3.2.1. RASFF Notifications

A search of the EU Rapid Alert System for Food and Feed (RASFF) found 23 notifications from 2020 to 2024. Of these, four alerts related to storage and labelling issues. Of the remainder, the largest proportion of alerts came from residues of Veterinary Medicinal Products (VMPs), specifically antibiotics, with nine notifications, most commonly chloramphenicol. Pesticide residues were responsible for five notifications, all of them originating in one country. Other notifications included the presence of unauthorised substances intended to treat erectile dysfunction, cannabinoids (both cannabidiol (CBD) and tetrahydrocannabinol (THC)) and glass particulates. The distribution of notifications is shown in Figure 2.

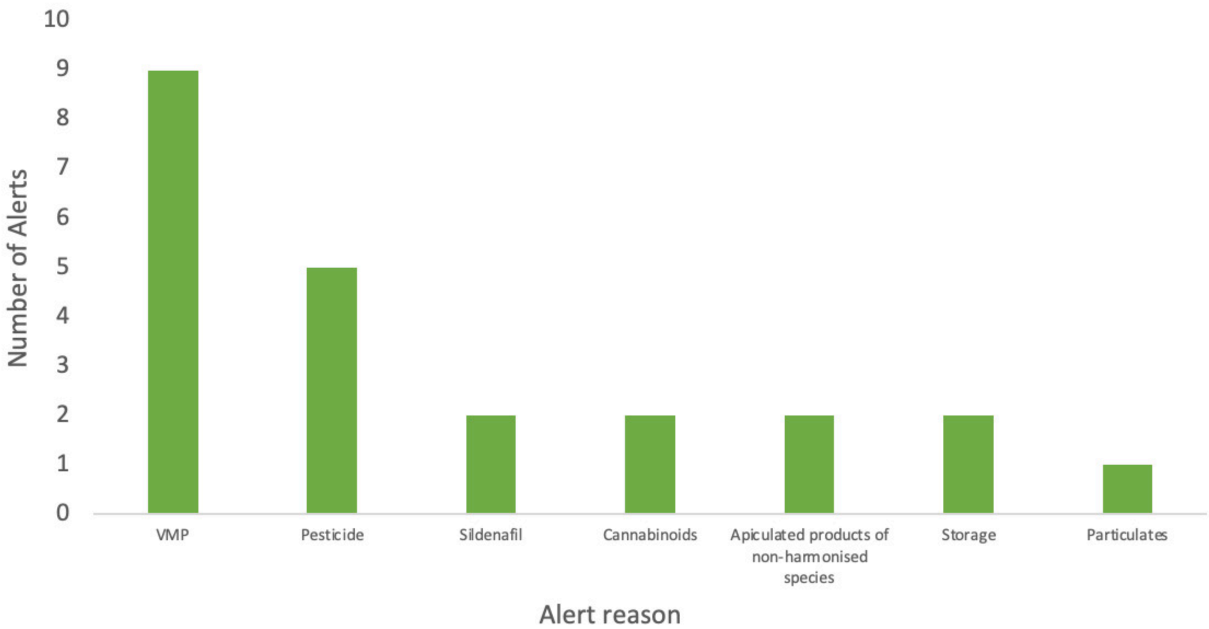

Figure 2. RASFF alerts for honey from 2020 to 2024 by hazard type

VMP = veterinary medicinal product

3.2.2. FSA Foodsignals dashboard

This database was searched for any events concerning honey that occurred in the previous year. All databases and countries were interrogated. There were 66 results including three RASFF alerts, 50 recalls, four border rejection and eight others.

Only one of the four border rejections was for honey and was triggered because it contained sildenafil and tadalafil (licenced medicines for treatment of erectile dysfunction). One result was for an infant botulism case in the USA. Of the recalls, 26 involved honey, with the others being products with honey as an ingredient. Of the 26, 13 were for fraud (pollen analysis) and four were unknown. For those with an identified hazard, five contained excess 5-hydroxymethyl furfural (HMF), one excess sucrose, one contained THC, one “traces of milk proteins” and one *Salmonella*. In the latter case the source report showed that the *Salmonella* detection was for a poultry product and so was not associated with honey. The same report recorded an issue with honey which, in fact, contained ciprofloxacin, a broad-spectrum antibiotic.

3.2.3. FSA Incidents

The FSA Incidents unit supplied a list of those involving “honey and royal jelly”. There were 39 in total, with the majority concerning issues around fraud/authenticity/illegal imports. Incidents relating to food safety included one each for antibiotics, unhygienic production, CBD, and ‘mad honey’ (honey containing grayanotoxins).

3.3. Literature review search methodology

Searching the literature was undertaken in two cycles. The first was a generic search of hazards in honey which produced a list of high-level categories of hazards, such as “pesticides”. A second, more targeted, cycle of searching was then undertaken using the specific hazard category. The second cycle used two different databases to obtain good coverage. Details of the search terms used are given in Appendix III.

A specific search was also conducted using the European Food Safety Authority (EFSA) website (https://www.efsa.europa.eu/en/search) for information concerning honey, which produced 63 hits. Many were updates on MRLs for various pesticides and others concerned bee health rather than honey. Relevant reports were considered as part of the hazard identification process.

Using the results of the general hazard search, three general review papers of hazards in honey were selected (Morariu et al., 2024; Petrovi et al., 2021; Sharma et al., 2023a). Their contents were compared to the results of the targeted searches to ensure that all significant hazards had been identified.

3.4. Microbiological Hazards

Microbial contaminants in honey can come from several sources including pollen, dust, other insects, and faeces produced by the bee itself (Jaradat et al., 2022) in addition to during processing and packaging.

A review (Grabowski & Klein, 2017) which, in addition to *C. botulinum*, identified that *Staphylococcus* spp., *Citrobacter* spp., *Escherichia coli*, *Hafnia alvei*, *Aspergillus* spp., *Fusarium* spp., *Trichoderma* spp. and

Chaetomium spp. could be detected in honey. However, it was also noted that “direct infections via honey were not registered” for these non-clostridia and most are not conventional foodborne pathogens. Many genera of yeasts may also be present in honey (Snowdon & Cliver, 1996). Other studies detected botulinum toxin-producing *Clostridium* spp., (*C. botulinum*, *C. baratii* and *C. butyricum*) (Formato et al., 2011; Gücükoğlu et al., 2014), *C. perfringens* (Grenda et al., 2018), *Bacillus cereus* and *S. aureus* (Yusoff et al., 2023). *Acinetobacter baumanii* has been detected (Jaradat et al., 2022) and while this is not a usual foodborne pathogen it can acquire antimicrobial resistance and is a problem in at risk groups (Howard et al., 2012).

Of these micro-organisms, the primary hazard is the spore-former *C. botulinum*. Another, lesser, hazard is *C. perfringens* which can also be present (Grenda et al., 2018). The genus *Bacillus* also forms spores. *Staphylococcus aureus* can survive under low moisture conditions and is also a common human pathogen. A number of other established hazards were identified, but these will most likely be inactivated during storage because of the inimical conditions. For example, *Salmonella* underwent a 6-7 $\log_{10}$ reduction when incubated in honey of pH 3.8 and water activity 0.55 at 22°C for 21 days (Alshammari et al., 2021).

Honey is naturally anti-microbial and these antimicrobial properties result from the combined effects of the high sugar content (lowering the water activity), the low pH, chemicals such as hydrogen peroxide, phenolic acids, flavonoids, methylglyoxal (which is found in Manuka honey) and other components. Growth of micro-organisms would therefore not be expected in honey conforming to the Codex standard and so their presence reflects low level environmental contamination and only organisms that can survive under these conditions (e.g. primarily spore-formers) may be present in honey when finally consumed.

Overall, sufficient information was available to indicate that foodborne hazards able to survive in honey should be subject to hazard characterisation, with the emphasis on *C. botulinum* and other toxigenic clostridia, *B. cereus* and *C. perfringens* as they are spore-formers and *Staphylococcus* as an organism that can survive and grow at lower water activity values than other foodborne bacterial pathogens. Other organisms have been detected in honey but are not classical foodborne pathogens and other *bona fide* foodborne pathogens are unlikely to survive and were dismissed at this stage.

3.5. Chemical Hazards

3.5.1. Metals

The literature search indicated that metals may contaminate honey. Heavy metals such as lead, arsenic and cadmium are present in the environment via both environmental and anthropogenic sources (EFSA Panel on Contaminants in the Food Chain, 2024). Large scale industrial activity and increases in transport pollution have resulted in increasing levels of metals in the environment, and in particular, soil (Binner et al., 2023). Due to this environmental contamination and transfer to nectar, pollen and bees (Eremia et al., 2010; Tesauro et al., 2023), toxic metals and metal micronutrients have been detected in honey (Jones, 1987; Smith et al., 2019). Metals detected in honey include lead, arsenic, mercury and other metal micro- and macronutrients such as copper, chromium, iron, zinc, nickel, manganese, cobalt, beryllium, vanadium, selenium, aluminium, calcium, potassium, and magnesium, among others (Islam et al., 2014; Ligor et al., 2022; Manouchehri et al., 2021).

A number of metals are controlled in a range of different commodities with prescribed maximum levels (MLs). Lead is controlled in honey with a ML of 0.1 mg/kg in accordance with the assimilated Regulation (European Commission, 2006a). Some metals are a known human health concern, in particular heavy metals. The information available was sufficient to indicate that metals in honey should be subject to hazard characterisation. Antimony (maximum 13.3 µg/kg in honey [Pisani et al., 2008]), arsenic (maximum 502 µg/kg [Bilandžić et al., 2012]), cadmium (maximum 3.81 mg/kg [Silici et al., 2016]), chromium (maximum 2.04 mg/kg [Šerevičienė et al., 2022]), lead (maximum 3.41 mg/kg [Bartha et al., 2020]), manganese (maximum 82 mg/kg [Stankovska et al., 2008]), and mercury (maximum 212 µg/kg [Toporcák et al., 1992]), were selected based on their higher toxicological concern and expert opinion.

3.5.2. Persistent Organic Pollutants (POPs)

The information obtained from the literature search highlighted that persistent organic pollutants (POPs) can be detected in honey. POPs, also known as persistent organic chemicals (POCs), are defined as ‘organic substances that persist in the environment, accumulate in living organisms and pose a risk to our health and the environment’ (European Chemicals Agency, 2024). As a result of bioaccumulation in plants, POPs can contaminate honey.

A review described the detection of a range of polychlorinated biphenyls (PCBs), both non-dioxin-like and dioxin-like, polybrominated diphenyl ethers (PBDEs) and polycyclic aromatic hydrocarbons (PAHs) in honey (Chiesa et al., 2017). Dioxins have been identified in honey (Özkök et al., 2017), but only in pine honey in picogram quantities and will therefore not be characterised. A further study identified short and medium chain chlorinated paraffins (SCCPs and MCCPs) (Dong et al., 2022). In addition, polyfluorinated substances (PFAS), specifically polyfluorinated carboxylic acids and polyfluorinated sulfonic acids, have been detected in honey (Surma et al., 2016). EFSA reported the adulteration of wax comb with paraffins, which would marginally contribute to the overall exposure to some POP contaminants including PAHs and PCBs (European Food Safety Authority, 2020b). Endosulfan group chemicals were detected in almost all samples of honey tested in a country where their use had been prohibited, with mean concentrations ranging from 2.31 to 5.48 ng/g ww (Villalba et al., 2024), and in a further study one sample exceeded the MRL at 0.026 mg/kg in honey produced by *A. dorsata* (giant honey bee) (Farooqi et al., 2017).

Overall, a number of POPs have been detected in honey which may be a potential human health concern (United Nations Environment Programme, n.d.). This information was sufficient to indicate that POPs should be subject to hazard characterisation. Specifically, endosulfans, PCBs, PDBEs, PAHs, S/MCCPs and PFAS will be characterised based on the evidence of their occurrence at relevant levels in honey.

3.5.3. Pesticides

From the literature review, a list of residues of pesticides detected in honey was compiled, resulting in approximately 150 different compounds (those exceeding MRLs are shown in Appendix IV), not taking into account isomeric forms. Owing to the widespread and varied use of pesticides, plus the sensitivity of detection methods, the number detected is large and concentrations in honey vary. Pesticide residues in food and feed are controlled according to MRLs and there is evidence that pesticide residues may exceed MRLs in honey.

Overall, pesticide residues are readily detectable in honey, and they may be present at levels exceeding relevant MRLs. Therefore, hazard characterisation will be performed for pesticides generally with a focus on those pesticide residues that were found to exceed MRLs in honey in reports by GB or EU regulatory authorities.

3.5.4. Veterinary Medicine Residues (including antibiotics)

Antibiotics are used to combat diseases in bees such as American and European Foulbrood (caused by the bacterial species *Paenibacillus larvae* and *Melissococcus plutonius*, respectively) and Nosemosis (caused by the fungal species *Nosema apis* and *N. ceranae*). Bees are prone to infestation by *Varroa* mites (*Varroa destructor* and *Varroa jacobsoni*) and a choice of treatment options, as discussed below, is available. As a result, residues of these compounds may be detected in honey (Reybroeck et al., 2012). Honey contamination can occur both directly in honey production or *via* transfer from contaminated wax or propolis (Mitrowska & Antczak, 2017).

A review (Sharma et al., 2023b) highlighted past studies on antibiotic residues detected in honey and categorised the compounds into seven classes: sulphonamides, tetracyclines, quinolines, nitrofurans, aminoglycosides, macrolides and nitroimidazoles. In addition, chloramphenicol, fumagillin and lincomycin were specifically named. Other references detected further antibiotics in honey, although all were able to be classified as above. Semicarbazide, a breakdown product of the nitrofuran, nitrofurazone, has also been detected in honey.

A survey of veterinary treatments in apicultural-products detected acaracides (chemicals that control mites and ticks) in honey (Lozano et al., 2019). Due to the lipophilicity of these compounds, higher concentrations can be found in wax than in honey (Lozano et al., 2019). An academic study (Bonerba et al., 2021) identified coumaphos (a mite treatment agent) in honey where it had not been applied and it was thought to have been introduced from contaminated foundation wax, a wax base plate added to hives as a foundation for honeycomb building. While amitraz degrades in honey other acaricides are stable (Korta et al., 2001).

The organic acids, formic, oxalic, lactic and acetic acids are used as VMPs for treatment of *Varroa* in organic honey production (and more generally) (Richards et al., 2021), but they are also present naturally. A standard for acid content is set by Codex (Codex-Alimentarius, 2022) as 50 milliequivalents per 1000 g for honey. A further study identified thymol, a thyme-derived plant oil, as another treatment of *Varroa* (Baša Česnik et al., 2019) although thymol is a naturally occurring compound in a variety of herbs and foods, and there is no requirement for a MRL for thymol in honey (The European Commission, 2015). Consequently, organic acids and thymol do not require hazard characterisation.

The use of chloramphenicol to maintain colony health in China and its detection in honey resulted in a two-year (2002-2004) prohibition of Chinese honey imports into the EU (including the UK at the time) and Canada, and it was subject to additional testing in the US (Everstine et al., 2013).

Overall, residues of a range of veterinary medicines can be detected in honey. These may be at levels exceeding the MRL or they may be not authorised for use in bees or are otherwise unacceptable in honey. The information was sufficient to indicate that residues of veterinary medicines should be subject to hazard characterisation generally, and specifically, those that have been found to exceed the MRL by GB or EU authorities or are otherwise unacceptable in honey.

3.5.5. Toxins

A study identified mycotoxins, specifically aflatoxins, in honey (Swaileh & Abdulkhaliq, 2013b) to a maximum of 22 µg/kg. Aflatoxins belong to the family of mycotoxins, which are produced by certain fungi and typically found contaminating crops such as maize, peanuts and certain tree nuts. The same study identified the presence of caffeine at a maximum of 3583 µg/kg, from *Camellia sinensis* and *Coffea arabica,* and nicotine from the plant family Solanaceae in honey (Swaileh & Abdulkhaliq, 2013b) to 9,389 µg/kg. Caffeine is commonly found in foods (European Food Safety Authority, n.d.); the content of caffeine in coffee is many times higher than has been detected in honey and, at the levels detected in honey, caffeine is not a specific concern for consumer health will not be characterised. A further study identified other mycotoxins in 28 honey samples, namely deoxynivalenol (25% positive, maximum 9.351 µg/kg), T2 (14.3% positive with a maximum of 1.637 µg/kg) and HT2 (17.9% positive, maximum 0.331 µg/kg) and ochratoxin A (50% positive, maximum 0.049 µg/kg) (Keskin & Eyupoglu, 2023). In a survey by EFSA (European Food Safety Authority, 2024) the presence of mycotoxins (aflatoxins, ochratoxin A and zearalenone) in honey was analysed and all samples were found to be compliant based on analytical findings below the LOD.

A review (Yan, 2022) highlighted a range of natural plant toxins identified in honey: picrotoxins, specifically tutin and its derivatives from *Coriaria* aborea (with one sample containing tutin at 3.6 µg/g, hyenanchin at 19.3 µg/g, tutin glycoside 4.9 µg/g, and tutin diglycoside at 4.9 µg/) and grayanotoxins from *Rhododendron sp.* (range 8.2-68.745 µg/g depending on the toxin). Both picrotoxins (Beasley et al., 2018) and grayanotoxins (Ullah et al., 2018) are associated with acute toxicity and poisoning in consumers following their consumption from honey.

A large number of pyrrolizidine alkaloids (PAs) are present in the plant families Asteraceae, Boraginaceae, Apocynacae and Fabaceae, in addition to triptolide from *Tripterygium* plants. PAs have been detected in honey (Casado et al., 2024) at a maximum of 159 µg/kg. They have been the subject of a recent review where detection rates of 90-100% were reported with a maximum concentration of 323.4 µg/kg (Lu et al., 2024).

Tropane alkaloids (TAs) (Z. Wang et al., 2023) have been detected in honey. In one study atropine (racemic mix of (-)-hyoscyamine and (+)-hyoscyamine) was detected in 13.47% of honey samples from 20 countries at concentrations exceeding 1 µg/kg, with one sample measured at 41.53 µg/kg. In another study, scopolamine was detected in honey at a maximum of 5.53 µg/kg (Fernández-Pintor et al., 2024).

Gelsedine-type alkaloids (indole alkaloids) (Yang et al., 2020a) from *Gelsemium elegans*, a plant of restricted geographical distribution and typically associated with Asia, have also been detected in honey and these may be a public health concern. Human cases, including an unknow number of fatalities, were linked to honey containing 14-(R)-hydroxy-gelsenicine (HGE) which also contained *G. elegans* pollen.

This information was sufficient to indicate that toxins should be subject to hazard characterisation. Specifically, aflatoxins, ochratoxin A, deoxynivalenol, trichothecenes (T2/HT2), picrotoxins, grayanotoxins, nicotine, pyrrolizidine alkaloids (PAs), tropane alkaloids (TAs) will be characterised.

3.5.6. Other Chemicals

The remaining hazards from the general hazard search were identified and collated.

During long-term storage or in processing of honey, sugars can degrade to form 5-HMF (Surma et al., 2023). 5-HMF is a furanic compound which forms as an intermediate in the Maillard Reaction (Ames, 1992) and from direct dehydration of sugars under acidic conditions (caramelisation) during thermal treatments applied to foods. 5-HMF is found in honey and many foods including beer, breakfast cereal and coffee. In honey, the organic 5-HMF is formed by the dehydration of fructose. It is not present in 'fresh' honey but is formed upon storage or heating.

For honey specifically, there are benefits to storing and aging the honey to increase the methylglyoxal concentration which is responsible for Manuka honey's antibacterial properties. As a result, the HMF concentration can be higher than in other honeys and UK surveillance of Manuka honey found that 11% of the samples contained HMF above the legal limit (Food Standards Agency, 2016). A study (Surma et al., 2023) found that HMF was detected in all samples and exceeded the maximum level set by Codex in 45% of samples with values ranging from 7.3-679 mg/kg. The concentrations varied significantly between floral sources and geographical locations. Honeydew honey contained the highest concentrations of HMF (679 mg/kg), exceeding the Codex maximum level by 17 times.

Perchlorate, an accumulating environmental pollutant derived from natural and anthropogenic sources has been detected in honey in two studies. One (Fei et al., 2024) identified perchlorate to be present in 95% of honeys tested up to concentrations of 612 μg/kg. The other study reported a similar prevalence (Fei et al., 2024).

Plasticiser residues from both environmental sources and from plastic honeycomb (artificial recyclable comb) have been detected (Di Fiore et al., 2023) with phthalic acid esters and bisphenol-A (BPA) and bisphenol-F (BPF) being identified. Of 107 samples tested 15.9% contained BPA up to 33.3 µg/kg, but no BPF (Inoue et al., 2003). There was no significant difference in samples from glass or plastic jars and the authors speculated that the BPA may have come from drums used for transporting bulk quantities. In other available studies; in one case, none of 39 honeys contained BPA (Lo Turco et al., 2016), and in another nine bisphenols were detected in 12 of 30 honey samples, with BPA quantifiable in two at 12.5 and 12.9 µg/kg (Martín-Gómez et al., 2024). Materials incorporating plasticisers are reported to be used throughout honey production (Díaz-Galiano et al., 2024) and plastic-derived compounds have been detected in honey stored in glass and plastic containers (von Eyken et al., 2020).

Information from FDA publications indicate that sildenafil (Viagra) has been detected in honey, although this appears to only be in products that are marketed as “sexual-enhancement” products (Food and Drug Association, 2022). In addition, cannabinoids have also been found in honey according to RASFF notifications. Cannabidiol (CBD) is regulated as a novel food and can be sold when it is authorised and labelled as such, while tetrahydrocannabinol (THC) is not permitted to be present in food.

Based on the evidence of their presence in food and as known potential concern for consumer health, HMF, perchlorate, phthalic acid esters and BPA will be characterised. Unauthorised pharmaceuticals (sildenafil) and regulated products (CBD) will not be characterised as they must not be present in honey and should be appropriately controlled, and no further assessment is required for the purpose of this risk profile.

3.6. Radiological

Radionuclides, also known as radioactive materials or radioactive isotopes, are unstable forms of elements that emit radiation as they undergo radioactive decay (Shah & Abdeljawad, 2024). Radionuclides can be found naturally in the environment or can be generated through human activities, such as emergencies arising from nuclear power generation accidents and historical nuclear weapon testing (Altekin et al., 2015). While some studies were not able to detect activity at quantifiable levels in honey, most studies could for the radionuclides identified in the literature listed in Appendix VI.

Another source of radioactivity in honey can be from the use of depleted uranium munitions, as may have occurred in 1999 in Serbia and Kosovo for example (Mihaljev et al., 2021). However, a wider study of environmental samples taken from Kosovo found that any contamination by uranium radionuclides was restricted to impact craters while surrounding environments were comparable with samples from other countries (Carvalho & Oliveira, 2010).

Measured activities of specific radionuclides are shown in Appendix VI. The activities are low when compared with those shown in section 5. It is noted that one survey (Abdullah et al., 2019) reported values in honey samples from one country that were consistently higher than found in other studies, for example K-40 activities of 137-1607 Bq/kg, contrasting with the highest reported in other locations at around 100 Bq/kg. The reasons for this discrepancy are unknown.

In the UK, The Radioactivity in Food and the Environment (RIFE) report is published each year, which brings together monitoring results for radioactivity in food and the environment. The main aim of the RIFE programme is to monitor the environment and diet of people living or working near nuclear and selected non-nuclear sites, with the aim of estimating the amount of radioactivity the public is exposed to. In the most recent report for 2022 one honey sample was tested and contained 1.3 Bq/kg C-137, which is comparable to data shown in Appendix VI. This sample was below the limit of detection for Co-60, Nb-95 and Am-241 (Government of the United Kingdom, 2022).

In summary many radionuclides have been detected at trace levels in honey including those such as Cs-137 that are derived from nuclear accidents, and others that are present naturally and may be introduced from other specific routes such as depleted uranium during armed conflict. Radionuclides in food are controlled and were therefore considered in the hazard characterisation.

3.7. Allergens

The results of the literature search suggest that sensitivity to honey and sub-components thereof is rare (<0.001% of the population) but can occur (Jhawar & Gonzalez-Estrada, 2022).

A number of papers reported allergenicity of honey components. For example, 8 of 12 allergens in honeybee venom have been detected in honey (Burzyńska et al., 2020; Burzyńska & Piasecka-Kwiatkowska, 2021). Other reports showed commonality of proteins in honey and bee-associated proteins (Bauer et al., 1996) and differential reactions to honeys containing pollen from different plants (Fuiano et al., 2006).

Some bee-keeping practices may introduce other allergenic products through supplementary feeding. Examples include mixtures of soybean flour, dried yeast when obtained as a by-product of brewing which contains gluten, and skimmed milk powder.

Fourteen major allergens must be highlighted on food labels within the ingredients list. They are: cereals containing gluten, crustaceans, eggs, fish, peanuts, soybeans, milk, nuts, celery (and celeriac), mustard, sesame, sulphur dioxide, lupin and molluscs (The Food Labelling (Declaration of Allergens) (England) Regulations 2008, n.d.). In a targeted survey 8 of 40 honey samples tested contained gluten (Bermingham et al., 2022), while milk allergenic proteins were detected in three. However, all samples contained gluten concentrations less than 20 mg/kg, which defines the maximum level of a gluten-free food claim (The Foodstuffs Suitable for People Intolreant to Gluten (England) Regulations 2010, 2010), and the milk proteins were at concentrations (0.368-0.567 mg/kg for Bos d 5 and 0.03-0.182 mg/kg Bos d 11) that the authors considered unlikely to cause a reaction. It is possible, though, that this could become a more significant issue if supplementary feeding was to be increasingly used.

Based on the information available, honey can contain pollen, venom, and other bee associated proteins which will be discussed further in the hazard characterisation. For major food allergens, there is no evidence of a specific public health concern relating to honey, and in any case, the health effects are well characterised generally and so no further discussion is merited.

3.8. Microplastics/Particulates (Including pollen)

There are a few reports on the contamination of honey by genetically modified pollen collected as part of natural foraging (Villanueva-Gutiérrez et al., 2014).

Much of the information found relates to pollen as a particulate in honey. Pollen is considered to be a natural constituent of honey and so there is no need to provide labelling to indicate that a honey contains GMO pollen, as long as the GMO is authorised for cultivation.

Beyond pollen, other relatively large particles can be present. In a survey of 70 Italian honeys using the “filth test”, carbon particles, inorganic fragments, insects, parts of insects, mites (arachnids), and mammal hairs (Canale et al., 2014) were identified. In another survey black particles (probably soot) were detected (Liebezeit & Liebezeit, 2015), and in another, other nano-sized iron oxides/hydroxides and barite (barium sulphate) (Papa et al., 2021). The presence of larger particles reflects an absence/ inadequacy of filtration or poor hygiene allowing re-contamination post-filtration.

Wax moths can be a pest of honeybees, and their larvae and eggs can contaminate honey (Sarwar, 2016).

Microplastics are small plastic particles and have been defined by the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) as being “synthetic particles or heavily modified natural particles with a high polymer content” within the size range of 0.1 to 5000 µm (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2021a) and are found in all environmental compartments (Alma et al., 2023). They can be categorised into two main types, primary microplastics which are intentionally produced for various purposes such as cosmetics and industrial applications, and secondary microplastics which are formed from the breakdown of larger plastic items over time due to weathering, ultraviolet (UV) radiation, microbial action, and/or mechanical action. This latter group includes, for example, microfibres shed from synthetic clothing, bags (Accinelli et al., 2022) and opening of water bottle lids. They have also been termed microplastic particles.

Microplastics have been found in various foods and drinks, including honey, although methodological detection and enumeration problems contribute uncertainty. The prevalence of microplastics in food can vary depending on the source and processing methods (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2021a).

Microplastics have been shown to be ingested by bees, contaminating their cuticle and digestive tract, and being transferred to honey, although the most accumulation was in the wax (Alma et al., 2023). Particles are therefore thought to be brought to the colony by foraging bees (Liebezeit & Liebezeit, 2015).

There are very few primary data sources regarding microplastics in honey, although it is often cited as a food that characteristically contains particulates. One publication (Mühlschlegel et al., 2017) claimed not to find evidence of microplastic presence, but fibres and fragments were recorded up to 660 fibres per kg honey, and a range of plastic types detected (Vitali et al., 2023). Data in another review showed concentrations less than this (up to 166/kg) (M. Jin et al., 2021) and the concentration of microplastics in honey was found to be less than in salt, fish sauce, salted seafood and seaweed elsewhere (Pham et al., 2023).

Nanoplastics (NPs) been defined in a number of ways, but NPs defined by the COT as plastic particles of a size between 1 nm and 0.1 µm (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2021a) and mainly result from degradation of larger plastic particles. No papers identifying nanoplastics specifically in honey were identified, but the papers cited above include size ranges of nanoplastic particles.

Overall, a range of particulates, including micro/nano plastics have been identified in honey. Particulates in general are a potential risk to consumers although there is no information suggesting that honey is of particular concern for particulates when compared with other commodities. With regards to micro and nano plastics, the human health effects are not well defined and there is no evidence suggesting a specific consumer risk related to honey. Therefore, particles including micro/nano plastics will not be characterised, but it should be noted that they may be present and honey production should be conducted in a way to reduce particulate contamination.

3.9. Hazards Taken Forward to Characterisation

A consolidation of the hazards identified and taken forward for characterisation from the search is summarised in Table 1.

Table 1. Hazards in Honey

Overall Category	Hazard Type	Hazards to be Characterised
Microbiological	Bacteria	*Clostridium botulinum, C. perfringens, Bacillus cereus* and *Staphylococcus aureus*
Chemical	Elements	Antimony, arsenic, cadmium, chromium, lead, manganese, and mercury
Chemical	Persistent Organic Pollutants (POPs)	Polychlorinated biphenyls, polybrominated diphenyl ethers, polycyclic aromatic hydrocarbons, short and medium chain chlorinated paraffins and polyfluoroalkylated substances
Chemical	Pesticides	Pesticide residues exceeding MRLs
Chemical	Veterinary Medicines	Veterinary medicines exceeding MRLs or otherwise unacceptable in honey
Chemical	Toxins	Aflatoxins, ochratoxin A, deoxynivalenol picrotoxins, grayanotoxins, nicotine, pyrrolizidine alkaloids, trichothecenes (T2/HT2), tropane alkaloids, gelsedine alkaloids
Chemical	Other	5-Hydroxymethylfurfural, perchlorate, phthalic acid esters, bisphenol A
Chemical	Radiological	General discussion on radiological contamination
Chemical	Allergens	Bee-derived proteins

4. Hazard characterisation

Hazard characterisation sections below provide a summary of the available information on the nature of the adverse health effects of the hazards identified in section 3. This includes (as appropriate) a description of the potential adverse health effects of the hazard, information relating to the dose-response relationship (including reference values or points of departure for risk assessment), a description of the severity of the effects and information on vulnerable groups. For the purposes of this profile and to provide contextual information, the hazard characterisation may provide additional information relating to the occurrence of the hazard in the commodity and relevant information on regulatory or legal limits applicable to the hazard (either in honey or in other commodities).

4.1. Microbial Contaminants

4.1.1. Neurotoxigenic clostridia and Infant Botulism

Clostridium botulinum spores contained in honey which has been fed to babies can germinate in their gastrointestinal tract and produce a neurotoxin (Arnon et al., 1979). This contrasts with botulism in adults where predominantly pre-formed toxin is ingested, and so infant botulism is regarded as a particular form of botulism. Infants are thought to be at risk as they do not have a fully developed gut flora (Rosow & Strober, 2015) and because of this, while the dose-response relationship is not known, a low dose may result in disease (Harris et al., 2021). Infant botulism was recognised in the 1970s with early papers linking honey fed to infants containing *C. botulinum* spores and cases of disease. However, not all cases can be attributed to honey with approximately 30% of cases in the USA resulting from honey consumption and the remainder from environmental exposure to spore-containing dust (Arnon et al., 1979). In Europe the situation is different, with 59% of cases of infant botulism being associated with a history of honey consumption (Aureli et al., 2002). Most cases are caused by *C. botulinum* types A and B (rarely E and F [Aureli et al., 2002; Goldberg et al., 2023]) but the other species *C. baratii* type F and *C. butyricum* type E can also cause disease (Cagan et al., 2010).

Honey can occasionally be contaminated with 10^3 – 10^4 spores/kg (Advisory Committee on the Microbiological Safety of Food, 2003).

The toxin produces immobility in the intestine and descending paralysis, resulting in the alternative name “floppy baby syndrome” (Kobaidze & Wiley, 2023). Disease usually occurs between two weeks and one year of age, with the median being around 10 weeks. Clinical signs include constipation, weakness and respiratory problems. Given sufficient supportive care the situation normally resolves although death can occur in a small proportion (<1%) of cases (Cagan et al., 2010; Rosow & Strober, 2015).

It is a rare condition (4.3 cases per million live births in Canada [Harris et al., 2021]) but nonetheless has been reported to represent 75% of the cases of botulism in the USA (Cagan et al., 2010), with an average annual incidence of 1.9 deaths of infants less than one year old per 100,000 live births. Globally, more than 1000 cases in total have been described (Aureli et al., 2002), with 90% occurring in the USA.

The Advisory Committee on the Microbiological Safety of Food (ACMSF) has published information on infant botulism (Advisory Committee on the Microbiological Safety of Food, 2003). This cites advice from the FSA and others that honey should not be fed to infants less than 12 months old. Additionally, it was recommended that honey should not be added to foods intended for infants less than 12 months old unless these foods receive a full botulinum cook (121°C for three minutes, a 12 $\log_{10}$ kill) or an equivalent process control (Ad hoc group on infant botulism, 2006). Similar advice is provided by many other stakeholders, e.g. the NHS (National Health Service, 2022), USCDC (Centers for Disease Control and Prevention, 2022), Scottish Beekeepers Association (Scottish Beekepers Association, 2010) and the Food Safety Authority of Ireland (Food Safety Authority of Ireland, 2024).

An opinion from the former Committee on Veterinary Measures relating to Public Health published in 2002 was that *C. botulinum* is the "only microbiological hazard in honey" or, elsewhere, "the main microorganism in honey of concern to human health" (Scientific Committee on Veterinary Measures Relating to Public Health, 2002). This was on the basis that other spore-formers detected have never been reported to cause disease where honey was the food consumed. The additional hazards discussed below are included as they may survive in honey and so most likely to become problematic in honey used as an ingredient of food that is improperly handled and where growth might resume.

The International Committee on Microbiological Standards for Foods categorise infant botulism a "Severe hazard for vulnerable populations, life-threatening or substantial chronic sequelae or long duration" (International Commission on Microbiological Specifications for, 2018).

4.1.2. Clostridium perfringens intoxication

Intoxications from this organism are most often associated with cooked ready-to-eat foods that have been temperature abused (stored at too high a temperature), such as pies, casseroles, stews or curries in which the organism grows to a high concentration. Meat and poultry outbreaks accounted for 92% of foodborne outbreaks with a single food identified in the US (Grass et al., 2013). None of the outbreaks cited in this paper involved honey, but the organism can be detected in honey (Maikanov et al., 2019) at prevalences rates ranging from 9% (Maikanov et al., 2019) to 37% (Grenda et al., 2017).

When ingested, the organism sporulates and releases a toxin that results in diarrhoea with abdominal cramps. Only a small proportion of cases (14%) vomit (Grass et al., 2013).

The high sugar content of honey suggests that any growth of this pathogen is unlikely.

In terms of severity, the International Committee on Microbiological Standards for Foods (ICMSF) categorise *C. perfringens* as “Moderate, not usually life-threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort.” (International Commission on Microbiological Specifications for, 2018). Moderate is the lowest category used by the committee.

4.1.3. *Bacillus cereus* intoxication

Intoxication occurs through the consumption of one of two toxins, emetic and diarrhoeal. The organism can be isolated from honey. For example 27% of honey samples contained the organism (López & Alippi, 2007), 78% were positive at $<10^4$/kg (Monetto et al., 1999), there was a maximum concentration of 3 x 10^3/g in a further study (Naila et al., 2021), and 15% of stingless bee honey samples were positive (Yusoff et al., 2023). Since the organism is present as spores at low concentration it cannot produce toxin in honey since 10^7-10^8 cells/g are required (Christiansson et al., 1989).

The ICMSF categorise *B. cereus* as “Moderate, not usually life-threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort.” (International Commission on Microbiological Specifications for, 2018). Moderate is the lowest category used by the committee.

4.1.4. *Staphylococcus aureus* intoxication

The organism produces an emetic toxin that results in vomiting for around 24 hours. It is normally associated with salty foods where it has a competitive advantage over other microorganisms, or cooked foods contaminated by a food handler. It can grow in low water activities compared with other bacterial pathogens (Hudson, 2014), the limit being 0.85 while the water activity of honey is 0.5 to 0.65. Although the most likely non-spore-forming pathogen to cause issues in honey, growth would only occur in improperly produced honey with an abnormally high-water content that would also support fermentation and spoilage by yeasts, so likely preventing consumption. The organism is unlikely to grow and produce toxin in honey meeting Codex standards. It has, however, been detected in honey at quite high prevalences (65-86%) (Nzeh et al., 2020).

The ICMSF categorise *S. aureus* intoxication as “Moderate, not usually life-threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort.” (International Commission on Microbiological Specifications for, 2018). Moderate is the lowest category used by the committee.

4.1.5. Conclusion on microbiological hazards

The predominant microbiological hazard is *C. botulinum* and its association with infant botulism. Other species of the genus that may cause the same disease do so less frequently and are controlled in the same manner as *C. botulinum*. Other foodborne pathogens that may be detected in honey have no record of producing foodborne disease and most will be inactivated over time.

4.2. Chemical

4.2.1. Metals

Based on the literature review performed, there is evidence of a wide range of different metals being detected in honey. These hazards originate from mining, vehicle emissions and activities such as smelting (Sharma et al., 2023a). The metals antinomy, arsenic, cadmium, chromium, lead, manganese, and mercury were determined for hazard characterisation, based on their higher toxicological concern. Of these metals, only lead has a specified maximum level (ML) for honey of 0.1 mg/kg, in accordance with assimilated commission regulation (EC) No. 1881/2006.

4.2.1.1. Lead

The toxicity of lead differs according to whether it is in organic or inorganic form; organic lead is more toxic than inorganic lead (Agency for toxic substances and disease registry, 2023). However, the dominant environmental exposure has always been to inorganic lead, while exposure to organic lead has predominantly been via occupational settings. Exposure can lead to a wide range of serious adverse health effects. Acute effects of lead poisoning include colic, constipation, nausea, vomiting and anorexia. However, owing to accumulation of lead in the body, adverse effects can occur from long-term dietary exposure at lower levels than would cause acute toxicity. The most critical effect is developmental neurotoxicity; encephalopathy, decreased nerve conduction and cognitive defects have been observed in humans, and children are more sensitive than adults. Developmental neurotoxicity resulting from exposure to lead is often assessed by decreased general intelligence (IQ) and the COT were not able to conclude on a threshold for exposure to lead below which developmental neurotoxicity was not observed (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2013). For risk assessment, for children, the COT concluded that the EFSA $BMDL_{01}$ of 0.5 μg/kg bw/day (associated with a 1-point decrement in IQ) should be used. For adults, EFSA established $BMDL_{10}$ of 0.63 mg/kg bw/d for nephrotoxicity and $BMDL_{01}$ of 1.50 μg/kg bw/d for cardiovascular effects (EFSA Panel on Contaminants in the Food Chain, 2010). In all cases an MOE of >1 was an indication that any risk from this exposure is likely to be small, with a MOE of >10 being sufficient to ensure no appreciable risk. Because toxicity will depend on total exposure to lead from all sources, it is important to consider combined exposures from food, water, and non-dietary sources (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2013). The ML for lead in honey is 0.1 mg/kg according to assimilated Regulation (EC) No. 1881/2006. Noting the exposure to lead from different sources and the absence of a threshold for adverse health outcomes, any exposure to lead from honey will add to cumulative exposure and is therefore undesirable.

Levels of lead of up to 3.41 mg/kg have been detected (Bartha et al., 2020) when compared to the ML for lead of 0.1 mg/kg therefore mitigations, controls and monitoring should be considered for lead contamination in honey.

4.2.1.2. Cadmium

Cadmium is a toxic metal and exposure is through, food, water and air, however food is understood to be the largest source of exposure (Committee on Toxicity of Chemicals in Food, 2018). Chronic ingestion of cadmium has been shown in experimental animals to result in a wide range of health effects including metabolic disorders, nephrotoxicity and hepatotoxicity as well as adverse effects for pregnant women and unborn babies (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2022; Genchi et al., 2020). Cadmium has been classified as a type 1 carcinogen by the International Agency for Research on Cancer (IARC), meaning this material is carcinogenic to humans. However, a report by the EC Joint Research Council (European Commission, 2008) stated that there is no evidence to show that cadmium causes cancer through the oral route of exposure. Therefore, EFSA has derived a tolerable weekly intake (TWI) of 25 µg/kg bw/week to protect against the adverse effects of cadmium.

There are MLs set out for cadmium in assimilated regulation (EC) No. 1881/2006. There is no ML for cadmium in honey, but MLs for other commodities range from 0.01 to 3.0 mg/kg. Detected levels of cadmium in honey ranged from below detection limit to 3.81 mg/kg (Silici et al., 2016).

4.2.1.3. Mercury

The toxicity of mercury differs according to whether it is in organic, inorganic, or metallic form; organic mercury (often in the form of methylmercury) is the most prevalent form in food products. The forms of mercury differ in their effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes (World Health Organisation, 2017). Organic mercury, and particularly methylmercury, is the form more extensively absorbed following ingestion and can cross the blood-brain barrier and the placenta. This can cause effects on neurodevelopment in the embryo or in young children (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2018a). In their risk assessment, the COT concluded that the EFSA HBGV (EFSA Panel on Contaminants in the Food Chain, 2012) was appropriate: a TWI for methylmercury of 1.3 µg/kg bw/week (expressed as mercury). There is current no ML for mercury in honey, however MLs for mercury in fishery products and food supplements are between 0.1-1.0 mg/kg according to assimilated commission Regulation (EC) No. 1881/2006. One study found honey from contaminated areas to contain 50 -212 µg/kg in comparison to uncontaminated areas where the levels of mercury were 1-3 µg/kg (Toporcák et al., 1992). Because exposure to mercury can come from different sources, any additional exposure to mercury will add to cumulative exposure and is therefore undesirable.

4.2.1.4. Arsenic

Arsenic toxicity depends on whether it is in inorganic or organic form, and inorganic arsenic is more toxic than the organic species (EFSA Panel on Contaminants in the Food Chain, 2009). The health outcomes associated with chronic ingestion of inorganic arsenic include neurodevelopmental effects, heart diseases, respiratory and kidney diseases, spontaneous abortion, stillbirth, infant mortality and cancer of the skin, bladder and lung (EFSA Panel on Contaminants in the Food Chain, 2024). Inorganic arsenic is a class 1 carcinogen by IARC (World Health Organisation, 2012). There is a lack of provision of data on the effects of organic arsenic species on humans; Ingestion of some of some organic arsenic compounds is not considered to be of toxicological concern. However, EFSA are due to publish a risk assessment on organic arsenic species and total risk from inorganic and organic arsenic species (EFSA Panel on Contaminants in the Food Chain, 2024).

The COT applied the $BMDL_{0.5}$ value of 3.0 µg/kg bw/day for inorganic arsenic by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in their risk assessment, with an endpoint of 0.5% increased incidence of lung cancer (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2016). The Committee concluded that based on the fact that the increase in cancer increased with the duration of exposure and inorganic arsenic does not appear to have a direct genotoxic mechanism, a MOE of 10 would be sufficient (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2016).

Levels of arsenic found in honey range from below the LOD to 227.77 µg/kg and mean values in samples range from 0.06-78.52 µg/kg (de Oliveira et al., 2017; Gaine et al., 2022; Ligor et al., 2022; Pisani et al., 2008; Ru et al., 2013; Tahboub et al., 2022).

There is current no ML for arsenic in honey, however MLs for inorganic arsenic in rice and rice-based products are between 0.1-0.3 mg/kg according to assimilated commission regulation (EC) No. 1881/2006.

4.2.1.5. Antimony

The toxicity of antimony and its compounds depends on their water solubility and oxidation/valence state, e.g. trivalent antimony is more toxic than pentavalent antimony whereas inorganic forms are more toxic than the organic forms (World Health Organisation, 2003). Antimony which has leached out of materials in which it has been used is likely to be in the pentavalent [Sb(V)] forms which is less toxic than the trivalent forms [Sb(III)]. The latter has been shown to be genotoxic *in vivo* (Sundar & Chakravarty, 2010). The IARC has classified antimony trioxide as possibly carcinogenic to humans (Group 2B) (World Health Organisation, 2022a). A TDI of 6 µg/kg bw for antimony was established by WHO using a sub-chronic drinking water study in rats, this was based on decreased body weight gain and reduced food and water consumption (World Health Organisation, 2003).

Levels of antimony in honey range from none detected (Batelková et al., 2012; Gałczyńska et al., 2021; Jovetić et al., 2018) up to 13.3 µg/kg (Pisani et al., 2008) with mean values ranging from 3.76 – 5.1 µg/kg (Hungerford et al., 2021; Kastrati et al., 2023; Pisani et al., 2008). There are no maximum levels for antimony in food, however, the EU limit for drinking water is 10 µg/L (Council of the European Union, 2020).

4.2.1.6. Manganese

Manganese is an essential dietary element that is required for biological functions. However, chronic excess dietary intake of manganese can lead to adverse neurological effects which range in severity: mood changes, slowed response rate, intellectual deficits, and compulsive behaviour leading to irreversible dysfunction in some severe cases (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2018b). These effects are primarily seen in occupational exposures, in mining and welding professions. In this case, inhalation is the main route of exposure.

There are no regulatory levels for manganese in food, but the WHO set a guideline value of 0.4mg/L for drinking water. In a scientific opinion published in 2023, EFSA (EFSA Panel on Nutrition, Novel Foods and Food Allergen, 2023) established a safe levels ranging from 2mg/day in infants to 8mg/day in adults, for drinking water (World Health Organisation, 2011). Levels of manganese in honey range from none detected (Batelková et al., 2012) to 82 mg/kg (Stankovska et al., 2008).

4.2.1.7. Chromium

The toxicity of chromium is dependent on the speciation of chromium. Chromium is most commonly found in two states, either chromium (III) or chromium (VI). Exposure to the more toxic chromium (VI) is primarily through drinking water although some exposure occurs through food (European Food Safety Authority, 2014). Although long term respiratory exposure to chromium (VI) can cause lung cancer, the IARC has concluded that there is not sufficient evidence to support that chromium (VI) ingested via food and water is a carcinogen. Both chromium (III) and (VI) can cause other non-carcinogenic chronic effects on the liver and kidney and in the blood (Committee on infectious diseases and committee on, 2018). EFSA concluded that dietary exposure to chromium would be considered unlikely to result in cancer in humans (European Food Safety Authority, 2014). EFSA established a TDI for chromium (III) of 300 µg/kg bw/d). For chromium (IV) ESFA concluded that risk assessment should be performed against the $BMDL_{10}$ of 1.0 mg/kg bw/d for combined adenomas and carcinomas with an MOE of 10000 being of lower concern (EFSA Panel on Contaminants in the Food Chain, 2014).

There are no regulatory levels for chromium in food, however the WHO have derived a guideline value of 0.05 mg/L in water (World Health Oragnisation, 2020). Levels of chromium in honey range from non-detected to 2.04 mg/kg (Quiralte et al., 2023; Šerevičienė et al., 2022).

4.2.1.8. Conclusion on Metals

A range of metals may contaminate honey and dietary exposure to metals, in particular heavy metals, may be a public health concern. The toxicity of different metals varies, and they have been detected in honey at varying concentrations. Therefore, a risk assessment would be required to determine the risk to consumers from contamination of honey with a specific metal at a particular concentration. Only lead has a prescribed ML in honey of 0.1 mg/kg and some honey has been reported to have contamination exceeding this level. While there are no MLs for other metals in honey, a number of heavy metals have been reported in honey at levels that would exceed relevant regulatory levels in other commodities where they are set; although this should not be taken to confirm a risk from honey without further assessment. As there are multiple sources of exposure to heavy metals, any significant additional exposures, for example from contaminated honey, is undesirable as it could contribute to the overall background exposure in the UK population.

4.2.2. Persistent Organic Pollutants (POPs)

POPs are organic substances that persist in the environment, accumulate in organisms, and potentially pose a risk to human health and the environment. Their presence in honey is dependent on nearby land use and the chemicals applied, and industrial sources such as electrical equipment, hydraulic fluids, paints and plastics. Although usually present at low levels there is the possibility that they may reach levels harmful to consumers (Food Standards Agency, 2021).

4.2.2.1. Polychlorobiphenyls (PCBs)

Polychlorobiphenyls (PCBs) are a group of chlorinated compounds that have been used for industrial applications. There are 209 possible congeners of PCBs, which can be further classified as dioxin like PCB (DL-PCB) and non-dioxin like PCB (NDL-PCB) based on similar biological activity to chlorinated dioxin species.

NDL-PCBs are reported as the sum of six PCB congeners (PCB 28, 52, 101, 138, 153, 180) as they represent approximately 50% of the total NDL-PCBs found in food and relevant degrees of chlorination. The German Federal Institute for Risk Assessment (BfR) assessed NDL-PCBs (BfR, 2018) and found that NDL-PCB mixtures only have a low potential for acute toxicity. However, thyroid effects, liver changes, neuronal effects, immunotoxicity, endocrine changes and reprotoxic effects have been observed in animal experiments after long(er) term exposures with individual NDL-PCB congeners. In these studies, the liver and the thyroid have been identified as the most sensitive target organs. The IARC assessed PCB-153 and classified it as Group 2B: possibly carcinogenic to humans. A HBGV for NDL-PCBs has not been established due to the insufficient toxicity data available. The MLs for NDL-PCBs are set in assimilated EU law, and whilst there is not a specific level set for honey the MLs range from 40 ng/g fat and 125-300 ng/g of wet weight for a range of other commodities (Commisson Regulation EU No 1259/2011: Amending Regulation (EC) No 1881/2006 as Regards Maximum Levels for Dioxins, Dioxin-like PCBs and Non Dioxin-like PCBs in Foodstuffs, n.d.). A survey by EFSA (European Food Safety Authority, 2012) found that NDL-PCBs were present in honey at a maximum level of 6.5 µg/kg.

DL-PCBs are a mixture of 12 non-ortho or mono-ortho congeners that exhibit similar biological activity to dioxins. Whilst dioxins themselves are not characterised further, dioxin and DL-PCB species may be considered together for risk assessment. COT assessed DL-PCBs in 2001 and concluded that the health effects most likely to be associated with low levels of exposures relate to the developing embryo/foetus and concluded that there is the potential for a range of adverse health effects. COT proposed a TDI of 2 pg WHO-TEQ/kg bw/day based upon effects on the developing male reproductive system mediated via the maternal body burden and considered this to be adequate to protect against other possible effects such as cancer and cardiovascular effects (Committee on Toxicity, 2018). EFSA re-evaluated DL-PCBs in 2018 and proposed a reduction to the TWI, to 2 pg WHO-TEQ/kg bw (Committee on Toxicity of

Chemicals in Food Consumer Products and the Environment, 2021b). COT performed a further assessment following the EFSA update and concluded it was not necessary to update their advice at this point. The MLs are the sum of dioxins and DL-PCBs and whilst there is not a specific level set for honey the MLs range from 1.24-10 ng/g fat and 6.5-20 ng/g of wet weight for a range of other commodities (Commisson Regulation EU No 1259/2011: Amending Regulation (EC) No 1881/2006 as Regards Maximum Levels for Dioxins, Dioxin-like PCBs and Non Dioxin-like PCBs in Foodstuffs, n.d.). A survey by EFSA (European Food Safety Authority, 2012) investigated the presence of the sum of dioxin and DL-PCBs in honey and found their presence with a maximum value of 0.17 pg WHO-TEQ/g.

4.2.2.2. Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) describe a large group of chemicals used as brominated flame retardants. The group includes ten homologues with 209 isomeric congeners. PBDEs were assessed by COT (Committee on Toxicity, 2015) who found that most commercial technical mixtures predominantly are comprised of the same eight congeners (BDE-28, -47, -99, -100, -153, -154, -183, -209). Most of the 209 forms have not been tested for their toxicological properties and toxicological data on commercial technical mixtures are not suitable for risk assessment of PBDEs in food. From the data available, the main toxicological targets are liver, thyroid hormone homeostasis, reproductive and nervous systems. The available toxicological data are insufficient to derive HBGVs and therefore the EFSA and COT adopted assessment against reference points from available studies using an MOE approach. The assessment was performed based on the calculated $BMDL_{10}$ for changes in locomotor activity or total physical activity in developmental neurotoxicity studies - Reference points of 172, 4.2, 9.6 and 19640 ng/kg bw/d were derived for BDE-47, -99, -153 and -209 respectively. There are no MLs set for PBDEs in food although European law states that PBDEs in food must be monitored (European Commission, 2014a), and an academic study found levels in honey for a sum of 26 congeners ranging from 1,030-3,470 ng/kg in developing countries and 2,720-10,550 ng/kg in developed countries (J. Wang et al., 2010).

4.2.2.3. Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a large class of compounds containing fused aromatic rings that contaminate food from the environment or during food processing. Not all PAHs have been assessed for toxicological information. Benzo[a]pyrene (BaP) has previously been used as the single marker for PAHs. However a mixture of BaP, benz[a]anthracene (BaA), benzo[b]fluoranthene (BbF) and chrysene (ChR), designated as PAH4, are considered to be a more suitable indicator of PAHs in food (Committee on Toxicity, 2019b). To date, fifteen PAHs have been concluded to be genotoxic *in vitro* and *in vivo*. BaP is classified as carcinogenic to humans (Group 1) by IARC and three others (cyclopenta[cd]pyrene, dibenz [a, h] anthracene, and dibenzo[a,l]pyrene) are classified as probably carcinogenic to humans (Group 2A). Whilst not all PAHs are equally carcinogenic, risk assessment of PAHs is typically assuming they are genotoxic carcinogens and assessments of BaP and PAH4 are made against the $BMDL_{10}$ for increased tumour incidence of 0.07 mg/kg bw and 0.34 mg/kg bw respectively, where an MOE of >10000 is of low concern.

A survey of honeys in Europe (Surma et al., 2023), identified PAHs in the range 0.76-18.98 µg/kg. There are no MLs determined for PAHs in honey, although MLs range between 1.0-6.0 µg/kg for BaP and 1.0-30 µg/kg for PAH4 in various commodities in assimilated EU law (The European Commission, 2011).

4.2.2.4. Chlorinated Paraffins

Chlorinated paraffins (CPs) are a large group of several thousand individual chemicals. They are chlorinated linear hydrocarbons with between 10 and 30 carbon atoms and varying numbers of chlorine atoms, with a maximum of one chlorine atom per carbon atom. Depending on the length of the carbon skeleton, CPs are classified as short (SCCPs: C10-13), medium (MCCPs: C14-17) and long chain (LCCPs: C18-26). Only SCCPs and MCCPs will be discussed as LCCPs have not been detected in honey. COT (Committee on Toxicity, 2009) evaluated CPs and, based on available toxicological data, was able to derive a TDI for both SCCPs and MCCPs. For SCCPs COT derived a TDI of 30 µg/kg bw based on increased kidney weight, mild nephritis in males and brown pigmentation in renal tubules in females. For MCCPs COT derived a TDI of 4 µg/kg bw for changes in relative liver weight and minimal changes in the inner cortex of the kidney. In addition, the TDI set to protect against toxicity in the liver and kidney was also considered to give adequate protection against any potential carcinogenicity, reproductive and developmental effects. There are no MLs set for CPs in food. An academic study (Dong et al., 2022) detected CPs in honey, with SCCPs at 2.8-53.4 ng/g and MCCPs 4.8–415 ng/g although all samples were from remote areas distant from industrial areas.

4.2.2.5. Polyfluoroalkyl substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a class of over 12,000 fluorinated substances that have been produced since the 1940s and which are, or have been, used in a broad range of consumer products and industrial applications. EFSA assessed 27 PFAS, which have been subject to monitoring in food (2014). EFSA reported that the main contributors of PFAS to human blood serum are four compounds: PFOA, PFOS, perfluorononanoic acid (PFNA) and perfluorohexanesulfonic acid (PFHxS) and assessed risks from the sum of these compounds (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2014). Based on available studies in animals and humans, effects on the immune system were considered the most critical and a $BMDL_{10}$ of 17.5 ng/mL for the sum of the four PFASs in serum was identified from epidemiological studies, and EFSA established a TWI of 4.4 ng/kg bw per week. This approach was reviewed by COT (Committee on Toxicity, 2022) who raised some concerns with the EFSA assessment. These included uncertainties with the critical endpoint used and reservations with some of the modelling used. COT are currently conducting their own extensive review of PFAS. In the meantime, the COT has advised that where risk assessments are undertaken for PFAS, consideration should be made of the various HBGVs established by different authoritative bodies for the specific compounds identified, recognising the uncertainties regarding the critical effects they are based on, and the modelling approaches used. The EU have set a MLs for PFOS, PFOA, PFNA, PFHxS and their sum in certain foods (The Expert Committee on Pesticide Residues in Food, 2019). Whilst there is not one for honey specifically, the MLs for the sum of PFAS ranges from 1.7-50 µg/kg for varying commodities. A survey by EFSA (European Food Safety Authority, 2022) found that PFOA was present in 3/30 honey samples between the levels of 0.25-0.47 µg/kg

4.2.2.6. Endosulfan isomers

Endosulfan is a chlorinated pesticide and a wood preservative. Endosulfan was evaluated by the Joint FAO/WHO Meeting on Pesticide Residues in 1998 when the ADI of 6 µg/kg bw and ARfD of 20 µg/kg were set. Endosulfan has been evaluated by EFSA as an undesirable substance in animal feed, although HBGVs were not established. COT reviewed endosulfan in the infant diet (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2014) and concluded that the available information did not indicate a toxicological concern regarding dietary exposures since exposures were below the ADI set by JMPR and levels were decreasing further. The GB MRL of endosulfan is 0.01 mg/kg in honey and surveys by PRiF (The Expert Committee on Pesticide Residues in Food, 2019) and EFSA (European Food Safety Authority, 2022) did not identify endosulfan isomers in honeys exceeding the MRL.

4.2.2.7. Conclusion on POPs

A range of different chemicals that fall under the category of POPs have been identified in honey and have potential to be a concern for public health. Toxicity and occurrence of different POPs in honey vary and therefore further assessment would be required to determine whether a specific POP detected in honey, at certain level, would be a risk to consumers. However, PAHs, in particular, may be of concern, owing to potential for genotoxicity and associated risks at low levels of exposure.

4.2.3. Pesticides

4.2.3.1. Hazard Characterisation of Pesticides

From the literature review conducted, more than 150 pesticide residues have been reported in honey (appendix IV), and a study (Panseri et al., 2014) reported that pesticides were detected in 94% of samples. Pesticides (insecticides, herbicides and fungicides) are used on crop plants or other vegetation to maintain plant health or control plant growth and, as a result, residues may be present in honey from the collection of treated pollen and nectar.

Pesticides are regulated in honey by monitoring levels of residues in relation to MRLs (Health and Safety Executive, 2024). Of note is that pesticides with low water solubility are less likely to accumulate in honey. Instead, these lipophilic pesticides accumulate in wax. Studies have shown increased pesticide levels in wax compared to honey (Lozano et al., 2019).

In a survey conducted by the UK Expert Committee on Pesticide Residues in Food (The Expert Committee on Pesticide Residues in Food, 2019), no pesticides were found to exceed the MRL. However, in a report by EFSA (European Food Safety Authority, 2022), 30 different pesticides were found, including some that are not-approved for use in EU such as amitraz, chlorfenvinphos and coumaphos (note that chlorfenvinphos and coumaphos are approved in EU as veterinary medicines). Forty-eight honey samples (5.5%) contained pesticides, thiacloprid, acetamiprid, tau-fluvalinate, chlorfenvinphos, bromide ions and copper compounds that exceeded the MRL. A further EFSA report (European Food Safety Authority, 2024) identified glyphosate as also exceeding its MRL in honey, in addition to further MRL exceedances for acetamiprid. The pesticides identified by the EFSA reports exceeding the MRL are summarised in Table 2.

The toxicity of pesticide residues and the potential adverse effects that may result from unacceptable levels of exposure depends on the toxicological profile of the substance, the dose-response relationship, and the level of exposure. MRLs are set for pesticide residues and occurrence of a residue below the relevant MRL indicates that there is not likely to be an unacceptable risk to consumers. However, an exceedance of an MRL does not necessarily indicate a concern for consumer health, it is typically taken as a trigger for a need for risk assessment or other enforcement action.

Table 2. Hazard characterisation of pesticides exceeding the MRL

Pesticide	Acute Reference Dose (mg/kg bw)	Acceptable Daily Intake (mg/kg bw/d)	Reference	Non-compliant samples (%)
Acetamiprid	0.025	0.025	(European Food Safety	≥ 0.569[a]

Pesticide	Acute Reference Dose (mg/kg bw)	Acceptable Daily Intake (mg/kg bw/d)	Reference	Non-compliant samples (%)
			Authority, 2016)	
Bromide ion	Not Set	0.1	(Joint FAO/WHO Meeting on Pesticide Residues, 1988)	29.2
Chlorfenvinphos	Not Set	0.0005	(Joint FAO/WHO Expert Committee on Food Additives, 1994)	0.796
Copper compounds	Not Set	0.15	(European Food Safety Agency, 2020)	33.3
Glyphosate	0.5	0.5	(European Food Safety Authority, 2023a)	4.00
Tau-fluvalinate	0.05	0.005	(European Food Safety Authority, 2010)	≥ 0.569[a]
Thiacloprid	0.02	0.01	(European Food Safety Authority, 2019)	0.114

[a] MRL exceedances in 5 or more samples, exact numbers are not specified (European Food Safety Authority, 2022)

4.2.3.2. Conclusion on Pesticides

Overall, a large number of pesticide residues have been detected in honey and the levels present may be in excess of their respective MRLs, and therefore a potential public health concern. Whilst an exceedance of an MRL does not confirm a consumer risk, it may be taken as a trigger for further investigation. Owing to the differences in toxicology between pesticides and the varying levels at which they have been detected, further investigation in the form of risk assessment may be required to determine the consumer risk from a specific pesticide occurring in honey at a certain level.

4.2.4. Veterinary Medicine Products (VMPs)

4.2.4.1. Hazard Characterisation of VMPs

VMPs may be present in honey as a result of their intended use for the control of bee pathogens. Annual surveillance by the Veterinary Medicines Directorate (Veterinary Medicines Directorate, 2022b) investigated the presence of a range of veterinary medicines, including antibiotics within honey and found that in 2022 all samples tested were compliant. However, a report by EFSA in 2022 (European Food Safety Authority, 2024) found that 42 samples (1.37%) were non-compliant (detected in levels over the LOD), with honey having the highest frequency of non-compliant samples for antimicrobials compared to all other commodities tested. Exceedances in honey were reported for erythromycin, streptomycin, sulfacetamide, sulfachlorpyrazine, sulfadiazine, sulfamethoxine, sulfamerazine, sulfamethazine, sulfamonomethoxine, sulfathiazole, sum of enrofloxacin and ciprofloxaxin, sum of oxytetracyline and its 4-epimer, tylon (tylosin and tylosin A), glyphosate and acetamiprid. Chloramphenicol has also been responsible for nine RASFF notifications between 2020 and 2024. Chloramphenicol is prohibited in the UK and no level of intake without risk can be identified owing to genotoxic potential, therefore MRLs cannot be established (Veterinary Medicines Directorate, 2022a). Glyphosate and acetamiprid are pesticides and were discussed in the previous section. The antibiotics identified by the EFSA reports exceeding the MRL are summarised in Table 3.

Table 3. Characterisation of antibiotics found in honey and proportion of non-compliant samples in one survey

Antibiotic name	Antibiotic Class	Acceptable Daily Intake (μg/kg bw)	Reference	Non-compliant samples (%) (Veterinary Medicines Directorate, 2022b)
Erythromycin	Macrolides	5	(Committee for Veterinary Medicinal Products, 2000)	3.57
Streptomycin	Aminoglycosides	25	(Committee for Veterinary Medicinal Products for Veterinary Use, 2006)	3.57
Sulfonamides	Sulfonamides	N/A[1]		3.04
Sum of Enrofloxacin and ciprofloxacin	Fluoroquinolones	6.2	(Committee for Veterinary Medicinal Products, 1998)	3.57
Oxytetracyline	Tetracyclines	3	(Committee for Veterinary Medicinal Products, 1995)	1.23
Trimethoprim	Diaminopyridines	4.2	(Committee for Veterinary Medicinal Products, 1997a)	3.57
Tylosin	Macrolides	6	(Committee for Veterinary Medicinal Products, 1997b)	0.49

[1] The Committee for Veterinary Medicinal Products has recommended MRLs for the combined residues of sulphonamides in meat and milk but did not itself set an ADI, though it referred to an ADI set by JECFA for one sulphonamide, sulfamethazine (also known as sulfadimidine) of 50 μg/kg bw. The MRLs set reflected those also set by JECFA. JECFA had set the ADI but also took the approach that MRLs for sulfonamides should be set at levels as low as practicable due to a risk of hypersensitivity reactions.

The use of antibiotics in food-producing animals contributes to the development of antimicrobial-resistant bacteria. These bacteria can be transmitted through the food chain and the environment and can transfer to humans through ingestion. This can lead to more serious infections with longer illness, increased frequency of hospitalisation, and treatment failures (Arsène et al., 2022).

A survey of 18 honey samples from Europe determined that most acaricides, including coumaphos, were present below the method's level of detection, with tau-fluvalinate present in 10 samples at less than the MRL (Fuente-Ballesteros et al., 2023). Another small survey of five samples did detect coumaphos and amitraz, but at less than the MRL (Lozano et al., 2019).

4.2.4.2. Conclusion on VMPs

Overall, residues of VMPs may be present in honey. The potential adverse effects that may result from exposure to residues of VMPs depends on the toxicological profile of the substance, the dose-response relationship and the level of exposure. The information available indicate that VMP residues may be present at levels above respective MRLs indicating there may be a concern for consumer health. Additionally, residues of VMPs which are not authorised, or which are specifically prohibited such as chloramphenicol, may be present and these may be a concern for consumer health. The presence of a residue of VMP in honey exceeding the MRL, or presence of a residue of a VMP that is not authorised, may require further action in the form of risk assessment to determine the risk to consumers.

4.2.5. Toxins

Toxins reported in honey and determined for hazard characterisation were, aflatoxins, ochratoxin A, trichothecenes (T2/HT2), deoxynivalenol, picrotoxins (tutin), grayanotoxins, pyrrolizidine alkaloids (PA), tropane alkaloids (TA) and gelsedine alkaloids (GA).

Mycotoxins are formed in the environment through the metabolism of fungi, and those considered here may be formed under specific conditions, e.g. aflatoxins in warm humid environments. In contrast, the other toxins are produced by specific species of plant that grow under specific conditions and so are confined to certain geographical regions. When bees forage on these plants the toxin may be taken back to the colony and subsequently contaminate the honey.

Fungi capable of producing ochratoxin A and aflatoxins have been isolated from bee pollen products (González et al., 2005) although toxins were not detected directly. However, mycotoxins were detected in pre-packaged bee pollen products (Nuvoloni et al., 2021). These products may not necessarily represent pollen taken back to the colony.

4.2.5.1. Aflatoxins

Aflatoxins are mycotoxins produced mainly by two fungal species *Aspergillus flavus* and *A. parasiticus*. The IARC concluded that naturally occurring aflatoxins are carcinogenic to humans (group 1), with a role in aetiology of liver cancer. EFSA (European Food Safety Authority, 2020a) assessed aflatoxins in food and did not consider it appropriate to establish a HBGV since aflatoxins are both genotoxic and carcinogenic and therefore applied the MOE approach in their risk assessment. However, EFSA noted, that the available data would only be sufficient for aflatoxin B1, yet aflatoxin G1 and aflatoxin B2 were also shown to be carcinogenic in rodents, albeit at lower potency than aflatoxin B1. Therefore, as a conservative approach, EFSA assumed the carcinogenic potency of “total aflatoxin” to be similar to aflatoxin B1. EFSA derived a $BMDL_{10}$ value of 0.4 µg/kg based on hepatocellular carcinoma incidence and proposed an MOE of 10,000 or higher would be of low health concern. There is no ML for aflatoxins in honey, although MLs range between 4-15 µg/kg for a sum of aflatoxin B1, B2, G1 and G2 for various commodities in assimilated EU law (European Commission, 2006b).

In a survey by EFSA (European Food Safety Authority, 2024), all samples of honey were shown to be below the LOD for aflatoxins. However, aflatoxins have been detected in honey at concentrations up to 22 µg/kg, with the highest concentrations found in honey produced in “humid hot semi-coastal regions” (Swaileh & Abdulkhaliq, 2013a). They have also been detected in honey from Asia (Rahman et al., 2014) and Europe (Kostić et al., 2017). In contrast, measurements in honeys from a number of countries did not detect aflatoxins (Eissa et al., 2014; Martins et al., 2003).

4.2.5.2. Ochratoxin A

Ochratoxin A (OTA) is regarded as a possible human carcinogen (Group 2b), in addition available toxicological information suggests that OTA may be genotoxic. EFSA (EFSA Panel on Contaminants in the Food Chain, 2020) established a $BMDL_{10}$ of 4.73 µg/kg bw/d for non-neoplastic effects and an MOE of ≥ 200 is considered to be of low concern for consumer health. For neoplastic effects, a $BMDL_{10}$ of 14.5 µg/kg bw/d was derived and an MOE of ≥ 10,000 is of lower concern.

In a survey of 28 honey samples OTA was detected in 50%, with a mean concentration of 0.0211 µg/g, a maximum of 0.049 µg/g and a minimum of 0.003 µg/g (Keskin & Eyupoglu, 2023).

4.2.5.3. Trichothecenes (T2/HT2)

Trichothecenes is used to refer to T2 and HT2 (type A trichothecenes) which are produced by a variety of *Fusarium* species and a small number of other fungi (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, n.d.). Critical adverse effects of T2 and HT2 are haematotoxicity, immunotoxicity, reduced body weight, and emesis. These effects occurred at lower doses than other adverse effects such as dermal toxicity, developmental and reproductive toxicity, and neurotoxicity. Haematotoxicity is considered the critical chronic effect of T2; T2 and HT2 have been previously reviewed by COT in 2018 (Committee on Toxicity, 2018). The COT previously agreed with EFSA's group ARfD of 0.3 µg/kg bw from 2017, with some caveats and EFSA's group TDI of 0.02 µg/kg bw for T2, HT2 and neosolaniol (NEO: a metabolite of T2). T2 and HT2 have been subject to recent re-evaluation by JECFA (World Health Organisation, 2022b) and COT are currently performing a further review.

In a survey of 28 honey samples, T2 was detected in 14.3%, with a mean concentration of 0.773 µg/g, a maximum of 1.637 µg/g and a minimum of 0.091 µg/g, and HT2 was detected in 17.9% with a mean concentration of 0.156 µg/g, a maximum of 0.331 µg/g and a minimum of 0.075 µg/g (Keskin & Eyupoglu, 2023).

4.2.5.4. Deoxynivalenol

Deoxynivalenol (DON) is a mycotoxin primarily produced by *Fusarium* fungi, occurring predominantly in cereal grains. The risks of DON to human health were assessed by EFSA in 2017 (EFSA Panel on Contaminants in the Food Chain, 2017). EFSA concluded that DON is genotoxic *in vitro* but the *in vivo* genotoxic potential of DON was inconclusive. Acute effects of DON in humans have been reported as nausea, vomiting, diarrhoea, abdominal pain, headaches, dizziness, fever and bloody stool. No evidence of lethality in humans has been reported. EFSA established a TDI of 1 µg/kg bw per day for DON based on reduced bodyweight gain in mice (applicable as a group-TDI for the sum of DON, 3-Ac-DON, 15-Ac-DON and DON-3-glucoside). Based on epidemiological data from mycotoxicosis a group-ARfD of 8 µg/kg bw per eating occasion was calculated.

In a survey of 28 honey samples DON was detected in 25%, with a mean concentration of 1.798 µg/g, a maximum of 9.351 µg/g and a minimum of 0.140 µg/g (Keskin & Eyupoglu, 2023).

4.2.5.5. Picrotoxins

Picrotoxin contamination of honey occurs when bees collect honeydew from insects that feed on tutu plants which only exist in New Zealand - *Coriaria arborea* and *Coriaria sarmentosa*. Tutu bushes contain a neurotoxin called tutin. There have been 36 reported tutin poisonings since 1980 (Ministry of Primary Industries, 2015). Reported poisonings are likely to be only a percentage of the actual number as some people who are poisoned may not connect their illness with honey. The former New Zealand Food Safety Authority (NZFSA) assessed tutin and set the ARfD at 2.5 µg/kg based on neurotoxicity and locomotor effects (Food Standards

Australia and New Zealand, 2014). There was insufficient information to characterise chronic toxicity. Food Standards Australia and New Zealand (FSANZ) (Food Standards Australia and New Zealand, 2014) carried out a human pharmacological study and found that tutin levels as low as 5.1 mg/kg in honey caused mild effects such as headaches and dizziness. The ML for honey is set at 0.7 mg/kg for both honey and comb honey (Ministry of Primary Industries, 2015). This was changed from the previous levels set at 2 mg/kg for honey (to account for the breakdown of tutin glycosides), and 0.1 mg/kg for comb honey (as despite the variability across the comb, harm is a result of tutin in the final product and there is no difference in risk between comb honey and extracted honey). The National Chemical Residue Programme in New Zealand (New Zealand Food Safety Authority, 2023) monitors the presence of tutin in honey and found that in 2021-2022 no samples of honey exceeded the ML.

A recently reported case identified tutin concentrations at 30-50 mg/kg of honey (Food Standards Australia and New Zealand, 2014).

4.2.5.6. Grayanotoxins

Grayanotoxins (GTXs), contained within the group of compounds known as grayananes, are found in specific rhododendron-derived honey, often called “mad honey” due to its neuroactive effects, although is also consumed as a folk medicine remedy (Yan, 2022). Acute intoxications reported in the last decades from European countries are mainly associated with imported honey from Turkiye or Nepal and no intoxication cases have been reported for honeys from EU origin (European Food Safety Authority, 2023b). Despite more than 1,000 cases of intoxication after ingestion being reported in the literature, only a few case reports provide quantitative information on grayananes in the implicated honey.

GTX I and GTX III are the most studied grayananes with respect to toxicological effect. The estimated intake the of sum of GTX I and GTX III reported in acute poisoning cases from consuming *Rhododendron* honey was as low as 4.8 μg/kg bw (European Food Safety Authority, 2023b). EFSA assessed grayanotoxins in honey in 2023 and determined the most relevant acute effects to be impairment of the nervous system and adverse cardiovascular effects (European Food Safety Authority, 2023b). There is evidence of genotoxicity *in vivo* of both *Rhododendron* honey and GTX III and EFSA concluded that grayananes should be considered to be an *in vivo* genotoxin. For acute effects, EFSA performed risk assessment against the reference point of 15.3 μg/kg bw for the sum of GTX I and GTX III based on a $BMDL_{10}$ for cardiac effects with an MOE of <100 indicating a concern for acute effects. Due to the lack of information on the underlying mode of action of genotoxicity and the lack of data on chronic toxicity and carcinogenicity, EFSA were unable to assess the risk related to chronic/repeated exposure. There is currently no ML or monitoring programme for grayanotoxins in honey set in the EU, but EFSA concluded that 0.05 mg/kg would not be expected to result in acute effects in all age groups. An academic review (Yan, 2022) reported GTX I at levels ranging from 0.61-26 mg/kg, GTX III in levels between 2.114 and 16.89 mg/kg and other grayanotoxins between 2.0 and 39.8 mg/kg.

4.2.5.7. Nicotine

EFSA assessed the public health risk of nicotine in food (wild mushrooms) in 2009 (European Food Safety Authority, 2009) and concluded that nicotine is acutely toxic by all routes of exposure (oral, dermal, and inhalation). Consistent with its action as agonist at the nicotinic receptors, it targets the peripheral and central nervous systems causing for example dizziness, salivation, increased heart rate and blood pressure.

EFSA established an ARfD of 0.0008 mg/kg bw, based on a lowest observed adverse effect level (LOAEL) of 0.0035 mg/kg bw for pharmacological effects after intravenous application of nicotine (i.e. slight, transient and rapidly reversible increase of the heart rate in humans). Due to the short biological half-life of nicotine in humans, it does not accumulate in the body and the most sensitive effect of nicotine is considered to be its effect on the cardiovascular system. Therefore, avoiding acute effects of nicotine would also protect from its chronic effects and EFSA established an acceptable daily intake (ADI) for nicotine at 0.0008 mg/kg bw/day that is the same as the ARfD.

Nicotine has been measured in honey at concentrations ranging from 178 to 9,389 µg/kg in 67% of the samples tested (Swaileh & Abdulkhaliq, 2013a), with the higher concentrations found in honey produced in the same area as tobacco plants. Elsewhere, nicotine was detected in approximately 7% of samples (Sadok et al., 2023) with the maximum concentration of 1.9 µg/kg.

4.2.5.8. Pyrrolizidine alkaloids

Pyrrolizidine alkaloids (PAs) are a large group of more than 350 natural toxins produced by plants, including the families Boraginaceae, Asteraceae and Leguminosae. COT assessed PAs in food (Committee on Toxicity, 2008) and noted that PAs are a large class of compounds with differing toxicities and that the variability in potency is an important consideration. PAs are known to cause veno-occlusive disease in humans and several PAs have been evaluated by IARC and categorised as Group 2B; possibly carcinogenic to humans. According to COT, the available information on human cases of poisoning do not provide sufficiently reliable exposure data to be used in establishing a HBGV. COT endorsed the COC’s recommendation to assess all PAs as a cumulative assessment group where it is prudent to assume that PAs are genotoxic and assess them using the $BMDL_{10}$ with an MOE of <10000 being of low concern. A $BMDL_{10}$

of 0.073 mg/kg bw/day was derived from a 2-year carcinogenicity study of lasiocarpine and should be used to assess exposure for any PA. Maximum levels for PAs have been set in regulation (EU) 2020/2040 for 'pollen and pollen products' at 500 µg/kg but are not in force in GB in these products or in honey. Studies by the FSA (Food Standards Agency, 2020) detected PAs in 65% of honeys tested with levels up to 251 µg/kg, which is consistent with data in a recent review (Lu et al., 2024).

4.2.5.9. Tropane Alkaloids

Tropane alkaloids (TAs) naturally occur in several plant families, such as Brassicaceae, Solanaceae and Erythroxylaceae (EFSA Panel on Contaminants in the Food Chain, 2013). The group of TAs includes around 200 compounds, common examples are: (-)-hyoscyamine, (-)-scopolamine and atropine, a racemic mix of (-)-hyoscyamine and (+)-hyoscyamine.

(-)-hyoscyamine, (-)-scopolamine inhibit the central nervous system (CNS) and autonomic nervous system (ANS). In humans, adverse effects are typically inhibition of saliva (dry mouth), sweating, dilation of pupils and paralysis of accommodation, change in heart rate, inhibition of urination, reduction in gastrointestinal (GI) tone and inhibition of GI secretion. Data informing on toxic effects of other TAs are very limited (EFSA Panel on Contaminants in the Food Chain, 2013).

EFSA (EFSA Panel on Contaminants in the Food Chain, 2013) performed a risk assessment on (-)-hyoscyamine and (-)- scopolamine, the TAs for which both occurrence and toxicity data were available. EFSA establish an acute reference dose (ARfD), as the pharmacological effects of (-)-hyoscyamine and (-)-scopolamine occur shortly after administration. EFSA derived an ARfD of 0.016 µg/kg bw/d.

Atropine, tropine and tropacocaine have been detected in honey samples using a newly developed antibody-based approach (Z. Wang et al., 2023), with 30.49% containing atropine. The atropine concentration exceeded 1 µg/kg in 13.47% of the samples. The authors cite three other studies where TAs were not detected, atropine was present in 22% of samples with 12.5 containing more than 1 µg/kg and a maximum of 3.8 µg/kg, and a third where scopolamine was present at a maximum of 27 µg/kg.

4.2.5.10 Gelsedine Alkaloids

EFSA list *Gelsemium spp.* as containing toxic substances (European Food Safety Agency, 2009). Gelsedine alkaloids (GA) are a class of indole alkaloids predominantly found in *Gelsemium elegans* (which also produces other alkaloids), commonly known as 'heartbreak grass', which is found in Asia and in particular China. Toxicological information to reliably characterise gelsemium alkaloids is limited; an academic study found the oral LD_{50} or a crude alkaloidal fraction *of Gelsemium elegans* to be 15 mg/kg bw in mice, and some specific gelsedine alkaloids have been reported to have an oral LD_{50} below 200 µg/kg bw (G.-L. Jin et al., 2014). Honey contaminated with alkaloids from *G. elegans* has been associated with a 2016 outbreak of intoxications and deaths following consumption of honey in China (Yang et al., 2020b). An analysis of outbreaks from 2010 to 2019 for the Yunnan province of China identified 27 “food poisoning events” involving 94 cases and 17 deaths (Liu et al., 2020) although the abstract does not define the toxin(s) involved.

The prevalence in honeys from Guangdong is reported at 80-84% with GA at an average concentration of 17.20 µg/kg (Yang et al., 2020b). In contrast, an experimental method was unable to detect *Gelsemium* alkaloids in 30 honey samples tested, although the authors noted that samples were obtained over a period in which the plant may have been not in full bloom (Ma et al., 2022).

4.2.5.11. Conclusion on toxins

A range of toxins has been detected in honey. Mycotoxins comprising aflatoxins, ochratoxin A and trichothecenes (T2, HT2) have been detected. Mycotoxins are not typically associated with honey and are more common in foods such as grains, cereals and dried fruit. They are also usually associated with commodities from warm and humid climates that promote fungal growth (World Health Organisation, 2018). If mycotoxins are found in honey it would be likely that they occur in honey produced where mycotoxin contamination is a wider issue. If mycotoxins found to be present in honey, particularly aflatoxins and ochratoxin for which there are concerns relating to genotoxicity and carcinogenicity, there may be a concern for consumer health and further assessment would be required.

Picrotoxins (tutin), grayanotoxins and GAs may be present in honey and have been reported to cause cases of poisoning from honey consumption. Tutin is associated with New Zealand only and is closely controlled. Grayanotoxins may be present in *Rhododendron* honey (sometime referred to as ‘mad honey’), particularly from Türkiye and Nepal. The risk from these hazards in honey has been assessed previously by regulatory bodies and mitigations and control measures should be in place and followed accordingly. GAs are predominantly associated with Asia, in particular China. The risk to consumers of GAs is less well documented but they have been associated with deaths following consumption of contaminated honey, therefore risk from GAs if detected in honey may warrant further assessment. Nicotine, PAs and TAs may also contaminate honey and owing to their toxicity at low concentrations and particularly for PAs with respect to potential genotoxicity, may be a potential concern that would merit further assessment. Overall, the likelihood presence of plant and other toxins in honey is related to the presence of the toxin (or toxin producing plant) in the area foraged by honey producing bees and this should be taken into account in any assessment of honey production.

4.2.6. Other Chemicals

Based on the information available, a number of other chemical contaminants have been detected in honey. 5-HMF, perchlorate and phthalic acid esters are characterised below.

4.2.6.1. Hydroxymethylfurfural (5-HMF)

According to Codex standards (Codex-Alimentarius, 2022), the Honey England Regulations (UK Parliament, 2015) and similar legislation for Scotland (The Scottish Parliament, 2003), Northern Ireland (The Government of the United Kingdom, 2015) and Wales (The National Assembly for Wales, 2003) HMF in honey can be present up to 40 mg/kg, or up to 80 mg/kg in countries with tropical climates, after processing or blending.

EFSA have evaluated 5-HMF (European Food Safety Authority, 2011) and concluded that whilst it is shown it to be genotoxic under certain experimental conditions and has carcinogenic potential in mice, no genotoxicity or carcinogenicity is expected in humans. Some of the concerns for adverse effects relate to formation of the more toxic substance 5-sulfooxymethylfurfural *in vivo*. However, 5-HMF is commonly found in many foods and at levels higher than have been reported in honey. Consequently, there is no specific concern relating to 5-HMF in honey (Capuano & Fogliano, 2011), particularly where the honey is compliant with standards for 5-HMF.

The concentration of 5-HMF varies with storage time and temperature. A review summarises studies reporting 5-HMF concentrations in honey with the associated storage conditions (Shapla et al., 2018). The highest concentration was 1136.76 mg/kg for honey stored for more than two years at 25-30°C, and all samples stored for less than six months met the Codex standard. However, even honey after a year’s storage at 4-6°C could contain non-compliant concentrations.

4.2.6.2. Perchlorate

Perchlorate is a chemical contaminant which is released into the environment from both natural and anthropogenic sources. Perchlorate is further formed during the degradation of sodium hypochlorite, which is used for the disinfection of water. The toxicity of perchlorate was assessed by EFSA (EFSA Panel on Contaminants in the Food Chain, 2015) and COT (Committee on Toxicity, 2019a) agreed with this opinion. The main adverse effects of perchlorate are on the thyroid where it can disrupt hormone synthesis and consequently may lead to the development of hypothyroid effects. EFSA established a TDI of 0.3 µg/kg bw using the $BMDL_{05}$ of 1.2 µg/kg bw from human dose-response data as reference point. There are no MLs determined for perchlorate in honey, although MLs range between 0.01-0.75 mg/kg for various commodities in assimilated EU law (European Commission, 2020).

In an academic study (Fei et al., 2024), perchlorate was detected in 95.4% of samples up to concentrations of 612 µg/kg and concentrations were marginally higher for monofloral honey than multifloral sources. Lychee honey (28-612 µg/kg) was shown to have the highest perchlorate concentrations of the monofloral honeys, with sunflower (0.7-7 µg/kg) and loquat honeys (4-9 µg/kg) the lowest.

4.2.6.3. Phthalic acid esters

Phthalate esters (phthalates) are the dialkyl or alkyl esters of phthalic acid. Phthalates have a variety of industrial uses, including as plasticisers that impart flexibility and durability to polyvinyl chloride products. Phthalates may be present in food due to their widespread presence as environmental contaminants or due to migration from food contact materials. The critical toxicological effects of phthalates are on reproduction (EFSA Panel on Food Contact Materials Enzymes Processing Aids, 2019).

Phthalates have previously been considered by COT, EFSA and WHO. EFSA (2005) set TDIs for several phthalates, namely for di-butylphthalate (DBP, 0.01 mg/kg bw per day), butyl-benzyl-phthalate (BBP, 0.5 mg/kg bw per day), bis(2-ethylhexyl)phthalate (DEHP, 0.05 mg/kg bw per day), di-isononylphthalate (DINP, 0.15 mg/kg bw per day) and di-isodecylphthalate (DIDP, 0.15 mg/kg bw per day). The COT produced a statement on phthalates in 2011 (Committee on Toxicity of Chemicals in Food Consumer Products and the Environment, 2011) where they reviewed and retained the TDIs previously set by EFSA for these phthalates.

A survey of 47 nectar honey samples detected plasticisers (dimethyl phthalate, diethyl phthalate, diisobutyl phthalate, dibutyl phthalate, bis(2-ethylhexyl) phthalate, and di-n-octyl-phthalate) in all of the samples but most of the individual analyses were at less than the limit of quantification (Notardonato et al., 2020). For example, dimethyl phthalate was only at a quantifiable concentration in one sample, at 12 µg/kg.

4.2.6.4. Bisphenol A (BPA)

BPA is a monomer that is used in manufacturing polycarbonates, epoxy resins and other polymeric materials and thermal printing in certain paper products.

In 2015 EFSA established a temporary tolerable daily intake (TDI) of 4 µg/kg bw/day based on benchmark dose for changes in mean kidney weight (EFSA Panel on Food Contact Materials, 2015). In 2023 EFSA revised the TDI to 0.04 ng/kg bw/day based on effects on Th17 cells in mice.

The COT discussed EFSA's draft re-evaluation of BPA at their February 2022 meeting and raised a number of concerns. The BfR published a full assessment of BPA in 2023, deriving a TDI of 200 ng/kg bw per day (0.2 µg/kg bw per day). The COT adopted the BfR TDI in February 2023. A full statement by the COT is due to be published later in 2024, providing detail on the underlying discussions and considerations of the data base that led to the adoption of the BfR TDI.

In one study of 107 samples tested, 15.9% contained BPA up to 33.3 µg/kg, but no BPF (Inoue et al., 2003). Bisphenol A was present at a maximum value of 107 µg/kg in another survey of 36 honey samples (Česen et al., 2016).

4.2.6.5. Conclusion on other chemicals

Of the other chemicals identified in honey, 5-HMF, perchlorate, phthalates and BPA were determined for characterisation. 5-HMF is specifically controlled in honey and has been detected at levels exceeding the relevant ML. Perchlorate, phthalates and BPA may occur in honey, with the latter two contaminants potentially from migration from plastic honeycomb or other plastic food contact materials. Perchlorate, phthalates and BPA have potential to be a public health concern and if detected in honey would require risk assessment to determine risk to consumers. However, based on the information available, there are no obvious or immediate public health concerns from 5-HMF, Perchlorate, phthalates and BPA in honey.

4.3. Radionuclides

4.3.1. Characterisation of Radionuclides

The presence of radionuclides in food, including honey, could pose health risks if present at high levels. Consuming food contaminated with radionuclides can result in accumulation of radioactivity in the body and could increase the risk of adverse health effects. For example, if food or drink that is contaminated with radioactive iodine is ingested, the radionuclide will accumulate and be retained in the thyroid gland, and increase the risk of thyroid cancer, particularly in children. Generally, exposure to radionuclides can result in an increased risk of certain types of cancer, the types of which and organs effected depending on the specific radionuclides (World Health Organisation, 2023).

Appendix V summarises studies reporting levels of radionuclides in honey.

4.3.2. Conclusion on Radionuclides

Overall, data for the presence of radionuclides do not exceed limits set in place to respond to nuclear emergency and would not result in a dose that would exceed the legal limit for members of the public. However, the potential for contamination of honey with radionuclides, under certain circumstances, should be borne in mind.

4.4. Allergens

4.4.1. Characterisation of Allergens

The allergenic proteins identified in honey are the glandular proteins produced by bees. Some individuals could cross-react to the pollen present in honey, which is primarily from the Compositae plant family that includes asters, daisies and sunflowers.

There are few reports of individual honey-related cases of anaphylaxis (Jhawar & Gonzalez-Estrada, 2022) and the prevalence of honey allergy is unknown in the UK.

The symptoms caused by sensitisation to honey range from a cough to anaphylaxis (Aguiar et al., 2017) and may include gastrointestinal symptoms such as abdominal pain, vomiting and diarrhoea (Bousquet et al., 1985). However, adverse reactions to honey are reportedly rare (<0.001% [Aguiar et al., 2017],) even in pollen sensitive individuals (Kiistala et al., 1995) although they can occur, as shown in a case where an individual allergic to sunflower pollen developed symptoms after eating honey containing sunflower pollen (Bousquet et al., 1985), anaphylaxis as reported in a review (Popescu, 2015), and as occurred in a six year old allergic to Compositae pollen (Di Costanzo et al., 2021).

Reactions to bee venom can be serious and the detection of bee venom proteins in honey has been noted (Burzyńska & Piasecka-Kwiatkowska, 2021), although the concentrations were low and examples of reactions caused by honey not identified.

4.4.2. Conclusion on Allergens

Overall, the proportion of the population sensitised to honey is unknown. Pollen is the most reported cause of adverse reactions to honey and while bee venom can also be present, any resulting reactions are not evident in the literature. There is no robust evidence of honey containing the specific food allergenic proteins at levels causing concern.

5. Hazard Prevention, Mitigation and Controls

5.1. Hazard Mitigation

This section covers mitigations for the hazards identified in section 3. The legislation, which is intimately linked with mitigations, is detailed in section 5.2.2 and Appendix VI. Most of the mitigations described below are in place and operational, while others are better described as under development but are included should they become used commercially in the medium-term future.

Mitigations described here can be formalised into codes of practice, and one has been produced by the British Honey Importers and Packers Association (BHIPA). This covers the importation, blending, packaging and marketing of honey to support statutory requirements (British Honey Importers & Packers Association, 2011). The code requires members to adhere to appropriate regulations (e.g. the Honey (England) Regulations 2015) and to sample products from new and existing suppliers in accordance with recognised procedures. This tests honey for quality (e.g., moisture content), ensures product is free from unauthorised VMPs and pesticides, and all authorised veterinary drugs adhere to the relevant MRL. The code requires that importers must take all reasonable steps and exercise due diligence to prevent product adulteration and false descriptions.

The code also includes quality control and assurance measures including adherence to GMP and Hazard Analysis Critical Control Point (HACCP).

5.1.1. Microbiological

Control of pathogens in foods is generally achieved through a system of HACCP analysis, and a review of HACCP as applied to honey production has been published (Formato et al., 2011). This covers stages for unprocessed honey production from maintaining colony health to collection of honey-containing supers, and states that ripened honey is composed of inhibitory hurdles (McIntyre & Hudson, 2009) that prevent bacterial proliferation.

The Codex Standard for Honey (Codex Alimentarius Commission, 2022) stipulates that products should comply with any microbiological criteria established in accordance with the Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods (CXG 21-1997), but there are no criteria applicable to honey.

The Health Protection Agency (Health Protection Agency, 2009) produced guidance for the interpretation of laboratory results for generic ready-to-eat food that would apply to honey. Results that indicate a High microbiological risk category are: Presence of *Campylobacter*, *Salmonella*, *Escherichia coli* O157:H7 and other Shiga Toxin Producing *E. coli*, *Shigella*, *Vibrio cholerae,* and pathogenic *Bacillus* spp. at >10^5/g, *C. perfringens* at >10^5/g, *L. monocytogenes* at >10^2/g, *S. aureus* and other coagulase positive staphylococci at >10^4/g, and *V. parahaemolyticus* at >10^3/g. Some of these tests would be inappropriate if applied to honey because of the lack of likelihood of occurrence (e.g. *Vibrio* spp.) since the criteria are generic for all RTE foods. The most relevant would be those where low numbers consumed can cause disease, such as *Salmonella* and *E. coli* O157:H7 but these organisms are inactivated in honey over time. There are no criteria for *C. botulinum*.

The primary sources of contamination by *C. botulinum* cannot be controlled via mitigation strategies applied during beekeeping, but methods of destroying both spores from this organism and vegetative cells from other species during processing have been explored, especially in academic research settings.

Ultrafiltration through a 10,000 molecular weight cut off membrane completely removed micro-organisms present (Itoh et al., 1999) but this degree of filtration would result in a product that did not meet Codex Standards which state “No pollen or constituent particular to honey may be removed except where this is unavoidable in the removal of foreign inorganic or organic matter” and “Honey which has been filtered in such a way as to result in the significant removal of pollen shall be designated filtered honey”. A similar phrase is included in the Honey (England) Regulations 2015 (section 5).

A review of emergent processing methods (Scepankova et al., 2021) identified high pressure, ultrasound, microwaves (which act through the heating alone and not through any intrinsic properties of the microwave itself), irradiation and ultraviolet light as potential means for decontaminating honey. The same paper also reports on potential quality impacts of these technologies. Currently these processes are under development and their relative safety and efficacy are unestablished.

Thermal processing of honey is considered one of the simplest and most effective methods for preventing microbial spoilage by yeasts and vegetative (non-spore-forming) cells. Heating conditions of 77°C for two minutes followed by rapid cooling to 54°C has been described as common, with 60°C for 30 minutes and 71°C for one minute reported as other treatments (Scientific Committee on Veterinary Measures Relating to Public Health, 2002). Vegetative organisms have been shown to be inactivated by microwave heating (Jaradat et al., 2022) but only by a maximum of the order of a 1 $\log_{10}$ reduction after 60 seconds exposure. These thermal profiles will not cause any significant reduction in *C. botulinum* spore numbers.

Secondary sources of spore contamination include food handling procedures, and cross contamination from equipment and the air (Formato et al., 2011). To prevent this source of contamination, beekeepers and manufacturers must adhere to Good Farming Practice (GFP) and Good Manufacturing Practice (GMP) in accordance with legislation.

Testing is not considered an appropriate control because of the low prevalence of spores making any testing programme impractical (Scientific Committee on Veterinary Measures Relating to Public Health, 2002). The key control for *C. botulinum* and the potential to cause botulism is public health messaging and labelling (Scientific Committee on Veterinary Measures Relating to Public Health, 2002) advising against feeding honey to infants less than one year of age. In addition “honey should not be added to foods specifically targeted at infants under 12 months of age (unless these foods receive a full botulinum cook or an equivalent process control” (Ad hoc group on infant botulism, 2006). Examples of organisations endorsing the provision of advice in respect to not feeding honey to children under 1 year of age are given in section 4.1.1.

5.1.2. Chemical

5.1.2.1. POPs and Metals

POP and heavy metal contamination in honey is correlated with the level of nearby pollution levels. For example, honey produced in the Apulia region of Italy was found to have higher traces of the POP benzofluoroanthene, when produced in intensive orchards or arable lands compared with that produced in urban areas (Panseri et al., 2020). This is primarily due to differences in agricultural practices (pesticide use, fuel for running equipment etc.). Sampling in Lithuania revealed a negative correlation between levels of heavy metals (lead, cadmium, copper, chromium and nickel) in honey and the distance of hives from different sources of pollution (landfills, railways, and roads) i.e. to closer to the site of pollution the more likely the honey was to be contaminated. This correlation is hypothesised to be due to pollution accumulating in plants and soil (Ševičienė et al., 2022). Therefore, efforts to reduce environmental pollution and not farming honey near contaminated land will reduce the presence of residues in honey.

The FAO/WHO and European Commission recognise that GFP in apiculture can be used in risk management plans to control environmental hazards in honey (metals, pesticide residues) (Formato & Smulders, 2011). For example, it is recommended that surroundings are surveyed before establishing apiaries to avoid intensive agricultural or heavy industrial/ traffic areas. Advice on suitability of habitats and hive location has been set out in the UKs Pollinator Action Plan, 2021 to 2024, which is led by DEFRA and other supporting organisations (Department for Environment, Food and Rural Affairs, 2022).

5.1.2.2. Pesticides

Strategies for mitigation of pesticide residues in honey are primarily based on reducing exposure of honeybees and, in particular, through reduction of exposure to flowering plants that are harvested by honeybees.

In GB the Health and Safety Executive (HSE) is responsible for MRLs in pesticides. A MRL is the maximum concentration of a pesticide residue in or on food or feed of plant and animal origin that is legally tolerated when a plant protection product is applied correctly (following good agricultural practice). An import tolerance is an MRL set on imported food or feed to meet the needs of international trade.

In the UK and EU, pesticides or plant protection products must be authorised before being placed on the market. Authorised uses must be supported with a satisfactory risk assessment which includes a consideration of risk to bees and to consumers (from honey) where applicable. Pesticides are required to be appropriately labelled with instructions for use and must be used in accordance with Good Agricultural Practice (GAP). The pesticide label may include instructions or mitigations that aim to reduce exposure to bees such as not to apply during flowering stages and in certain weather conditions etc. Where pesticides are used according to the conditions of authorisation, residues exceeding the MRL in honey should not occur.

The National Honey Monitoring Scheme (National Honey Monitoring Scheme, 2024) aims to collect data on the landscape in which bees live and the environmental pressures that they experience. Part of the scheme involves identifying the plant species reflected in the pollen contained within honey samples. The other part tests for a panel of around 90 pesticides in a subset of the samples. Summary results provided on the website were that pesticides were not found at levels “that would considered to be any risk to people”. Pesticides were detected in most samples, multiple pesticides could be detected in individual samples, pesticides were detected in samples regardless of the environment, and unauthorised pesticides were detected. This last point was attributed to residues present in the soil after use had been discontinued.

Whilst there is no requirement for pesticide users to communicate with beekeepers, it is recommended. The British Beekeepers Association have developed voluntary initiatives to promote responsible pesticide use (Initiative, 2023). The initiative includes a tool called ‘BeeConnected’ and notifies registered beekeepers when a registered farmer in their location is planning on spraying crops. This is particularly useful for small scale beekeepers as they can move hives accordingly or apply other preventative measures such as physically covering hives to reduce exposure.

5.1.2.3. Veterinary Medicines

A primary means by which to reduce residues of veterinary medicines in honey is to reduce the use of veterinary medicines in apiculture; this may be achieved through Good Beekeeping Practices (GBP) and Biosecurity Measures in Beekeeping (BMB). The FAO have published guidelines on GBP including 'good beekeeping practice for sustainable agriculture' (Food and Agriculture Organisation of the United Nations, 2021a) and 'Good Beekeeping practices' (Food and Agriculture Organisation of the United Nations, 2020). When used together GBPs and BMB increase honeybee health and reduce the need for antibiotics and other veterinary medicines, which in turn reduces the likelihood of residues in honey.

Where veterinary medicines are required to be used, limiting their residues in honey is dependent upon responsible use. The FAO have developed guidelines on responsible use of antimicrobials in beekeeping. They aim to protect both honeybees, human health (e.g. reducing the risks of residues in hive products and preventing development of antimicrobial resistance) and the environment (Food and Agriculture Organisation of the United Nations, 2021b). Antibiotic residues in honey are subjected to monitoring programmes (e.g. UK Residue Surveillance). Whilst antibiotics are not authorised for use in the UK, this scheme identifies unauthorised usage in addition to residues over the MRL of imported honey.

5.1.2.4. Toxins

Toxin contamination is usually mitigated through the use of monitoring programmes which involve the testing of honey, not only from the UK but that which has been imported (see 4.2.5.1).

Tutin is controlled under New Zealand legislation (Appendix VII). "Tutin management can be shown in five ways:

- Laboratory testing
- Placing honey supers into hives after 1st July and harvesting from them by 31st December
- Situating hives where the foraging radius does not have a significant quantity of Tutu
- Situating hives in the bottom two thirds of the South Island (below 42° South as the insect involved does not live in this area)
- Demonstrating low risk in areas by targeted testing of honey over several years"

The Codex Alimentarius has set out a code of practice to reduce pyrrolizine alkaloid contamination (Codex Alimentarius Commission, 2014). This involves weed management (removal/reduction) practices of PA containing plants, mechanical methods such as pulling or ploughing, chemical methods such as the use of herbicides and using biological methods. Whilst there are no specific mitigations for honey, implementation of these methods will reduce a bee's exposure to PA containing plants.

France regulates comb honey from *Agarista salicifolia* and other endemic plants containing GTXs at regional level and only for the flowering season (from 1 November to 31 March) (European Food Safety Authority, 2023b). In 2010, Germany (BfR) issued a recommendation discouraging consumption of Rhododendron honey originating from the Turkish Black Sea coast.

5.1.2.5. Other chemicals

The Codex Standard includes maximum concentrations for HMF, which is used as an indicator of honey quality (Shapla et al., 2018). Its formation is controlled through correct processing of honey, especially avoiding heating at too high a temperature for too long.

No evidence was found for the potential control or mitigation for perchlorate in honey. For BPA and phthalates control can be exerted by ensuring that food contact materials used meet appropriate legislative requirements and specific migration limit where use is permitted. There is insufficient evidence to evaluate the balance between environmental contamination and that which might occur during processing.

5.1.3. Radionuclides

Mitigations in the event of a nuclear accident consist of monitoring and testing according to the legislation described in 5.2.2.4.

5.1.4. Allergens

Consumer packages of honey would need to be labelled appropriately to warn consumers of their presence, see section 5.2.2.5.

5.1.5. Physical

Larger particles can be removed by filtration, depending on the pore size of the filter. However, pollen is a normal constituent of honey and maize pollen has a diameter of around 100 μm, indicating the size of particles that may be present. Unless particulates are removed entirely by ultrafiltration then they constitute a source of the contaminants discussed elsewhere and honey that has been ultrafiltered must be labelled accordingly.

5.2. Hazard Controls

5.2.1. Import conditions

Honey produced by *A. mellifera* bees can only be imported into the UK from countries that have market access approval and have an approved residue monitoring plans in accordance with Decision (EU) 2011/163. Imported products must also be accompanied by appropriate health certificated based on the Regulation (EU) 2019/628 (Animal and Plant Health Agency, 2024a, 2024b). Many EU and non-EU countries including China are listed as trading partners with approved residue monitoring control plans that meet UK compliance for products of animal origin.

5.2.2. Regulations Applicable to the UK

5.2.2.1. Overarching

Europe's legislation (Directive 2001/110/EC, the "Honey Directive") contains compositional criteria that are largely consistent with those cited above (Council of the European Union, 2001). It contains the phrase "Honey must, as far as possible, be free from organic or inorganic matters foreign to its composition".

The Honey Directive was amended by Directive 2014/63/EU and clarifies that pollen is a natural constituent of honey and not an ingredient (European Commission, 2014b).

England has the Honey (England) Regulations 2015 (UK Parliament, 2015) which implements the honey directive. This carries a schedule of compositional criteria which are consistent with those prescribed by Codex. Northern Ireland (The Government of the United Kingdom, 2015), Wales (The National Assembly for Wales, 2003) and Scotland (The Scottish Parliament, 2003) (amended in 2005), again focus on labelling and compositional limits. All apply to honey produced by *Apis mellifera*. In the compositional criteria is contained the phrase "It must, as far as possible, be free from organic or inorganic matters foreign to its composition". These four sets of Regulations implement the EU "Honey Directive".

In addition, there is assimilated legislation regarding fundamental food safety (European Commission, 2002), general hygiene of food production, including direction to use HACCP-based principles (assimilated Regulation (EC) No 852/2004) (European Union, 2004a), and products of animal origin (POAO) in particular under assimilated Regulation (EC) No 853/2004 (European Union, 2004b).

Assimilated Regulation (EC) No 853/2004 includes coverage of the importation of POAO from outside the community (third countries) and, in summary, these provisions include (among others):

- The third country should be on a list of countries from which importation of the product is permitted
- The establishment despatching the food should be on a list of establishments from which importation of the product is permitted
- Health and identification marking requirements
- The requirements of EC 852/2004

Legislation applies to organic honey (European Commission, 1999) and includes origins of bees, siting of hives, bee feed and chemicals that can be used to control diseases of bees. Allopathic chemicals can be used if other means “would be unlikely to eradicate a disease or infestation”, but the alternatives formic acid, lactic acid, acetic acid, oxalic acid, menthol, thymol, eucalyptol and camphor are listed and may be used when authorised.

5.2.2.2. Microbial Contaminants

There are no microbiological criteria in assimilated Regulation 2073/2005 (European Union, 2005) specifically for honey, but as a ready to eat (RTE) food unable to support the growth of *L. monocytogenes* there are criteria of 100 CFU/g for “Products placed on the market during their shelf-life” and nil tolerance “Before the food has left the immediate control of the food business operator, who has produced it” (assuming that advice is followed not to feed to infants as there are stricter (nil tolerance) criteria for foods intended for infants and RTE foods for special medical purposes). However, the Regulations also note that in the case of honey “Regular testing against the criterion is not required in normal circumstances”.

5.2.2.3. Chemicals

Contaminants (POPs / metals)

Assimilated legislation concerning the maximum level of contaminants (including POPs and metals) permitted in foodstuffs is in force (European Commission, 2006a). For POPs and most metals, there is no specific ML set for honey although, a specific criterion for lead in honey applicable to GB has been given and is a maximum of 0.10 mg/kg wet weight.

Pesticides

Honey is included in the list of animal products that are subject to a residue surveillance programme (Government of the United Kingdom, 2020) which is required by legislation to be aligned with the devolved administrations. This is an annual HSE programme of testing agreed by the sample collection agencies, the laboratories and the FSA.

Pesticides may only be used in accordance with the conditions of their authorisation in under assimilated Regulation 1107/2009 in UK and Regulation EC 1107/2009 in EU. Pesticide products are required to be appropriately labelled with instructions for use. Where pesticides are used in accordance with their authorisation, the label instructions and where good agricultural practice is followed, unacceptable levels of residues should not occur. Residues of pesticide active substances in food and feed are regulated through maximum residue levels (and import tolerances) under assimilated regulation 396/2005.

Veterinary medicines

Many veterinary medicines in honey have internationally agreed safety requirements recommended by FAO and WHO Expert Committee on Food Additives which are then adopted by Codex. The Codex Alimentarius standard for honey (Codex Stan 12-1981) sets out international standards on essential composition and quality. It states that residues of veterinary drugs covered in the standard shall comply with maximum residue limits.

The Veterinary Medicines Directorate (VMD) in the UK is responsible for operating an annual surveillance plan that analyses animal food products, including honey, for residues of authorised veterinary medicines, prohibited substances and other contaminants (Veterinary Medicines Directorate, 2020). Honey samples from England and Wales are collected by the National Bee Unit (NBU), whereas honey samples from Scottish farms are collected by the Scottish Government. Samples from Northern Ireland (NI) are collected by the Department of Agriculture, Environment and Rural Affairs (DAERA), ensuring the surveillance plan is performed across the entire UK. The samples are then analysed by Fera Science Ltd in Great Britain and Agri-Food and Biosciences Institute (AFBI) in NI. The laboratories performing analyses must have the appropriate methodology accreditation (e.g., ISO 17025) to ensure competence to carry out standardised methods (Ltd, 2024).

When results indicate that an unacceptable residue is present in a honey sample, an investigation is launched at the farm responsible for production. The investigation is carried out to establish the cause of residue presence and whether legislative breaches have occurred. For minor breaches, the beekeeper will be given advice on how to prevent reoccurrence. However, for more serious cases, the VMD may take further action such as disposal of stock and prosecution. Discovery of non-compliant samples will also result in the farm being targeted for further sampling to ensure the presence of residues have been effectively resolved.

MRLs applicable to GB and honey are listed on the UK Government website (Table 4). Those applicable to NI are the same as for the EU.

Table 4. GB MRLs for pharmacologically active substances in honey

Pharmacologically active substance	Marker residue	MRL
Amitraz	Sum of amitraz and all metabolites containing the 2,4-DMA moiety, expressed as amitraz	200 µg/kg
Coumafos	Coumafos	100 µg/kg

No MRLs have been established for antibiotics in honey and are controlled by testing.

Toxins

There is no ML for mycotoxins in honey.

New Zealand legislation concerning Tutin is described in Appendix 15.4.

No specific legislation covering grayanotoxins was located. However, EFSA have recommended "Integration of the monitoring of grayananes in *Rhododendron* honeys on the EU market in the national control activities is recommended, especially from specific regions of production (e.g. Alps and Pyrenees)" (European Food Safety Authority, 2023b). This is because two species of concern, *R. luteum* and *R. Ferrugineum*, grow in those regions. Placing on the market honey containing grayanotoxin would be covered by assimilated EU law Regulation (EC) 178/2002 (otherwise known as general food law). Article 14 states that food shall not be placed on the market if it is unsafe.

5.2.2.4. Radionuclides

There are limits applied to food under EU legislation in response to emergencies. Assimilated Council Regulation (Euratom) 2016/52 (Council of the European Union, 2016) gives "maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency" in the UK or EU. Commission Implementing Regulation (EU) 2020/1158 covers "conditions governing imports of food and feed originating in third countries following the accident at the Chernobyl nuclear power station".

The former provides a list of foods and maximum permitted levels as in Table 5. Honey is included in "Other food except minor food" since it is not listed as a minor food (Annex II of the Regulation). These limits come into force through legislation placed by the Department of Health and Social Care under FSA recommendations.

Table 5. Maximum permitted levels of radioactive contamination of food (adapted from Council Regulation (Euratom) 2016/52

Isotope Group	Infant food[1] (Bq/kg)[2]	Dairy Products[3] (Bq/kg)	Other food except minor food[4] (Bq/kg)	Liquid food[5] (Bq/kg)
Sum of the isotopes of strontium, notably Sr-90	75	125	750	125
Sum of isotopes of iodine, notably I-131	150	500	2000	500
Sum of alpha-emitting isotopes of plutonium and transplutonium elements, notably Pu-239 and Am-241	1	20	80	20
Sum of all other nuclides of half-life greater than 10 days, notably Cs-134 and Cs-137[6]	400	1000	1250	1000

[1] Infant food is defined as food intended for the feeding of infants during the first 12 months of life which meets, in itself, the nutritional requirements of this category of persons and s put up for retail sale in packages which are clearly identified and labelled as such.
[2] The level applicable to concentrated or dried products is calculated on the basis of the reconstituted product as ready for consumption. Member States may make recommendations concerning the diluting conditions in order to ensure that the maximum permitted levels laid down in this Regulation are observed.
[3] Dairy produce is defined as products falling within the following CN codes including, where appropriate, any adjustments which might subsequently be made to them: 0401 and 0402 (except 0402 29 11).
[4] Minor food and the corresponding levels to be applied to them are set out in Annex II of the Regulation.
[5] Liquid food is defined as products falling within heading 2009 of Chapter 2 of the combined nomenclature. Values are calculated taking into account consumption of tap water and the same values could be applied to drinking water supplies at the discretion of competent authorities in Member States.
[6] C-14, tritium and potassium-40 are not included in this group.

Implementing Regulation (EU) 2020/1158 (assimilated) (The European Commission, 2020) lists countries (including Great Britain but excluding Northern Ireland) associated with deposition from Chernobyl and divides food into “milk and milk products and food for infants and young children” and “all other products”, which would include honey. The limit for all other products is 600 Bq/kg of Cs-137.

Codex have also published guideline levels (GLs) for traded foods following a nuclear emergency (Codex Alimentarius Commission, 1995) and this information is shown in Table 6. Codex state that there is no need to add the contributions for the different groups and that they should be treated independently, but that the activities for the different radionuclides within each group should be added. They apply to foods prepared for consumption, i.e. not to dried or concentrated foods. In addition, for foods that are consumed in small amounts, such as spices, the guidelines can be increased by a factor of 10. It is stated that “as far as generic radiological protection of food consumers is concerned, when radionuclide levels in food do not exceed the corresponding GL, the food should be considered as safe for human consumption”.

Table 6. Codex guidelines for radionuclides in imported foods following a nuclear emergency (adapted from Codex [Codex Alimentarius Commission, 1995])

Product Name	Representative radionuclides	Level in Bq/kg
Infant foods[1]	Pu-238, Pu-239, Pu-240, Am-241	1
Infant foods[1]	Sr-90, Ru-106, I-129, I-131, U-235	100
Infant foods[1]	S-35[2], Co-60, Sr-89, Ru-103, Cs-134, Cs-137, Ce-144, Ir-192	1000
Infant foods[1]	H-3[3], C-14, Tc-99	1000
Foods other than infant foods	Pu-238, Pu-239, Pu-240, Am-241	10
Foods other than infant foods	Sr-90, Ru-106, I-129, I-131, U-235	100
Foods other than infant foods	S-35[2], Co-60, Sr-89, Ru-103, Cs-134, Cs-137, Ce-144, Ir-192	1000
Foods other than infant foods	H-3[3], C-14, Tc-99	10000

[1] When intended for use as such.

[2] This represents the value for organically bound sulphur.

[3] This represents the value for organically bound tritium.

In response to the Fukushima incident, a limit was imposed on foods including honey. The Food Standards Agency has reviewed these emergency measures post EU exit (Food Standards Agency, 2022) and the legislation subsequently revoked.

5.2.2.5. Allergens

The FSA lists the legislation applicable to allergens on its website.

The legislative framework around the provision of food allergen information in the UK is largely contained in assimilated Regulation (EU) No 1169/2011 for England and Wales and Regulation No 1169/2011 for NI. The Food Information Regulations 2014 (FIR) and equivalent regulations in Northern Ireland, Scotland and Wales establish the enforcement measures for Food Information for Consumers in the UK.

Fourteen major allergens must be highlighted on food labels within the ingredients list. They are: cereals containing gluten, crustaceans, eggs, fish, peanuts, soybeans, milk, nuts, celery (and celeriac), mustard, sesame, sulphur dioxide, lupin and molluscs (The Food Labelling (Declaration of Allergens) (England) Regulations 2008, n.d.). Some of these may be included in supplemental bee food, although the evidence for the presence of gluten and milk protein in honey lies in one paper only (Bermingham et al., 2022). The same paper failed to detect egg, peanut, soy, hazelnut, cashew or mould allergens.

The definition of gluten free is given in The Foodstuffs Suitable for People Intolerant to Gluten (England) Regulations 2010 (The Foodstuffs Suitable for People Intolreant to Gluten (England) Regulations 2010, 2010).

5.2.2.6. Physical

Contaminants found in honey should be controlled through the implementation of a HACCP-based food safety programme as described in Regulation (EC) No 852/2004. To the knowledge of the authors there are no specific metrics for assessing the acceptability of food in terms of, for example, numbers of insect parts per unit weight. However, assimilated Regulation (EC) No 178/2002 requires that “Food shall not be placed on the market if it unsafe” and “Food shall be deemed to be unsafe if it is considered to be: (a) injurious to health; (b) unfit for human consumption”.

6. Conclusions

Honey can be contaminated by a broad range of hazards of which most are chemicals, although honey may also contain microbiological, radiological and allergen hazards.

The most concerning microbiological hazard is *C. botulinum* and the most likely acute adverse outcome from honey consumption is the potential for infant botulism to occur if honey is fed to infants less than a year old. Since there is no practical means of removing spores from honey or preventing their entry, control is mediated through public health messaging to parents and carers of infants under one year of age. Given current controls, disease is uncommon, and this suggests that those controls are effective.

A range of heavy metals have been detected in honey. Lead has a specific ML in honey and has been reported in honey at levels exceeding the ML by approximately 40 times. Whilst MLs do not exist for other metals in honey, some have been detected in honey at levels that would exceed relevant MLs (or other guidance values) in commodities where they have been set. For some heavy metals, cumulative dietary exposure is a concern and any significant additional exposure from honey would therefore be undesirable.

For pesticides and veterinary medicines, surveys and other testing programmes show that hazards, when present, are typically at low concentrations. Honey was typically found to be compliant with MRLs. However, some exceedances of MRLs do occur and therefore a consumer risk cannot be definitively ruled out. Some residues of VMPs that are not authorised in bees in GB (notably antibiotics), and VMPs that are specifically prohibited such as chloramphenicol, may occur.

Some toxins found in honey, for example tutin, and grayanotoxins and gelsedine alkaloids have been reported to cause acute toxicity from consumption of contaminated honey and therefore are a potential concern for public health.

Tutin poisoning, which is an issue confined to New Zealand, is controlled by spatial separation between the source of the toxin and the hives, as well as various other steps provided by New Zealand Competent Authority in a Standard. The lack of incidents suggest that this control strategy is effective.

Grayanotoxins, may be introduced into honey via nectar from a few species of *Rhododendron* that are of restricted geographical distribution, originating primarily from the Black Sea area of Turkiye and Nepal. Grayanotoxins cause toxicity sometimes referred as mad honey disease. Cases of mad honey disease continue to be reported, for example there were between three and nine cases per year globally between 2010 and 2017 (Ullah et al., 2018). In contrast to tutin, no specific controls on mad honey could be located other than a ban on imports imposed by South Korea (Ullah et al., 2018) where it is consumed for its perceived medicinal benefits.

Gelsedine alkaloids were implicated in one outbreak involving fatalities, but the outbreak is not described in detail and so further details are unavailable.

Aflatoxins and ochratoxin are not commonly associated with honey and are typically found in food such as grains, cereal, nuts and dried fruit. However, they have been detected in honey and owing to concerns relating to genotoxicity and carcinogenicity, in particular, they may be a concern if present.

Pyrrolizidine alkaloids (PAs) may be detected in honey and are assumed to be genotoxic carcinogens and are a potential public health concern. Nicotine and tropane alkaloids have been detected in honey and owing to potential to cause toxicity at low levels of exposure, these may also be a concern if present. PAHs may also occur in honey and, as for all genotoxic carcinogens, would be of potential concern for public heath if present.

For all chemical contaminants, the risk to consumers is dependent upon the nature of the adverse effects of the substance, the dose-response relationship, and the level of exposure. Therefore, whilst detection of a chemical contaminant in honey does not necessarily confirm a public health concern, a risk assessment would be required to provide more information and to conclude on the risk.

With respect to physical, radiological and allergen hazards, no evidence was found that suggested a concern for public health occurring from the consumption of honey under normal circumstances.

For metals, toxins and other environmental chemical contaminants, the likelihood of their presence in honey is related to the presence of that specific substance (or source of the substance) in the area where the honey is produced, this should be considered when performing any assessment or audits.

For hazards such as pesticides and veterinary medicines, these should be controlled by appropriate use, in accordance with relevant regulation and the application of reliable monitoring schemes.

Overall, there are no practical means by which hazards can be removed from honey once it has been produced in the hive and allow the final product to be called honey. In most cases, therefore, control is based on assurance that the hazard has not been introduced based on codes of practice etc. and through the use of MRLs/MLs/standards with associated sample testing programmes to verify the efficacy of the preventative measures. Mitigation of infant botulism differs since contamination is not manageable and so exposure to the at-risk group minimised through public health messaging.

Other than infant botulism, incidents of disease resulting from honey consumption have been confined to exposure to toxins that originate from particular plants within defined geographical areas. These hazards are amenable to control, as shown by the New Zealand competent authority's control of tutin.

7. Uncertainties and Knowledge gaps

The level of uncertainty was estimated according to the categorisation defined in the ACMSF report on risk representation (Advisory Committee on the Microbiological Safety of Food, 2020). Justifications for the uncertainty assigned to each area of the risk profile are provided in Table 7.

Table 7. Categories of uncertainty defined in the ACMSF report on risk representation[1]

Category	Definition
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions.
Medium	There are some but no complete data available; evidence is provided in a small number of references; authors report conclusions that vary from one another.
High	There are scarce or no data; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them.

[1] (Advisory Committee on the Microbiological Safety of Food, 2020; Bermingham et al., 2022)

Knowledge gaps were identified during the review of information for this risk profile. As well as the uncertainty and justification, Table 8 includes notes on identified knowledge gaps and discussion on their potential impact. Where appropriate, the impact of a knowledge gap is discussed as low, medium or high with justification. This is necessarily subjective but takes into account the scope of this risk profile and the levels of uncertainty.

Table 8. Assessed level of uncertainty and justification, including impacts of knowledge gaps

Risk profile section	Notes on uncertainty (including impacts of knowledge gaps)	Uncertainty
Hazard Identification	Manual literature review is subject to human error leading to relevant hazards being overlooked. This risk was minimised by using an initial "broad brush" search followed by more focused searches for each group of hazards initially identified. However, the existence of unknown emerging hazards cannot be ruled out. Not all papers identified were available in full form, but the title and abstract are sufficient to identify the hazards covered in the full paper. Many controls recommended are applicable to multiple hazards as they consider the nature of honey production by bees and the associated harvesting processes. A review of other data sources did not identify any more hazards beyond those identified in the original searches.	Low
Hazard characterisation	International literature was obtained since requests to export to the UK could come from any part of the world. Some hazards were less well-defined that others. Information on microplastics was the least well defined because of limited knowledge around health effects. Some hazard categories included long lists of chemicals. For instance, within POPs and microplastics, it was not possible to characterise all potential chemical compounds that could be present. These are often considered emerging hazards as they cover groups of chemicals that have not yet been fully defined and characterised. Those which were identified in literature as either most commonly found at higher concentrations in honey or of known health concerns were included. These groups may continue to expand and the information around toxicity and prevalence of the chemicals within them is likely to be dynamic and the information included in this risk profile could become quickly out of date. The impact of the noted knowledge gaps regarding emerging hazards is considered low – medium. This risk profile includes information on mitigation measures, many of which can be effective without full knowledge of emerging hazards. The COT recommended that a risk assessment of nano/ microplastics could not be carried out because of the data gaps identified. Other hazards (e.g. microbiological) are well-defined. The scope of this risk profile is for risks associated with honey and means to mitigate them where possible. It is not a full risk assessment.	Low/ Medium
Risk mitigation and management options	Risk mitigation and management options are aimed at a range of hazards and different areas of the supply chain. Information sources for this section include international guidance, standards and codes of practise which are widely supported and available. Also included are some controls under development that are not in commercial use but might be in the future. Some of the mitigation measures and management options identified are likely effective and applicable in the context of a range of hazards, while some, e.g. messaging to parents/caregivers for control of infant botulism, are specific. Knowledge gaps and	Low

Risk profile section	Notes on uncertainty (including impacts of knowledge gaps)	Uncertainty
	uncertainties regarding legislation and control are discussed below. The impact of the noted knowledge gaps associated with risk mitigation measures is considered unknown but likely to be low. It is unclear what the impact of uncertainty and gaps in knowledge around emerging hazards may be on the effectiveness of risk mitigation and management options.	
Legislation and control	Information on UK import, and domestic legislation was clear and available, as was assimilated EU legislation. It was not possible to summarise the legislation of all countries globally and neither was it possible to cover all of the generic background food safety legislation, instead the focus was on information specific to honey (e.g. New Zealand control of tutin). It is recognised that legislation is difficult to search and some relevant information may be missing. For example, the USA has legislation at the state level. The impact of the noted knowledge gaps is considered to be low given that international trade in foods is reliant on mutually acceptable controls for generally recognised hazards.	Low
UK consumption patterns	Chronic consumption estimates for honey have been obtained using the DNSIYC and the NDNS for all age groups between four months and 95 years. Consumption estimates made with a small number of consumers may not be accurate. This is not a full risk assessment and so does not impact the scope of the risk profile in the same way as for a risk assessment where it would be important to estimate exposure.	Low
International trade and production	UK HMRC data was extracted from the FSA Trade Visualisation Tool, which is considered a reliable and timely data source. This is updated on 16th of each month. There is a two-month time lag, for example January data would be updated on 16th March. Sometimes there may be a delay due to HRMC data availability. This is only relevant for the time period for which the data was extracted. Imports could be subject to significant change in a short space of time. UN Comtrade data are for country of dispatch, not country of origin. In the analysis, it is assumed that all exports of a commodity from a country originated from that country, i.e., no re-exporting. Although data for both imports and exports are given, they are not symmetrical – i.e., the volume of a commodity that country A exports to country B often doesn't match the volume that country B imports from country A. In general, import data are more reliable and so have been used throughout the analysis. UN Comtrade is not fully up to date for all countries (not even up to 2020 for some) but information up until 2022 has been provided. It is also self-reported and may be subject error. The impact of the noted knowledge gaps is considered low because the missing data are not considered to affect the scope of the risk profile significantly.	Low

Acknowledgements

We would like to thank David Alexander, Jessica Cairo, Kathryn Callaghan, Neill Chappell, Taryn Davey, Mike Dickinson, Barbara Doerr, Jo Edge, Ieva Gudynaite-Bouaziz, Marianne James, Dimitrios Maimouliotis, Barry Maycock, Cath Mullholland, Amy Neill, Kay Rylands, Joe Shavila, Chloe Thomas, Paul Tossell, and Mark Willis for providing *ad hoc* expert advice, reviews and information.

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Appendices

Appendix I - UK consumption data

The table shows data for acute and chronic consumption according to recipe type (no recipes, foods with >5% honey and foods with >1% honey)

Age Range	Recipe type	Acute cons.[1] mean (g/ person/ day)	Acute cons. 97.5th %ile (g/ person/ day)	Acute con. max[1] (g/ person/ day)	Acute cons. mean (g/ kg bw /day)	Acute cons. 97.5th %ile (g/kg bw/day)	Acute cons. max (g/ kg bw/ day)	Chron. cons.[1] mean (g/ person/ day)	Chron. cons. 97.5th %ile (g/ person/ day)	Chron. cons. max[1] (g/ person/ day)	Chron. cons. mean (g/ kg bw /day)	Chron. cons. 97.5th %ile (g/kg bw/ day)	Chron. cons. max (g/ kg bw/ day)	Number consuming of respondents in population group
4-11 mo	Without recipes	5.8	13	17	0.66	1.7	2.2	1.9	5.9	7.2	0.22	0.69	0.79	16/1408
12-18 mo	Without recipes	7.9	26	38	0.72	2.5	3.6	2.5	7.5	15	0.23	0.71	1.4	79/1275
1.5-3 yrs	Without recipes	9.8	27	32	0.67	1.7	2.3	4.4	18	26	0.3	0.98	1.9	117/1157
4-10 yrs	Without recipes	14	48	80	0.6	2.1	3.3	5.4	20	48	0.23	0.99	1.4	281/2537
11-18 yrs	Without recipes	15	48	75	0.27	0.84	1.1	5.3	19	35	0.098	0.41	0.56	167/2657
19-64 yrs	Without recipes	15	48	110	0.21	0.69	1.4	6.5	28	61	0.09	0.38	0.8	651/5094
65+ yrs	Without recipes	15	48	85	0.21	0.62	1.4	7.8	24	72	0.11	0.41	1.2	234/1538
4 – 11 mo	Foods ≥ 5% honey	6	13	17	0.69	1.7	2.2	2	5.8	7.2	0.22	0.68	0.79	17/1408
12-18 mo	Foods ≥ 5% honey	7.4	25	38	0.68	2.4	3.6	2.5	7.4	15	0.23	0.71	1.4	88/1275
1.5 -3 yrs	Foods ≥ 5% honey	9.7	29	32	0.66	1.7	2.3	4.3	14	26	0.29	0.98	1.9	122/1157
4 - 10 yrs	Foods ≥ 5% honey	14	48	80	0.57	2.1	3.3	5.2	20	49	0.22	0.9	1.4	301/2537
11 - 18 yrs	Foods ≥ 5% honey	12	48	75	0.21	0.78	1.1	4.3	16	35	0.078	0.34	0.56	223/2657
19 - 64 yrs	Foods ≥ 5% honey	13	48	110	0.2	0.69	1.4	5.4	23	49	0.084	0.34	0.8	760/5094

Age Range	Recipe type	Acute cons.[1] mean (g/ person/ day)	Acute cons. 97.5th %ile (g/ person/ day)	Acute con. max[1] (g/ person/ day)	Acute cons. mean (g/ kg bw /day)	Acute cons. 97.5th %ile (g/kg bw/day)	Acute cons. max (g/ kg bw/ day)	Chron. cons.[1] mean (g/ person/ day)	Chron. cons. 97.5th %ile (g/ person/ day)	Chron. cons. max[1] (g/ person/ day)	Chron. cons. mean (g/ kg bw /day)	Chron. cons. 97.5th %ile (g/kg bw/ day)	Chron. cons. max (g/ kg bw/ day)	Number consuming of respondents in population group
65 + yrs	Foods ≥ 5% honey	14	48	85	0.19	0.62	1.4	7.0	24	72	0.1	0.39	1.2	268/1538
4 – 11 mo	Foods ≥ 1% honey	3.5	10	17	0.41	1.3	2.2	1.2	4.6	7.2	0.14	0.58	0.79	17/1408
12-18 mo	Foods ≥ 1% honey	4.4	20	38	0.41	1.8	3.6	1.5	6.5	15	0.14	0.67	1.4	88/1275
1.5 -3 yrs	Foods ≥ 1% honey	5.5	24	32	0.38	1.6	2.3	2.4	13	26	0.16	0.8	1.9	122/1157
4 - 10 yrs	Foods ≥ 1% honey	7.3	40	80	0.3	1.6	3.3	2.8	15	49	0.12	0.69	1.4	301/2537
11 - 18 yrs	Foods ≥ 1% honey	6	32	75	0.11	0.63	1.1	2.2	13	35	0.04	0.24	0.56	223/2657
19 - 64 yrs	Foods ≥ 1% honey	9.1	40	110	0.13	0.57	1.4	3.9	20	61	0.054	0.29	0.8	760/5094
65 + yrs	Foods ≥ 1% honey	10	41	85	0.14	0.6	1.4	5.2	24	72	0.074	0.38	1.2	268/1538

[1] cons=consumption [2] Maximum

The following are the food codes from the NDNS and DNSIYC used to estimate UK consumption

Recipe Group	Food code	Food name
Without recipes	2214	HONEY (IN JARS)
Without recipes	2213	HONEYCOMB
Foods containing ≥ 5% honey	4109	APPLE PIE MADE WITH SHORT CRUST PASTRY, APPLE, AND HONEY
Foods containing ≥ 5% honey	3053	BACON CHOPS IN HONEY WITH PEPPERS AND OLIVE OIL
Foods containing ≥ 5% honey	8044	CEREAL BARS MADE WITH OATS ONLY (UF)
Foods containing ≥ 5% honey	7665	CEREAL CRUNCHY BARS
Foods containing ≥ 5% honey	9894	GAMMON STEAKS IN HONEY MUSTARD & GINGER (M&S)
Foods containing ≥ 5% honey	3317	GUINEA FOWL WITH FLORA, OLIVE OIL, PEPPERS & WINE
Foods containing ≥ 5% honey	2214	HONEY (IN JARS)
Foods containing ≥ 5% honey	8200	HONEY BISCUITS
Foods containing ≥ 5% honey	10265	HONEY MUSTARD DRESSINGS AND MARINADES PURCHASED
Foods containing ≥ 5% honey	2213	HONEYCOMB
Foods containing ≥ 5% honey	7760	KULFI INDIAN ICE-CREAM
Foods containing ≥ 5% honey	10238	NESTLE NESTUM HONEY CORNFLAKE CEREAL FORTIFIED
Foods containing ≥ 5% honey	7976	NOUGAT
Foods containing ≥ 5% honey	10132	OPTIVITA BERRY BREAKFAST CEREAL
Foods containing ≥ 5% honey	6997	YOGURT, GREEK STYLE, COWS, WITH HONEY, WHOLE MILK
Foods containing ≥ 1% honey	4109	APPLE PIE MADE WITH SHORT CRUST PASTRY, APPLE, AND HONEY
Foods containing ≥ 1% honey	8151	ASDA GOLDEN BALLS CEREAL FORTIFIED
Foods containing ≥ 1% honey	11198	ASDA HONEY NUMBER– FORTIFIED - FS
Foods containing ≥ 1% honey	3053	BACON CHOPS IN HONEY WITH PEPPERS AND OLIVE OIL
Foods containing ≥ 1% honey	4242	BANANA SMOOTHIE, SEMI-SKIMMED MILK AND SOFT SCOOP ICE-CREAM
Foods containing ≥ 1% honey	8910	BOULDERS BREAKFAST CE'EAL, TESCO\'S
Foods containing ≥ 1% honey	8044	CEREAL BARS MADE WITH OATS ONLY (UF)
Foods containing ≥ 1% honey	10060	CEREAL BARS WITH FRUIT AND NUTS, COATED, UNFORTIFIED
Foods containing ≥ 1% honey	10058	CEREAL BARS WITH NUTS, NO FRUIT, NOT COATED, UNFORTIFIED

Recipe Group	Food code	Food name
Foods containing ≥ 1% honey	7665	CEREAL CRUNCHY BARS
Foods containing ≥ 1% honey	11056	CHEWY TOFFEE POPCORN BAR, E.G. WEIGHTWATCHERS-FS
Foods containing ≥ 1% honey	2962	CHICKEN BREASTS, WITH SKIN, TOMATO AND VEGETABLE SAUCE
Foods containing ≥ 1% honey	2819	CHICKEN IN COOK IN SAUCE WITH HONEY AND MUSTARD
Foods containing ≥ 1% honey	8138	CHOCOLATE BREAKFAST CEREAL UNFORTIFIED
Foods containing ≥ 1% honey	6310	CHOCOLATE CRISP BISCUIT BAR
Foods containing ≥ 1% honey	8466	COUS COUS WITH ADDITIONS COOKED
Foods containing ≥ 1% honey	8086	CRUNCHY NUT CLUSTERS KELLOGGS
Foods containing ≥ 1% honey	10512	CRUNCHY NUT CORNFLAKES KELLOGGS ONLY
Foods containing ≥ 1% honey	5328	CRUNCHY/CRISPY MUESLI TYPE CEREAL WITH NUTS
Foods containing ≥ 1% honey	9894	GAMMON STEAKS IN HONEY MUSTARD & GINGER (M&S)
Foods containing ≥ 1% honey	6924	GLAZED BAKED GAMMON
Foods containing ≥ 1% honey	3317	GUINEA FOWL WITH FLORA, OLIVE OIL,PEPPERS & WINE
Foods containing ≥ 1% honey	10320	HARVEST MORN HONEY NUT CORNFLAKES
Foods containing ≥ 1% honey	3008	HONEY & NUT BRAN FLAKES OWN BRAND
Foods containing ≥ 1% honey	2214	HONEY (IN JARS)
Foods containing ≥ 1% honey	8200	HONEY BISCUITS
Foods containing ≥ 1% honey	224	HONEY COATED PUFFED WHEAT INCLUDING QUAKER SUGAR PUFFS AND OWN BRAND
Foods containing ≥ 1% honey	8486	HONEY LOOPS, KELLOGGS ONLY
Foods containing ≥ 1% honey	10468	HONEY MONSTER HONEY WAFFLE BREAKFAST CEREAL FORTIFIED
Foods containing ≥ 1% honey	10265	HONEY MUSTARD DRESSINGS AND MARINADES PURCHASED
Foods containing ≥ 1% honey	6824	HONEY NUT SHREDDED WHEAT, NESTLE
Foods containing ≥ 1% honey	6011	HONEY ROASTED PEANUTS
Foods containing ≥ 1% honey	2213	HONEYCOMB
Foods containing ≥ 1% honey	10578	KELLOGGS FIBRE PLUS CEREAL BARS
Foods containing ≥ 1% honey	10870	KELLOGGS ORIGINAL HOT OAT KRUMBLY

Recipe Group	Food code	Food name
Foods containing ≥ 1% honey	10885	KELLOGGS SPECIAL K HONEY CLUSTER
Foods containing ≥ 1% honey	10330	KELLOGGS SPECIAL K OATS AND HONEY
Foods containing ≥ 1% honey	10355	KELLOGGS SPECIAL K SUSTAIN CEREAL
Foods containing ≥ 1% honey	11066	KELLOGS–HONEY POPS - FS
Foods containing ≥ 1% honey	7760	KULFI INDIAN ICE-CREAM
Foods containing ≥ 1% honey	228	MULTIGRAIN START KELLOGGS
Foods containing ≥ 1% honey	8712	NESTLE CLUSTERS BREAKFAST CEREAL
Foods containing ≥ 1% honey	5334	NESTLE FIBRE 1 ONLY
Foods containing ≥ 1% honey	8169	NESTLE GOLDEN NUGGETS FORTIFIED
Foods containing ≥ 1% honey	9275	NESTLE HONEY NUT CHEERIOS
Foods containing ≥ 1% honey	8163	NESTLE HONEY OATS AND MORE FORTIFIED
Foods containing ≥ 1% honey	10238	NESTLE NESTUM HONEY CORNFLAKE CEREAL FORTIFIED
Foods containing ≥ 1% honey	7976	NOUGAT
Foods containing ≥ 1% honey	8156	OAT GRANOLA
Foods containing ≥ 1% honey	10132	OPTIVITA BERRY BREAKFAST CEREAL
Foods containing ≥ 1% honey	3181	PORK STEAKS OR SHANK WITH HONEY & MUSTARD SAUCE PURCHASED
Foods containing ≥ 1% honey	3656	PORK, LEAN, WITH SHERRY, HONEY, LEMON AND SOY SAUCE
Foods containing ≥ 1% honey	2861	STIR FRY BEEF WITH CUCUMBER, HOISIN/SOY SAUCE, AND HONEY
Foods containing ≥ 1% honey	11422	TOBLERONE ORIGINAL
Foods containing ≥ 1% honey	5243	TRIPLE CHOCOLATE SUNDAE EG. M&S
Foods containing ≥ 1% honey	8760	WHEAT FLAKE CEREAL WITH DRIED FRUIT
Foods containing ≥ 1% honey	6997	YOGURT, GREEK STYLE, COWS, WITH HONEY, WHOLE MILK
Foods containing ≥ 1% honey	5361	YOGURT, WHOLE MILK, WITH ADDED SUGAR, NO FRUIT

Appendix II – Trade data

UK Exports

Table 9. The 15 countries importing the largest volumes (tonnes) of honey from the UK, and percentage of the total per country, between 2016 and 2022

Country	2016 (t)[1]	2017 (t)	2018 (t)	2019 (t)	2020 (t)	2021 (t)	2022 (t)	Total (t)	Percentage[2]
Ireland	669	1,200	1,982	2,491	3,326	1,327	939	11,933	58.69
Spain	301	154	41	111	52	169	110	938	4.61
France	135	142	130	117	61	57	263	905	4.45
Germany	282	178	116	56	164	65	13	874	4.30
Netherlands	344	87	140	54	51	52	80	807	3.97
Poland	56	38	43	59	63	224	312	794	3.91
China	121	48	106	205	177	63	27	747	3.67
USA	78	129	102	94	43	84	123	653	3.21
UAE	105	82	71	43	56	93	85	534	2.63
Italy	81	71	135	8	31	29	67	503	2.47
Saudi Arabia	53	49	50	59	56	83	66	416	2.05
Belgium	107	3	4	2	1	287	5	408	2.01
China, Hong Kong	61	64	53	42	48	33	43	343	1.69
Singapore	8	16	13	22	43	43	118	264	1.30
Japan	21	21	20	20	31	38	59	211	1.04

[1]Rounded to the nearest whole number, [2]rounded to two decimal places

UK Imports

Table 10. Imports of honey to the UK in tonnes (t) and as a percentage (%) of the total, from 2016 to 2022 by exporting country

Country	2016 (t)	2016 (%)	2017 (t)	2017 (%)	2018 (t)	2018 (%)	2019 (t)	2019 (%)	2020 (t)	2020 (%)	2021 (t)	2021 (%)	2022 (t)	2022 (%)	Total (t)	Total (%)
Argentina	527	1.28	673	1.47	997	1.98	689	1.41	427	0.80	341	0.76	490	0.95	4,144	1.2
Australia	268	0.65	292	0.64	341	0.68	187	0.38	78	0.15	187	0.42	227	0.44	1,582	0.47
Austria	0	0	0	0	3	<0.1[1]	0	0	2	<0.1	0.1	<0.1	75	<0.1	5	<0.1
Belgium	502	1.22	522	1.14	470	0.93	342	0.70	130	0.24	375	0.83	617	1.20	2,956	0.88
Bosnia and Herzegovina	0	0	0	0	0	0	0	0	40	<0.1	20	<0.1	0	0	60	<0.1
Brazil	650	1.58	380	0.83	387	0.77	555	1.14	562	1.05	791	1.76	742	1.44	4,067	1.2
Bulgaria	40	<0.1	81	0.18	64	0.13	17	<0.1	11	<0.1	33	<0.1	115	0.22	360	0.11
Canada	0.9	<0.1	0	0	0	0	0	0	573	1.08	6	<0.1	25	<0.1	605	0.18
Chile	42	0.1	0	0	20	<0.1	0	0	22	<0.1	0	0	0.5	<0.1	84	<0.1
China	26,771	65	31,162	68	35,354	70	34,125	70	35,548	67	28,388	63	36,767	72	228,115	68
Croatia	0	0	0	0	0	0	0	0	0	0	0	0	0.2	<0.1	0.2	<0.1
Colombia	0	0	0	0	58	0.12	0	0	0	0	0	0	0	0	58	<0.1
Cyprus	0.3	<0.1	0	0	0	0	0	0	0	0	0	0	4.6	<0.1	4.9	<0.1
Czechia	92	0.22	41	<0.1	90	0.18	7	<0.1	0	0	0.01	<0.1	2	<0.1	233	<0.1
Denmark	47	0.11	8	<0.1	0	0	0.9	<0.1	2	<0.1	0.3	<0.1	23	<0.1	81	<0.1
Dominican Republic	0	0	68	0.15	0	0	0	0	0	0	0	0	0	0	68	<0.1
Djibouti	0	0	0	0	0	0	21	<0.1	0	0	0	0	0	0	21	<0.1
Estonia	0	0	0.2	<0.1	0.3	<0.1	0.03	<0.1	0.3	<0.1	1.8	<0.1	8.6	<0.1	11.1	<0.1
Ethiopia	54	0.13	44	0.10	21	<0.1	0.2	<0.1	0	0	0	0	0	0	118	<0.1
France	322	0.13	335	0.73	318	0.63	136	0.28	81	0.15	306	0.68	353	0.69	1,850	0.55
Germany	1,325	3.22	1,615	3.53	1,252	2.50	1,039	2.13	1,209	2.30	720	1.60	896	1.74	8,057	2.40
Greece	66	0.16	97	0.21	129	0.26	180	0.37	179	0.37	70	0.34	164	0.32	886	0.26
Guatemala	42	0.10	237	0.52	0	0	0	0	0	0	0	0	0	0	279	<0.1
Hong Kong	0	0	0	0	0	0	0	0	0	0	0	0	16	<0.1	16	<0.1
Hungary	887	2.2	848	1.9	269	0.53	284	0.58	213	0.40	104	0.23	122	0.24	2,726	0.81

Country	2016 (t)	2016 (%)	2017 (t)	2017 (%)	2018 (t)	2018 (%)	2019 (t)	2019 (%)	2020 (t)	2020 (%)	2021 (t)	2021 (%)	2022 (t)	2022 (%)	Total (t)	Total (%)
India	3	<0.1	7	<0.1	219	0.43	0	0	17	<0.1	6	<0.1	5	<0.1	257	<0.1
Indonesia	0	0	0	0	0	0	0	0	0.3	<0.1	0	0	0	0	0.3	<0.1
Ireland	419	1.02	289	0.63	622	1.23	1,042	2.14	331	0.62	348	0.77	405	0.79	3,456	1.03
Israel	0	0	0	0	3	<0.1	0	0	0	0	0	0	0	0	3	<0.1
Italy	353	0.86	822	1.8	110	0.22	108	0.22	276	0.52	956	2.1	325	0.63	2,951	0.88
Kyrgyzstan	0	0	0	0	0.8	<0.1	0.8	<0.1	0.3	<0.1	0	0	0	0	1.9	<0.1
Kuwait	0	0	0.001	<0.1	0	0	0	0	0.001	<0.1	0	0	0	0	0.002	<1
Latvia	7	<0.1	7	<0.1	8	<0.1	6	<0.1	16	<0.1	13	<0.1	29	<0.1	85	<0.1
Lithuania	15	<0.1	16	<0.1	12	<0.1	10	<0.1	12	<0.1	9	<0.1	45	<0.1	119	<0.1
Madagascar	0	0	0	0	0	0	0.2	<0.1	0	0	0	0	0	0	0.2	<0.1
Mexico	3,697	9.00	3,223	7.03	4,415	8.80	3,228	6.60	2,479	4.70	2,078	4.60	2,095	4.10	21,214	6.30
Moldova	0	0	0	0	0	0	10	<0.1	1	<0.1	0.9	<0.1	23	<0.1	35	<0.1
Mongolia	0	0	0	0	0	0	0	0	81	0.15	406	0.9	650	1.30	1,137	0.34
Netherlands	433	1.05	73	0.16	450	0.89	85	0.17	119	0.22	97	0.22	72	0.14	1,329	0.40
New Zealand	1,350	3.3	1,513	3.3	1,336	2.6	1,758	3.6	2,206	4.1	1,909	4.2	1,301	2.5	11,373	3.4
Panama	0	0	0	0	0	0	0	0	0	0	0	0	45	0.10	45	<0.1
Poland	225	0.55	288	0.63	628	1.2	1,711	3.5	4,866	9.1	5,349	12.0	1,606	3.1	14,674	4.4
Portugal	15	<0.1	40	<0.1	21	<0.1	16	<0.1	16	<0.1	20	<0.1	22	<0.1	150	0.05
Romania	448	1.1	506	1.1	283	0.56	334	0.68	671	1.3	281	0.62	497	0.97	3,018	0.90
Russia Federation	0	0	0	0	0	0	0	0	0	0	0	0	3	<0.1	3	<0.1
Slovakia	295	0.72	0	0	0	0	0	0	0.01	<0.1	0.3	>0.1	0.5	<0.1	296	0.10
Slovenia	0	0	0	0	0	0	0	0	0	0	0.4	<0.1	0.7	<0.1	1.1	0.10
Spain	688	1.7	814	1.8	758	1.5	688	1.4	731	1.4	421	0.94	902	1.8	5,003	1.5
Sweden	0	0	0.001	<0.1	0.3	<0.1	0	0	0	0	0	0	0.1	<0.1	0.4	<0.1
Switzerland	0.2	<0.1	0	0	0.1	<0.1	0	0	0.05	<0.01	0.2	<0.1	0	0	0.6	<0.1
Thailand	0	0	1	<0.1	0	0	0	0	0	0	0	0	0	0	1	<0.1
Turkey	0	0	1	<0.1	0.9	<0.1	2.7	<0.1	22	<0.1	174	0.39	199	0.39	400	0.12

Country	2016 (t)	2016 (%)	2017 (t)	2017 (%)	2018 (t)	2018 (%)	2019 (t)	2019 (%)	2020 (t)	2020 (%)	2021 (t)	2021 (%)	2022 (t)	2022 (%)	Total (t)	Total (%)
Ukraine	237	0.58	489	1.1	328	0.73	466	0.65	392	0.95	329	0.73	437	0.85	2,677	0.80
Unassigned	2	<0.1	0.5	<0.1	0.5	<0.1	0	0	0	0	0	0	0	0	2.6	<0.1
United Arab Emirates	0	0	0	0	0	0	0	0	0	0	0.02	<0.1	0.03	<0.1	0.05	<0.1
United States of America	0.04	<0.1	0	0	0	0	0	0	0	0	3	<0.1	4	<0.1	7	<0.1
Uruguay	22	<0.1	85	0.19	127	0.25	42	0.10	32	0.06	110	0.24	105	0.2	523,955	0.16
Vietnam	1,197	2.9	1,222	2.7	1,339	2.7	1,666	3.4	1,917	3.6	1,054	2.3	2,006	3.9	10,401	3.1
Zambia	126	0.31	0	0	0	0	21	<0.1	43	<0.1	114	0.25	46	<0.1	351	0.10
Total (kg)	41,171		45,800		50,434		48,778		53,306		45,021		51,391			

[1] <0.1 and >0

Global Trade Snapshot

Table 11. Honey exports from the 15 highest volume (tonnes) exporting countries, from 2016 to 2022 (UN Comtrade)

Country	2016 (t)	2017 (t)	2018 (t)	2019 (t)	2020 (t)	2021 (t)	2022 (t)	Total 2016-2022 (t)	Percentage of total
Argentina	81,183	70,321	686,920	63,522	68,985	60,406	71,738	1,103,075	21.26
China	65,302	129,274	123,478	120,845	132,469	145,886	156	873,257	16.83
India	35,793	52,980	58,231	65,351	54,834	70,514	86,183	423,885	8.17
Ukraine	56,968	67,907	49,366	55,683	80,872	61,167	48,372	420,336	8.10
Brazil	24,202	27,053	28,524	30,039	45,728	47,190	36,886	239,622	4.62
Germany	25,862	25,584	23,935	26,317	30,773	30,920	21,984	185,376	3.58
Spain	26,667	24,833	23,090	22,471	28,263	28,442	27,869	181,635	3.50
Hungary	18,553	23,633	22,018	21,003	23,063	18,329	16,341	142,940	2.75
Mexico	10,337	23,213	22,753	15,105	15,838	25,076	27,443	139,766	2.69
Poland	13,731	15,240	14,646	17,074	24,691	19,277	15,036	119,696	2.31
Viet Nam	17,250	14,210	13,631	12,597	13,428	21,125	15,313	107,554	2.07
Canada	17,955	19,462	18,836	12,082	9,426	7,531	11,155	96,446	1.86
Romania	10,371	12,249	11,326	11,495	13,743	12,679	12,183	84,045	1.62
Bulgaria	9,001	13,302	10,719	12,950	12,834	12,137	12,738	83,681	1.61
New Zealand	9,626	9,636	8,033	8,439	12,645	12,118	10,498	70,995	1.37

Appendix III - Literature search terms used

Search terms and databases used with a summary of the hits used in hazard identification

Hazard	Search terms	Database	Hits	Notes
General (also used for other chemical)	TITLE-ABS-KEY (honey AND (contam* OR hazard) AND NOT (fraud OR adulter* OR method))[1]	Scopus	1374	423 were useful
Microbiological	TITLE-ABS-KEY (hazard* AND (honey OR apicult*) AND microbiol*)	Scopus	23	Seven were new and available
Microbiological	((honey) AND (pathogen)) AND (foodborne)	PubMed	219	The vast majority were irrelevant, 19 were novel and available
Elements	TITLE-ABS-KEY ((honey) AND (heavy AND metal))	Scopus	394	Many were irrelevant, for example, describing novel detection methods which used spiked honey samples, or were investigating the effect of heavy metals on honeybee health, or investigating honeybees as bio-monitors.
Elements	((honey) AND (heavy AND metal))	PubMed	444	Most duplicates of Scopus or irrelevant
Persistent Organic Pollutants	“TITLE-ABS-KEY (honey AND persistent AND organic AND pollutant)”	Scopus	29	Duplicate hazards were detailed in a majority of references
Persistent Organic Pollutants	“honey AND persistent organic pollutant”	PubMed	16	All were duplicate references or hazards to those found in the Scopus search or were not relevant
Pesticides	“TITLE-ABS-KEY (hazard AND (honey OR apicult* OR wax) AND pesticide*)”	Scopus	128	Most concerned hazards that had already been identified, were duplicated or were not related to human health. In addition, references from the general search were extensively used and references within these papers were also followed up.
Pesticides	“hazard AND (honey OR apicult* OR wax) AND pesticide*” (“AND NOT antibiotic” was required as initial searches focused on antibiotic residues)	PubMed	123	As above
Antibiotics and Veterinary Medicines	“TITLE-ABS-KEY (hazard AND (honey OR apicult*) AND antibiotic*)”	Scopus	32	Most were considered to be irrelevant, referring to studies using spiked honey for method development or where hazards were identified in duplicate

Hazard	Search terms	Database	Hits	Notes
Antibiotics and Veterinary Medicines	“TITLE-ABS-KEY (hazard AND (honey OR apicult* AND veterin* AND NOT antibiotic*)”	Scopus	18	Most were considered to be irrelevant, referring to studies using spiked honey for method development or where hazards were identified in duplicate
Antibiotics and Veterinary Medicines	“(Hazard) AND (honey) AND (antibiotic)”	PubMed	27	Most were duplicates of Scopus and the remaining results identified antibiotics or veterinary residues already addressed or otherwise not relevant.
Antibiotics and Veterinary Medicines	“(hazard) AND (honey) AND (veterinary) NOT (antibiotic*)”	PubMed	28	Most were duplicates of Scopus and the remaining results identified antibiotics or veterinary residues already addressed or otherwise not relevant.
Toxins	“TITLE-ABS-KEY (hazard AND (honey OR apicult*) AND toxin*)”	Scopus	17	The majority regarded bee health, were not relevant or detailed duplicate hazards
Toxins	“(hazard) AND ((honey) OR (apicult*)) AND (toxin)”	PubMed	12	Introduced three new hazards
Radiological	TITLE-ABS-KEY (honey AND (radiological OR radioactivity OR radionuclide OR radiation) AND (contam* OR detect* OR presence))	Scopus	250	21 had relevant titles and content
Radiological	"honey"[Title/ Abstract] AND "radioactivity"[Title/ Abstract]	PubMed	12	5 were relevant and new
Allergens	TITLE-ABS-KEY (honey AND anaphyl* AND NOT (bee OR sting))	Scopus	43	Most were not relevant (not referring to honey)
Allergens	TITLE-ABS-KEY (honey AND (allerg* OR hypersens*) AND react* AND NOT (bee* OR dressing*))	Scopus	54	Eleven were relevant and new
Allergens	(honey[Title/ Abstract]) AND (allergen[Title/ Abstract]) and (honey[Title/ Abstract]) AND (anaphylactic[Title/ Abstract])	PubMed	71 39	Ten were relevant and new Two were relevant and new
Microplastics/	TITLE-ABS-KEY	Scopus	66	Only two concerned honey

Hazard	Search terms	Database	Hits	Notes
particulates	(particulat* AND honey)			
Microplastics/ particulates	TITLE-ABS-KEY (microplastic* AND honey)	Scopus	45	14 were relevant
Microplastics/ particulates	((honey[Title/ Abstract])) AND (particulate[Title/ Abstract])	PubMed	26	0 additional
Microplastics/ particulates	(honey[Title/ Abstract]) AND (microplastics[Title/ Abstract])	PubMed	25	One new hit

[1] The exclusions were used to avoid hits relating to fraud (which is only considered in a food safety context, where fraud or adulteration results in contamination with a hazard) and to papers developing methods for detecting hazards in honey

Appendix IV – Pesticide MRL exceedances in honey[1]

Data to illustrate exceedances of MRLs for pesticides in honey (including wax)

Pesticide	MRL (mg/kg)	Prevalence of samples > MRL	Maximum concentration (mg/kg)	Mean concentration (mg/kg)	Range (mg/kg)	Reference
Acetamiprid	0.05	1/710	ND	ND	ND	(European Food Safety Authority, 2022)
Acetamiprid	0.05	ND	0.13	0.02	ND	(Gaweł et al., 2019)
Acetamiprid	0.05	ND	0.29	0.0013	ND	(Mitchell et al., 2017)
Acetamiprid	0.05	ND	ND	0.015	ND	(Tanner & Czerwenka, 2011)
Bromide ion	0.05	14/710	ND	ND	ND	(European Food Safety Authority, 2022)
Chlorfenvinphos	0.01	7/710	ND	ND	ND	(European Food Safety Authority, 2022)
Chlorfenvinphos	0.01	ND	0.19[2]	0.019[2]	ND	(Marti et al., 2022)
Chlorfenvinphos	0.01	ND	0.084	0.036	0.012-0.084	(El Agrebi et al., 2020b)
Chlorfenvinphos	0.01	ND	6.40[2]	0.2[2]	0.001-6.4[2]	(Shimshoni et al., 2019)
Chlorfenvinphos	0.01	ND	ND	1.79[2]	ND	(Navarro-Hortal et al., 2019)
Chlorfenvinphos	0.01	ND	16.9[2]	1.32[2]	0.03-16.9[2]	(Calatayud-Vernich et al., 2018)
Copper compounds	Not set	16/710	ND	ND	ND	(European Food Safety Authority, 2022)
Glyphosate	0.05	1/25	ND	ND	ND	(European Food Safety Authority, 2024)
Glyphosate	0.05	ND	0.054[2]	0.28[2]	ND	(El Agrebi et al., 2020a)
Glyphosate	0.05	ND	0.32[2]	0.064[2]	ND	(El Agrebi et al., 2020a)
Glyphosate	0.05	ND	0.32[2]	0.062[2]	ND	(El Agrebi et al., 2020a)
Glyphosate	0.05	ND	0.34	ND	0.01-0.34	(Bergero et al., 2021)
Tau-fluvalinate	0.05	ND	0.57[2]	0.24[2]	0.016-0.57[2]	(Marti et al., 2022)
Tau-fluvalinate	0.05	ND	1.73[2]	ND	ND	(Issa et al., 2020)
Tau-fluvalinate	0.05	ND	6.46[2]	0.503[2]	0.01-6.46[2]	(El Agrebi et al., 2020b)
Tau-fluvalinate[2]	0.05	ND	8.68[2]	0.476[2]	ND	(El Agrebi et al., 2020b)
Tau-fluvalinate	0.05	ND	0.914	0.417	ND	(El Agrebi et al., 2020b)

Pesticide	MRL (mg/kg)	Prevalence of samples > MRL	Maximum concentration (mg/kg)	Mean concentration (mg/kg)	Range (mg/kg)	Reference
Tau-fluvalinate	0.05	ND	0.054	0.024	0.012-0.054	(Bommuraj et al., 2019)
Thiacloprid	0.2	2/710	ND	ND	ND	(European Food Safety Authority, 2022)
Thiacloprid	0.2	ND	0.2	0.032	ND	(Gaweł et al., 2019)
Thiacloprid	0.2	ND	0.47	0.0024	ND	(Mitchell et al., 2017)
Thiacloprid	0.2	ND	0.13	ND	ND	(Laaniste et al., 2016)
Thiacloprid	0.2	ND	0.27	ND	0.005-0.27	(Tanner & Czerwenka, 2011)

ND=No data
[1]Data selected to illustrate a range of values above the MRL
[2]Values from beeswax

Appendix IV – Antibiotics and veterinary medicine MRL exceedances in honey

Data to illustrate exceedances of MRLs for pesticides in honey

Antibiotic/VMP	Class	Prevalence samples > MRL	Maximum concentration (mg/kg)	Mean concentration (mg/kg)	Range (mg/kg)	Reference
Ciprofloxacin	Quinolone	1/28	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Ciprofloxacin	Quinolone	ND	ND	0.004-0.0743	ND	(He et al., 2023)
Ciprofloxacin	Quinolone	ND	ND	0.00021-0.00665	ND	(He et al., 2023)
Ciprofloxacin	Quinolone	ND	0.0742	ND	ND	(Y. Jin et al., 2017)
Enrofloxacin	Quinolone	1/28	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Enrofloxacin	Quinolone	ND	ND	0.0025	ND	(He et al., 2023)
Enrofloxacin	Quinolone	ND	0.0281	ND	ND	(Y. Jin et al., 2017)
Erythromycin	Macrolide	2/56	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Erythromycin	Macrolide	ND	ND	ND	0.050-1.78	(Al-Waili et al., 2012)
Erythromycin	Macrolide	ND	0.0788	ND	0.0067-0.0788	(Shoaei et al., 2024)
Oxytetracycline	Tetracycline	1/81	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Oxytetracycline	Tetracycline	ND	0.335	ND	0.023-0.335	(Saridaki-Papakonstadinou et al., 2006)
Oxytetracycline	Tetracycline	ND	0.25	ND	0.027-0.25	(Johnson et al., 2010)
Sulfonamides[1]	Sulfonamide	52/1741	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Sulfonamides[1]	Sulfonamide	ND	0.0086-0.022	ND	ND	(Kim et al., 2021)
Sulfonamides[1]	Sulfonamide	ND	0.0051	ND	0.00096-0.0051	(Kirkan et al., 2020)
Sulfonamides[1]	Sulfonamide	ND	0.0059	ND	0.0018-0.0059	(Economou et al., 2012)
Sulfonamides[1]	Sulfonamide	ND	ND	ND	0.00195-0.0132	(Shoaei et al., 2024)
Trimethoprim	Diaminopyridine	1/28	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Trimethoprim	Diaminopyridine	ND	0.00284	ND	0.00002-0.00284	(Y. Wang et al., 2022)

Antibiotic/VMP	Class	Prevalence samples > MRL	Maximum concentration (mg/kg)	Mean concentration (mg/kg)	Range (mg/kg)	Reference
Tylosin	Macrolide	1/81	ND	ND	ND	(Veterinary Medicines Directorate, 2022b)
Tylosin	Macrolide	ND	ND	ND	7.6-70.3 (ng/kg)	(von Eyken et al., 2018)

ND=No data

[1] Includes: Sulfacetamide, Sulfachloropyridazine, Sulfadiazine, Sulfadimethoxine, Sulfamerazine, Sulfamonomethoxine and Sulfathiazole

Appendix V – Radionuclides in honey

Illustrative data for activity of radionuclides that have been detected in honey

Radionuclide	Detected	Quantitative data available	Minimum (Bq/kg)	Maximum (Bq/kg)	Mean (Bq/kg)	Reference
Bi-214	Yes	No	ND[1]	ND	ND	(Handa et al., 1997)
Cs-134	Yes	No	ND	ND	ND	(Franić & Branica, 2019)
Cs-134	Yes	No	ND	ND	ND	(Molzahn & Assmann-Werthmüller, 1993)
Cs-134	Yes	No	ND	ND	ND	(Handa et al., 1997)
Cs-134	Yes	No	ND	ND	ND	(Bunzl et al., 1988)
Cs-137	< LOQ[2]	ND	ND	ND	ND	(Caridi et al., 2022)
Cs-137	< LOQ	ND	ND	ND	ND	(Şirin et al., 2022)
Cs-137	< LOQ	ND	ND	ND	ND	(Bulubasa et al., 2021)
Cs-137	< LOQ	ND	ND	ND	ND	(Esposito et al., 2002)
Cs-137	Yes	No	ND	ND	ND	(Franić & Branica, 2019)
Cs-137	Yes	Yes	>0.03 in 68 of 122 samples	ND	ND	(Kaste et al., 2021)
Cs-137	Yes	Yes	ND	2.80	1.03	(Dizman et al., 2020)
Cs-137	Yes	Yes	ND	~12	4.33	(Panatto et al., 2007)
18.2Cs-137	Yes	Yes	ND	105.9	18.2	(Altekin et al., 2015)
Cs-137	Yes	Yes	ND	651	ND	(Molzahn & Assmann-Werthmüller, 1993)
Cs-137	Yes	Yes	43	680	ND	(Fisk & Sanderson, 1999)
Cs-137	Yes	No	ND	ND	ND	(Handa et al., 1997)
Cs-137	Yes	Yes	Two from 17 >0.5	ND	ND	(Čokeša et al., 1995)
Cs-137	Yes	Yes	ND	>600	ND	(Bunzl et al., 1988)
Cs-137	Yes	Yes	<MDA[3]	0.8	ND	(Xarchoulakos & Lasithiotakis,

Radionuclide	Detected	Quantitative data available	Minimum (Bq/kg)	Maximum (Bq/kg)	Mean (Bq/ kg)	Reference
						2022)
Cs-137	Yes	Yes	0.11	16.39	ND	(Borawska et al., 2013)
H-3	Yes	No	ND	ND	ND	(Fresquez et al., 1997)
I-131	Yes	No	ND	ND	ND	(Bunzl et al., 1988)
K-40	Yes	Yes	32	74	ND	(Mihaljev et al., 2021)
K-40	Yes	No	ND	ND	ND	(Şirin et al., 2022)
K-40	Yes	Yes	ND	ND	24.08	(Bulubasa et al., 2021)
K-40	Yes	Yes	7.35	43.36	ND	(Dizman et al., 2020)
K-40	Yes	Yes	7.9	102.2	ND	(Xarchoulakos & Lasithiotakis, 2022)
K-40	Yes	Yes	137	1607	ND	(Abdullah et al., 2019)
K-40	Yes	No	ND	ND	ND	(Handa et al., 1997)
K-40	Yes	No	ND	ND	ND	(Čokeša et al., 1995)
K-40	Yes	Yes	ND	ND	27.1	(Djuric et al., 1997)
K-40	Yes	Yes	41.37	105.2	ND	(Khandaker et al., 2023)
K-40	Yes	Yes	7.28	101	ND	(Meli et al., 2016)
K-40	Yes	Yes	<LOQ	87	ND	(Esposito et al., 2002)
K-40	Yes	Yes	5.52	98.89	ND	(Borawska et al., 2013)
Na-22	Yes	Yes	<1	1.70	ND	(Mihaljev et al., 2021)
Pb-210	Yes	Yes	<MDA	1.70	ND	(Xarchoulakos & Lasithiotakis, 2022)
Pb-214	Yes	No	ND	ND	ND	(Handa et al., 1997)
Po-210	Yes	Yes	<MDA	2.31	ND	(Xarchoulakos & Lasithiotakis, 2022)
Po-210	Yes	Yes	ND	ND	0.029	(Pearson et al., 2016)
Po-210	Yes	Yes	0.006	0.384	ND	(Wieczorek et al., 2020)
Po-210	Yes	Yes	0.03	1.98	ND	(Meli et al.,

Radionuclide	Detected	Quantitative data available	Minimum (Bq/kg)	Maximum (Bq/kg)	Mean (Bq/kg)	Reference
						2016)
Ra-226	<LOQ	No	ND	ND	ND	(Esposito et al., 2002)
Ra-226	Yes	Yes	1.9	11.1	ND	(Mihaljev et al., 2021)
Ra-226	Yes	No	ND	ND	ND	(Şirin et al., 2022)
Ra-226	Yes	No	<1.08	7.35	ND	(Bulubasa et al., 2021)
Ra-226	Yes	No	<MDA	0.73	ND	(Dizman et al., 2020)
Ra-226	Yes	No	5	44	ND	(Abdullah et al., 2019)
Ra-226	Yes	No	ND	ND	ND	(Handa et al., 1997)
Ra-226	Yes	No	3.49	4.51	ND	(Khandaker et al., 2023)
Ra-228	Yes	Yes	0.99	1.74	ND	(Khandaker et al., 2023)
Rn-220	Yes	Yes	1.8	3.9	ND	(Misdaq & Mortassim, 2008)
Rn-220	Yes	Yes	1.1	4.2	ND	(Misdaq & Mortassim, 2009)
Rn-222	Yes	Yes	2.3	8.1	ND	(Misdaq & Mortassim, 2008)
Rn-222	Yes	Yes	1.5	10.6	ND	(Misdaq & Mortassim, 2009)
Ru-103	Yes	No	ND	ND	ND	(Bunzl et al., 1988)
Sr-90	<LOQ	No	ND	ND	ND	(Iammarino et al., 2016)
Th-232	<LOQ	No	ND	ND	ND	(Esposito et al., 2002)
Th-232	Yes	Yes	<1	2	ND	(Mihaljev et al., 2021)
Th-232	Yes	No	ND	ND	ND	(Şirin et al., 2022)
Th-232	Yes	Yes	ND	ND	1.51	(Bulubasa et al., 2021)
Th-232	Yes	Yes	0.57	3.43	ND	(Dizman et al., 2020)
Th-232	Yes	Yes	10	162	ND	(Abdullah et al., 2019)
Th-232	Yes	Yes	1.1	4.2	ND	(Misdaq & Mortassim, 2009)
Th-232	Yes	Yes	ND	ND	0.26	(Djuric et al., 1997)

Radionuclide	Detected	Quantitative data available	Minimum (Bq/kg)	Maximum (Bq/kg)	Mean (Bq/kg)	Reference
U-234	<LOQ	No	ND	ND	ND	(Pearson et al., 2016)
U-235	Yes	Yes	<1	0.82	ND	(Mihaljev et al., 2021)
U-235	Yes	Yes	ND	ND	0.11	(Djuric et al., 1997)
U-235	Yes	Yes	<MDA	0.11	ND	(Xarchoulakos & Lasithiotakis, 2022)
U-238	<LOQ	No	ND	ND	ND	(Bulubasa et al., 2021)
U-238	<LOQ	No	ND	ND	ND	(Pearson et al., 2016)
U-238	<LOQ	No	ND	ND	ND	(Esposito et al., 2002)
U-238	Yes	Yes	<10	21.5	ND	(Mihaljev et al., 2021)
U-238	Yes	Yes	<MDA	0.048	ND	(Xarchoulakos & Lasithiotakis, 2022)
U-238	Yes	Yes	1.5	10.6	ND	(Misdaq & Mortassim, 2009)
U-238	Yes	Yes	ND	ND	2.3	(Djuric et al., 1997)
U-238	Yes	Yes	<LOD[4]	0.043	ND	(Meli et al., 2016)

[1] ND = No data, [2] Limit of quantification, [2] Minimum detectable activity, [3]Limit of detection (assumed)

Appendix VI - International legislation and standards relevant to honey

Codex Alimentarius Commission

The CAC has a voluntary standard for honey, 12-1981 (Codex Alimentarius Commission, 2022). Since it is international in perspective it applies to all honeys produced by honeybees, unlike the EU Directive that is specific to honey produced by *A. mellifera*. It contains a description of the food and compositional requirements. These include:

Moisture content: 20% for honey other than heather honey (23%).

Fructose and glucose: not less than 60g/100g other than for honeydew honey (45g/100g).

Sucrose content: not more than 5g/100g except for Alfalfa (*Medicago sativa*), Citrus spp., False Acacia (*Robinia pseudoacacia*), French Honeysuckle (*Hedysarum*), Menzies Banksia (*Banksia menziesii*), Red Gum (*Eucalyptus camaldulensis*), Leatherwood (*Eucryphia lucida*) or *Eucryphia milligani* (not more than 10g/100g) or Lavender (*Lavandula* spp) or Borage (*Borago officinalis*) (not more than 15g/100g).

Water insoluble solids for honeys other than pressed honeys, not more than 0.1g/100g, and pressed honeys not more than 0.5g/100g.

In respect to contaminants, “Honey shall be free from heavy metals in amounts which may represent a hazard to human health” and should comply with the maximum defined by the CAC. Similarly, the MRLs for pesticides set by CAC should be adhered to. Hygiene standards should be those of the General Principles of Food Hygiene (CXC 1-1969) and should comply with “any microbiological criteria established in accordance with the Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods (CXG 21-1997)”

Other metrics include free acidity, diastase activity, HMF content, and electrical conductivity.

China

The effects of changes in regulations with respect to chloramphenicol used for the prevention of bee disease on the Chinese industry have been assessed (Wei et al., 2012). It is contended that the reduction in MRLs imposed by major export markets from a maximum of 10 to 0.3 ppb has resulted in a reduction in exports. This is reflected in data for the EU where the MRL reduced from 10 ppb in 2001 to 0.1 ppb in 2002 and then was increased to 0.3 ppb in 2005. Trade changed from 32.3 $US million to a low of 1.6 in 2003-2004, and then increased to 22.0 in 2005. It was concluded that decreasing MRLs had significantly affected China's exports.

China has legislation controlling exported honey (Food and Agriculture Organisation, 2000). These administrative measures were set up to manage exported honey and to improve its quality to meet importing country criteria. The State provides a registration scheme for honey exporters, with a ban on exports from producers not registered. Part of the system assesses compliance with specifications and hygiene requirements.

There is a national standard for honey, GB 14963-2011 (Ministry of Health of the People's Republic of China, 2011). It includes a limit for zinc (25 mg/kg) and states that veterinary drugs residues and agricultural chemical limits should meet the criteria contained within GB 2762 and GB 2763. *Salmonella*, *Shigella* and *S. aureus* should all be absent in 25g, with colony counts <10^3 CFU/g, coliforms <0.3 MPN/g, moulds and osmophilic yeasts each <200 CFU/g. It also contains a more general provision "The nectar, secretion or honeydew got from the plant by bees must be safe and non-poisonous and cannot be originated from a toxic honey plants such as *Tripterygium wilfordii* Hook. F.,*Macleaya cordata* (willd.) R. Br, *Stellera chamaejasme* L., etc"

Standard GB2762 contains limits for lead of 0.5 mg/kg, and while GB 2763 contains limits for over 7000 pesticides, none are specifically for honey.

Mexico

A draft standard was produced in 2018 (Ministry of Agriculture, L., Rural Development, Fisheries and Food (Mexico), 2018) to which comments were assessed in 2020 (Ministry of Agriculture and Rural Development, 2020). The draft applied to *A. mellifera* only and covers the general definitions given by Codex. In terms of food safety:

5.3 The honey must not contain any additional ingredients, it must be free of insect fragments as well as any other foreign matter; it must not have begun to ferment (except in mangrove honeys), or produce effervescence.

5.4 Honey shall not contain any additives such as colourings, flavourings, preservatives and microbial inhibitors.

and

6.2.8 Hydroxymethylfurfural (HMF), expressed in mg/kg in honey packed for more than 6 months. Maximum 80.00 mg/kg.

6.2.9 Hydroxymethylfurfural (HMF) from honey of declared origin from tropical climate regions. Maximum 80.00 mg/kg.

6.2.10 Diastase index (Schade scale). Minimum 8.0 (For low-enzyme honeys, the minimum diastase index will be 3.0 as long as the HMF content does not exceed 15 mg/kg).

6.3 Pollutants and toxic wastes: the product covered by this standard shall comply with the provisions of the Agreement laying down the criteria for determining maximum limits of The National Program for the Control and Monitoring of Toxic Residues in Goods of Animal Origin, Aquaculture and Fisheries Resources, and the Program for the Monitoring of Toxic Residues in Animals, as well as the consultation module, which are regulated by the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food and those others published for this purpose by the Secretariat.

European Union

According to technical guidelines by the EU commission (SANTE/11956/2016) (European Commission, 2018) MRLs for honey are only required in the following circumstances:

- When a substance is applied during the flowering stage of a crop which is foraged by bees
- When a substance with systemic properties is applied prior to the flowering stage, including treatment of seeds, of a crop which is foraged by bees
- From uses on non-target plants (in-field weeds and adjacent plants) when a substance is applied during the flowering period from April to September
- From succeeding crops after application of a persistent and systemic active substance
- *Via* honeydew collected from plant-sucking insects in forestry (such as *Picea* spp., *Abies* spp, *Pinus* spp. and *Quercus* spp.)

Where the conditions above do not apply, the MRL is set at the limit of quantification (LOQ) determined for the active substance. In the absence of a specific LOQ in honey for the active substance under consideration, the default value of 0.05 mg/kg can be used.

EU countries must check foods of animal origin for the presence of residues of veterinary medicines. A list of prohibited and unauthorised, and authorised products is has been published (European Commission, 2022a) and the same document specifies the sampling strategy to be used for risk based control plans, randomised plans and for products imported from third countries. Factors affecting the sampling strategy are also discussed. More information in respect to the multi-annual national control plan and the frequency of official controls is supplied in the implementing regulation (European Commission, 2022b) and in earlier legislation.

A paper published by the International Honey Commission compared the Codex and EU standards (Bogdanov et al., 1999) but they were drafts at the time and the comparison is not current. However, it does observe that globally-targeted quality criteria may not be appropriate for all countries and indeed that some producers or regions may wish to adhere to more stringent standards.

Because of problems with fraudulent and deceptive practices, steps have been taken to establish a list of third countries' establishments producing honey for human consumption (European Commission, 2023). There is a period of twelve months from publication for countries to comply and this concludes in September 2024.

New Zealand

Bee products intended for export to countries that require official assurances (export certificates) must meet requirements under the Animal Products Act 1999. "These requirements include operating under a registered Risk Management Programme (RMP), which is usually based on a template using a Code of Practice (COP); participate in the residues monitoring programme, which tests for contaminants in bee products – this is governed by a Regulated Control Scheme (RCS); and meet general requirements for export and any overseas market access requirements (OMARs)."

The Ministry for Primary Industries produces guidance for businesses producing honey (Ministry for Primary Industries, n.d.).This requires businesses to have a registered plan or programme under the Food Act 2014 or the Animal Products Act 1999 and to manage Tutin contamination of honey. Exporters to countries needing an export certificate must have a RMP. In addition, the Biosecurity Act 1993 relates to the control of pests and unwanted organisms. The Agricultural Compounds and Veterinary Medicines Act 1997 manages risk associated with the use of agricultural compounds and includes risks to public health and ensuring that "the use of agricultural compounds does not result in breaches of domestic food residue standards".

Tutin contamination is managed two ways 1) testing to ensure that the concentration is within limits (0.7 mg/kg for both honey and comb) and 2) meeting requirements of the standard for Tutin control (Ministry for Primary Industries, 2016).

Food standards Australia New Zealand publish approval for the limit for Tutin in honey and comb, as described above in 2014 (Food Standards Australia New Zealand, 2014). It is possible that the level quoted could change in future in analytical techniques for the quantification of Tutin glycosides are successfully developed.

United States

The states of the Union have various laws and guidance, as listed by the Association of Food and Drug Officials (Association of Food and Drug Officials, 2024). In the USA legislation at the State level applies as well as at the Federal level. There is no current standard for honey but the “Honey Identification and Verification Enforcement Act” (The HIVE Act) was introduced to Congress in July 2023 (United States Government, 2023). This will introduce a Standard for honey within one year of the date of enactment of the Act.

The FDA has tested imported honey for the presence of chloramphenicol and other antibiotics issuing “import alerts” to (or “red listing”) specific shippers from several countries (Ferrier, 2021). Once an import alert is imposed the consignment is held without check until non-compliance can be disproven.

The FDA has also produced recommendations for levels of contamination that are acceptable following a nuclear incident, known as “Derived Intervention Levels” (DILs) (US Food and Drug Administration, 2004) (Table 12. USFDA Derived Intervention Levels for Domestic and Imported Foods Either Accidentally or Intentionally Contaminated with Radionuclides based on [Food Standards Agency, 2022]). DILs represent the radioactivity levels at which “protective measures should be considered” and assume that ingestion of contaminated food will only occur over the period of a year. The derivations of these DILS are given in the document cited.

Table 12. USFDA Derived Intervention Levels for Domestic and Imported Foods Either Accidentally or Intentionally Contaminated with Radionuclides based on (Food Standards Agency, 2022)

Radionuclide group	Derived intervention level (Bq/kg)
Sr-90	160
I-131	170
Cs-134 + Cs-137	1200
Pu-238 + Pu 239 + Am-241	2
Ru-103 + Ru-106[1]	(C3/6800) + (C6/450) <>

[1] Due to the large difference in DILs for Ru-103 and Ru-106, the individual concentrations are divided by their respective DILs and then summed. C3 and C6 are the concentrations, at the time of measurement, for Ru-103 and Ru-106 respectively.

The DIL for each radionuclide group is applied independently. Each DIL applies to the sum of concentrations of the radionuclides in the group at the time of measurement.

Applicable foods are prepared for consumption. For dried or concentrated food products such as powdered milk or concentrated juices, adjust by a factor appropriate to reconstitution, and assume that the reconstitution water is not contaminated. For spices that are consumed in very small quantities use a dilution factor of 10.

Canada

Within specific guidance for honey, the Canadian Food Inspection Agency (CFIA) provides specific information for food safety (Canadian Food Inspection Agency, 2023). It provides information on general production hygiene and on avoiding lead contamination and guidelines for safe drug use within a “Preventative Control Plan”. While there is no limit for lead in honey a concentration of 0.1 ppm "suggests that avoidable lead contamination has taken place. Steps suggested for avoiding lead contamination include:

- Choose lead-free equipment. A warning is given to be wary of stainless steel containers that have lead seams
- Where lead is present in equipment, minimise exposure time and temperature
- Clean equipment properly so that there is no honey in contact with potentially lead-containing materials for extended periods
- Test honey to identify sources of lead contamination

The CFIA operates a national chemical residue monitoring programme for food, including honey. Samples are assessed with compliance to the Food and Drugs Act and Regulations and the Safe Food for Canadians Act and Regulations. In addition to MRLs there are also Working Residue Levels (WRLs) that “provide guidance to honey producers on residue levels which are deemed not to pose undue risk to human health”, although listing of these drugs and their WRLs does not represent approval for use. The WRLs are shown below in Table 13 (Health Canada, 2017). Honey with residues above the WRL will be subject to a risk assessment and subsequent action based on the outcome.

Table 13. Canadian Recommended Working Residue Levels for Honey

Drug Product	Recommended WRL (ppm)
Chlortetracycline	0.03
Erythromycin	0.03
Lincomycin	0.03

Drug Product	Recommended WRL (ppm)
Penicillin	0.003
Streptomycin	0.0375
Sulphonamide Drugs	0.03
Tetracycline	0.075
Chloramphenicol	Banned-no WRL
5-Nitrofuran compounds	Banned-no WRL

The Veterinary Drugs Directorate, which is part of Health Canada, sets standards and oversees the use of veterinary drugs in the food supply and shown below (Table 14) are the maximum residue limits for veterinary drugs that are permitted to be present in honey (Government of Canada, 2024).

Table 14. Canadian Maximum Residue Levels specific for honey

Veterinary drug	MRL (ppm)
Fumagillin	0.025
Lincomycin	0.75
Oxytetracycline	0.3
Tylosin A and B	0.2 (sum of tylosin A and B, calculated as tylosin A)

Other

A paper (Thrasyvoulou et al., 2018) describes international legislation and comments on the fact that there is no official name for honeys made by species other that *A. mellifera*, and it recommends that provisions need to be made for these honeys in the countries where they are produced since they have different properties to the dominant honey. However, there is nothing in this paper that relates to hazards in honey, since it concerns more quality and authenticity.

Malaysia has a Standard for Kelulut (stingless bee honey) (Department of Standards Malaysia, 2017). In this the honey shall be free from foreign matter and not contain any food additives. There are values for compositional parameters in both raw and processed honey, as well as microbiological criteria for total plate count, yeast and mould count, and coliforms. The honey should be processed appropriately in accordance with Malaysian Standards and the Food Hygiene Regulations 2009.