RISK ANALYSIS

Risk Profile: Imported Eggs and Egg Products

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FSA Research and Evidence

This risk profile identifies and characterises the primary hazards associated with shell eggs and egg products (EEPs) imported into the United Kingdom (UK) from domestic poultry species. The scope includes liquid, dry, cooked, and preserved egg products, excluding composite foods containing eggs or egg products. The document aims to provide essential background information on food safety concerns related to imported EEPs, support the assessment of market access requests for exporting EEPs to the UK, and assist in audit and assurance activities for EEP imports.

A comprehensive literature review and analysis of incident and alert data identified over 100 potential hazards in eggs. Through expert judgement and inclusion criteria, 22 key hazards were shortlisted for characterisation. The microbiological hazards characterised include *Campylobacter* spp., *Listeria monocytogenes,* and non-typhoidal *Salmonella* (*Salmonella* Enteritidis and *Salmonella* Typhimurium), with *Salmonella* Enteritidis being the most frequently reported hazard. Chemical hazards characterised include agricultural contaminants (aflatoxins, ochratoxin A, pyrrolizidine alkaloids), biocides (fipronil, chlorate), environmental contaminants (persistent organic pollutants, melamine, metals), and various pesticides, veterinary medicinal products, and feed additives.

Risk factors for microbiological hazards include hygiene and biosecurity failures, flock age and size, and environmental conditions. Chemical hazards are linked to environmental exposure and misuse of substances. Mitigation measures for microbiological hazards include eradication and

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vaccination programmes, while chemical hazard mitigation focuses on environmental controls and monitoring programmes. Regulatory measures in Great Britain and Northern Ireland are in place to control both chemical and microbiological hazards in eggs.
This risk profile supports the Department for Environment, Food and Rural Affairs (DEFRA) and the Food Standards Agency (FSA) in ensuring the safety of imported EEPs and guiding market access and audit activities.

1. Executive Summary

This risk profile identifies and characterises the main hazards associated with shell eggs and egg products (EEPs) from domestic poultry species imported into the United Kingdom (UK). Liquid, dry, cooked and preserved egg products were in scope, while composite foods containing eggs or egg products were not.

The information is intended for the Department for Environment, Food and Rural Affairs (DEFRA) and its SPS Trade Assurance (UK Office), as well as the Food Standards Agency (FSA) and its Imports Market Access Assurance (IMAA) team. The document has three primary objectives:

- Provide background on food safety concerns related to imported EEPs.
- Support the assessment of market access requests to export EEPs to the UK.
- Assist audit and assurance activities for EEP imports.

A comprehensive literature review and analysis of incident and alert data identified over 100 potential hazards that can be present in eggs. Through the use of inclusion criteria and expert judgement, 22 key hazards were shortlisted for characterisation.

The microbiological hazards that were taken forward to characterisation were *Campylobacter spp.*, *Listeria monocytogenes*, and non-typhoidal *Salmonella* (*Salmonella* Enteritidis and *Salmonella* Typhimurium). *Salmonella* Enteritidis was the most frequently reported hazard in EEPs across all hazard types, and the main hazard involved in outbreaks associated with EEPs.

The chemical hazards that were characterised include: agricultural contaminants (aflatoxins, ochratoxin A (OTA) and pyrrolizidine alkaloids (PAs)), biocides (fipronil and chlorate), environmental contaminants (persistent organic pollutants (POPs) such as dioxins, polychlorinated biphenyls (PCBs), polychlorinated naphthalenes (PCNs), and per- and

polyfluoroalkyl substances (PFAS)), melamine, metals (arsenic, cadmium, chromium, copper, lead, mercury, selenium) and a number of pesticides, veterinary medicinal products (VMP) and feed additives.

Risk factors for microbiological hazards include hygiene and biosecurity failures and the age and the size of the flock. Aflatoxin and OTA formation in feed is linked to a hot and humid climate, whereas PA concentrations are expected to be higher where nutrient availability is low and there is high soil moisture. For environmental contaminants and metals, proximity to anthropogenic sources of these contaminants are likely to impact the levels detected in eggs. Biocide, pesticide, feed additive and VMP residues are linked to the misuse of approved substances or illegal use of substances that are banned or not authorised for use in layer farms or egg processing environments.

Hazards may enter the egg during its formation or after it is laid. Pathogenic microorganisms such as *Salmonella* Enteritidis and chemicals such as mycotoxins, PAs, environmental contaminants, metals, pesticides and veterinary medicines follow the former route. These hazards are introduced to the egg within the reproductive system of the birds, either after environmental exposure of the animal, primarily via feed and water, or because they are part of the birds' natural flora.

To mitigate microbiological hazards that are introduced to the egg during its formation, eradication and vaccination programmes, including for breeder flocks, are likely to be the most effective. Mitigation measures for chemicals in eggs and egg products are primarily related to the environment of the poultry farm, and the poultry feed and water. Monitoring programmes can also be effective.

Alternatively, hazards may enter the egg after it is laid, when it comes into contact with contaminated surfaces. Such hazards include microorganisms such as *Salmonella* Typhimurium, *Listeria monocytogenes* and *Campylobacter* spp. and biocides which are used in animal husbandry or egg processing environments.

Controls for microbiological hazards in eggs are predominantly concerned with the control of *Salmonella* but can be equally applied to mitigate other microbiological hazards. They include biosecurity measures, pest control, sampling and testing regimes, vaccination programmes, cleaning and disinfection programmes, product traceability, full documentation of activities undertaken, and records that can be audited independently.

In contrast to chemical hazards, microbiological hazards can be mitigated in industrial settings via heat treatment such as pasteurisation. Most egg products are pasteurised to destroy bacteria, however certain egg products may undergo milder processes due to heat sensitivity and shell eggs are not always pasteurised.

Regulatory measures are employed to control both chemical and microbiological hazards in eggs, and extensive regulations are in place in Great Britain (GB) and Northern Ireland (NI).

2. Background

2.1. Introduction and Scope

This risk profile identifies and characterises the main hazards associated with imported eggs and egg products (EEPs) of domestic poultry species that may be a concern for public health. Key controls, mitigation measures and relevant UK and EU regulations (applicable to Northern Ireland (NI)) are summarised along with common industry production methods and management processes, general UK consumption patterns and information on global production and trade. This information will be used by the Department for Environment, Food and Rural Affairs (DEFRA) UK Office for SPS Trade Assurance (UK Office) and the Food Standards Agency (FSA) Imports Market Access Assurance (IMAA) Team to:

- Provide background information on potential food safety concerns relating to imported EEPs
- Contribute to the overall evidence package used for assessment of specific third country market access requests to export EEPs to the UK
- Support related audit and assurance activities

This risk profile does 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 EEPs, instead it describes the main human health hazards that may need to be considered in relation to the control of imported EEPs. This risk profile does not make public health recommendations or otherwise constitute public health advice. It is intended to inform on the hazards potentially associated with EEPs and to guide market access audit and assurance activities relating to imported EEPs. Identification of hazards in this profile does not necessarily indicate a present concern for public health from EEPs. 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 EEPs. This risk profile does not address issues concerning fraud or authenticity unless there is an identified food safety consequence.

Two categories of eggs are included in this risk profile, namely shell eggs and egg products. Definitions are provided in Table 1.

Table 1. Definitions

Term	Definition	Reference
Shell eggs	Eggs in shell, fresh, preserved, or cooked, other than eggs for hatching	Assimilated Reg. (EC) 1308/2013 (European Parliament, 2013)
Egg products	Products resulting from the processing of eggs, or of various components or mixtures of eggs, or from the further processing of such processed products	Assimilated Reg. (EC) 853/2004 (European Parliament, 2004)
Poultry	Fowls, guinea fowl, ducks, geese, quails, pigeons, pheasants, partridges and ratites (ratitae), reared or kept in captivity for breeding, the production of meat or eggs for consumption, or for restocking supplies of game	Assimilated Reg. (EC) No 798/ 2008 (European Commission, 2008b)
Fowls	Not defined in legislation but taken to mean hens and turkeys for this risk profile	
Eggs and egg products of domestic poultry species	Products as defined in assimilated Regulation 798/2008 for human consumption (HC) and products for HC traded under the following Harmonised System (HS) codes: • 040721 “fresh eggs of domestic fowls, in shell (excl. fertilised for incubation)” • 040729 “fresh birds' eggs, in shell (excl. of domestic fowls, and fertilised for incubation)” • 040790 “birds' eggs, in shell, preserved or cooked” • 0408 “birds' eggs, not in shell, and egg yolks, fresh, dried, cooked by steaming or by boiling in water, moulded, frozen or otherwise preserved, whether or not containing added sugar or other sweetening matter” • 350211 “egg albumin”, frozen or otherwise preserved, whether or not containing added sugar or other sweetening matter”	Assimilated Reg. (EC) No 798/ 2008 (European Commission, 2008b) UK Integrated Online Tariff (Gov UK, 2024b)

Assimilated Reg. (EC) 853/2004, which lays down specific hygiene rules for food of animal origin, provides a different definition for eggs which excludes broken and cooked products (European Parliament, 2004). Since those were within the scope of the profile this definition was not considered appropriate.

While preserved eggs and egg products which may contain other ingredients are in scope, composite food containing eggs or egg products are not.

2.2. Commodity Description

This risk profile concerns EEPs, that are imported into the UK. However in this section legal requirements in the UK, good industry practice in the UK and UK egg assurance schemes (e.g. Lion Code and Laid in Britain) are

discussed. The details outlined in this section may not be implemented as such in other parts of the world, but equivalent schemes aimed at ensuring the quality and safety of EEPs may be in place, and so the UK information is provided to aid comparison.

2.2.1. Shell (table) eggs

The following section focuses primarily on hen eggs as these are by far the most commonly imported EEPs (see section 2.4). Eggs from other species are discussed when information was readily available.

According to the Advisory Committee on the Microbiological Safety of Food (ACMSF), production of table eggs from other species, such as ducks, quail, geese, turkeys, ostriches and seagulls, varies between countries and typically such eggs are sold as small-scale alternative, niche or luxury commodities (ACMSF, 2016).

2.2.2. The hen reproductive system

The hen's reproductive system is made of the ovaries and the oviduct (Figure 1) (Kaspers, 2024). Eggs are produced from the inside out, starting with yolk formation in the ovaries and each successive layer being formed in different parts of the oviduct. This process takes 24-26 hours to complete (Kaspers, 2024). A representation of the egg layers can be seen in Figure 2.

Egg formation starts with the hens' genetic material, called the oocyte or the ova. These are stored in follicles in the ovary (Figure 1A and B). The yolk forms around the blastodisc, which is a clear disc containing the female genetic information. The liver produces the egg yolk components (predominantly lipoproteins: triglycerides, phospholipids and cholesterol) which are transported to the ovary via the bloodstream (Nys & Guyot, 2011).

The yolk is then released from the ovary into the oviduct (Nys & Guyot, 2011). The opening of the oviduct, the infundibulum (Figure 1C), is where fertilisation of the egg takes place and where the vitelline membrane is formed (Nys & Guyot, 2011). This is a thin membrane that limits exchanges of the material between the yolk and the white and is a barrier against bacterial penetration. It is formed through specialised cells in the oviduct, ovaries and the liver.

The egg then moves further along the oviduct to the magnum (Figure 1D), where the albumen (egg white) is deposited. The role of the albumen is to protect the egg yolk and provide nutrients for a developing embryo (Nys & Guyot, 2011).

The next stage is formation of the two membrane layers (Figure 2) (Kaspers, 2024) in the section of the oviduct called the isthmus (Figure 1E) (Nys & Guyot, 2011). The membrane layers prevent the albumen from spreading out towards the shell. The inner membrane, the peri-albumen, may be involved in limitation of bacterial penetration.

Finally, the eggshell is formed, and this process can take 20-24 hours, the longest phase in the egg development process (Kaspers, 2024). Shell development occurs in three stages (Nys & Guyot, 2011):

- Nucleation phase: eggshell membrane fibres are synthesised, and the organic components are laid down on the outer shell membrane.
- Shell mineralisation: migration of the egg into the uterus (Figure 1F) where progressive hydration of egg albumen dilates the egg, creating its ovoid shape and allowing close contact with the uterine wall allowing calcium deposition to occur, forming the hard outer shell.
- Termination of the mineralisation: calcium deposition stops and pigments comprised of porphyrins are secreted in the uterus which adds colour to the shell.

The expulsion of the egg (oviposition) by the oviduct is controlled by hormones and hormone-like substances (prostaglandins), that facilitate the uterine muscle contraction, and relaxation of the sphincter between the uterus and vagina (Nys & Guyot, 2011). The process lasts a few minutes.

A number of factors can affect the egg laying process. The diet needs to contain a large amount calcium along with other micronutrients to produce a healthy egg (Anonymous, 2018). Eggs with stronger eggshells are better able to resist pathogen penetration and internal content contamination. Hens under stress or on an inadequate diet may lay eggs that have thinner shells or reduced shell integrity, which can result in microcracks in the shell. This can result in contamination of the egg post-oviposition (Harage & Al-Aqaby, 2024).

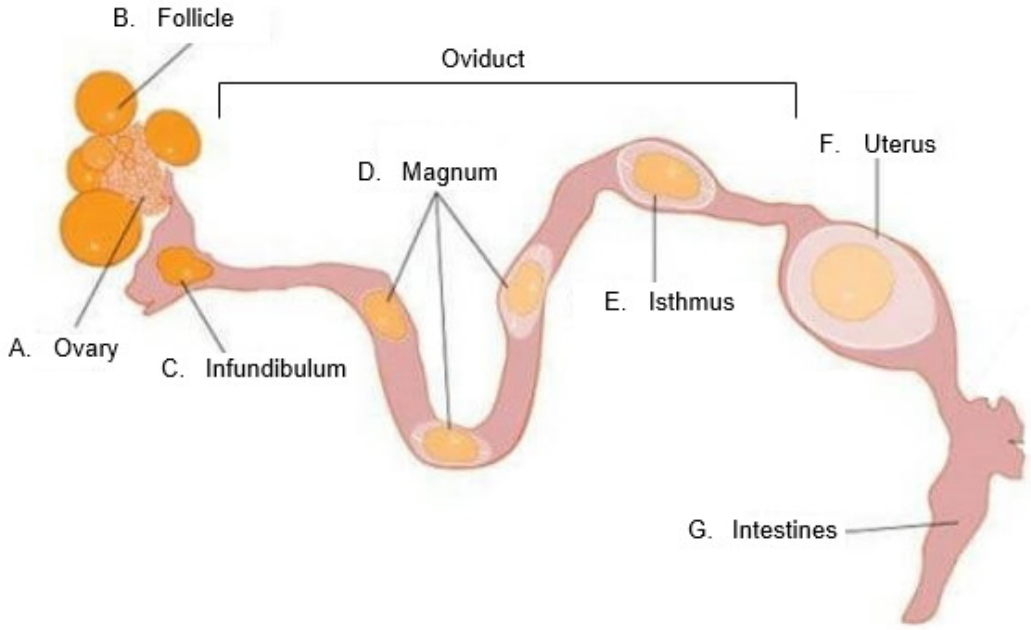

Figure 1. Diagram of the hen reproductive system [Modified from (Eggbert Eggs, 2024)]

2.2.3. Anatomy and physical properties of the egg

Eggs are an important food commodity that provide nutritional benefits, e.g. high-quality proteins (i.e. protein which contains all the amino acids required in the human diet), vitamins A, B12, D and E. They also offer functional benefits in food production e.g. the coagulant capacity of proteins, the foaming capacity of albumen proteins and the emulsifying capacity of the yolk (EFSA, 2014c). An egg is composed of the yolk (~30%), albumen or egg white (~60%) and shell membranes and shell (~10%) (Froning & Singh, 2024). Figure 2 shows the general structure of an egg.

The porous eggshell is predominantly composed of calcium carbonate and is formed in layers. The outermost layer, the cuticle, is formed last (USDA, 2000). The cuticle is a protein carbohydrate complex which protects the egg against dehydration and provides a barrier to many micro-organisms present on the surface of the egg by blocking the pores in the other layers of the shell (EFSA, 2005).

Underneath the shell are a pair of shell membranes; these are fibrous layers, which are composed of a protein core surrounded by carbohydrate. Many of the proteins in the fibres are antibacterial (EFSA, 2005).

Further in, the albumen is made of four viscous layers of varying thickness (Stadelman et al., 1995). Water is the major component of the albumen as well as numerous proteins, many of which can be antibacterial (EFSA, 2005).

The yolk is predominately composed of proteins and lipids, as well as vitamins and minerals, and it has a slightly acidic to neutral pH (USDA, 2000). Unlike the other component parts of the egg, it does not possess antimicrobial properties (USDA, 2021).

The approximate pH of the new-laid whole egg is 6.58, with the pH in the egg white being 7.96 and in the yolk 6.10 (FDA, 2023). The water activity($a_{W)}$ is 0.97 (Schmidt & Fontana, 2007). Both the pH and the moisture in the egg change as a function of time and temperature (Y. B. Kim, Lee, et al., 2024). The pH in the egg becomes alkaline (~10) as the egg ages and cannot support microbial growth (USDA, 2021). These parameters are often favourable to bacterial growth as can be seen in Table 5,Table 7 and Table 8. However, pH and a_W act synergistically with other parameters such as storage temperature, oxygen availability, salt levels, etc to determine whether microbial growth and/ or survival is likely.

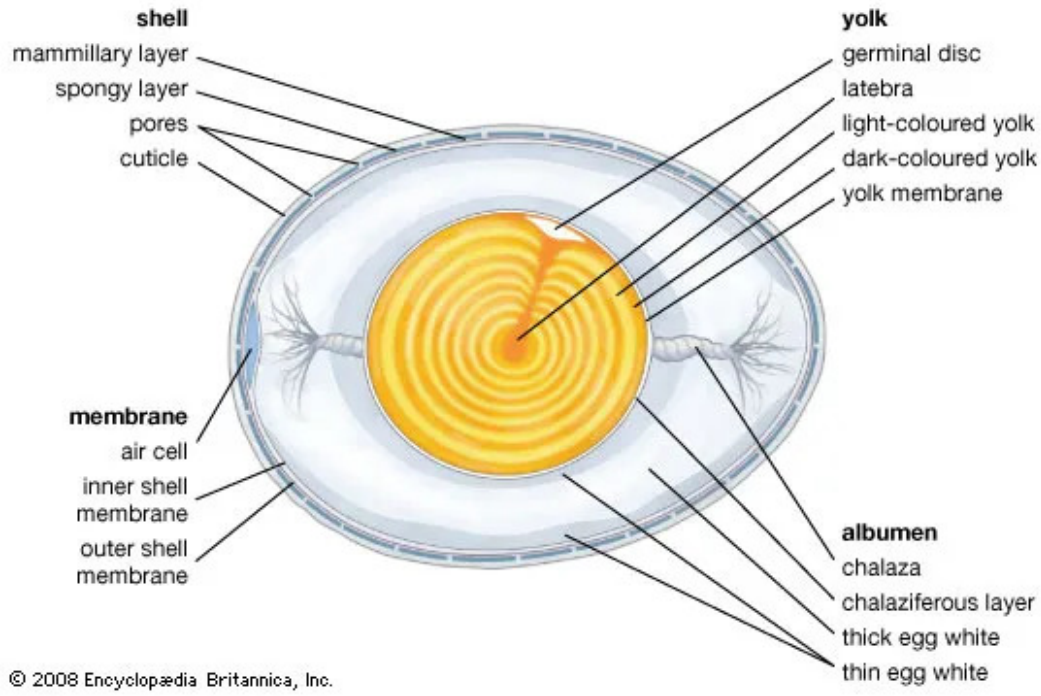

Figure 2. Anatomy of an egg [Diagram taken from (Froning & Singh, 2024)]

The structure of the egg does not change between bird species. However, the proportions of the various egg components reflect the species, with the proportion of the shell varying the most (Nys & Guyot, 2011).

2.2.4. Legal requirements and good practice in egg production

In the UK and the EU (applicable in NI), egg production and distribution is governed by a number of regulations as discussed in this section. Additionally, the FSA appointed independent veterinarians to consider what criteria an industry food safety scheme would need to meet for the

eggs to be considered 'very low' risk for *Salmonella*. They helped develop a science-based Matrix (i.e. a set of independent standards for production of shell eggs considered to be very low risk in relation to *Salmonella*) that can be used to facilitate consistent and independent assessment of all UK egg production assurance schemes and support the FSA egg consumption advice to vulnerable consumers (Unpublished).

The key elements of the matrix include:

- Sampling and testing throughout the production chain, including at the hatcheries, feed mills, and laying flocks. The testing schemes should include environmental samples, raw materials and final product (feed or eggs) samples and should be conducted by suitably trained staff.
- Vaccination programmes for both the breeding and laying flocks, use of antimicrobials exclusively to treat animal diseases and appropriate timing of use of products such as essential oils and acidification.
- Pest control on the farm and in the feed mills.
- Robust biosecurity controls, usually including physical barriers at the entrance to the farm, in addition to well-defined floor areas, dedicated footwear and overalls by house, and no access to pets.
- Tamperproof traceability for class A eggs, including location and date of laying.
- Cleaning and disinfection programmes, including between flocks
- Fully documented temperature-controlled environment, from farm to retail, in line with the current recommendations on temperature control for eggs (constant temperature below 20 °C until shell eggs reach the consumers).
- Records of activities such as sampling and testing, personnel training, any accidents such as feed spillage, pest control and temperature controls must be maintained at all times.
- Independent auditing with clear documentation of "critical" standards must be carried out. Schemes must appoint certification bodies holding UKAS accreditation, or equivalent, having ISO17065 accreditation.

- Clear guidelines on processes to be followed in the event of *Salmonella* being detected must be available, including processes of re-testing/contesting the result where appropriate, the process by which birds may be depleted and eggs sold/ disposed of, and vaccination programmes after a positive result has been received.

Any references to UK good industry practice refers to schemes adhering to the principles in the matrix. Not all steps in the safety scheme are prescribed in legislation. Such schemes may differ by country but for eggs to be imported into the UK, equivalent safety measures must be in place in exporting countries. Practices in countries other than the UK and the EU are also mentioned whenever possible.

2.2.4.1. Traceability and grading

In the UK and EU, egg traceability and record-keeping are mandatory. According to assimilated Reg. (EC) No 589/2008 and DEFRA guidance on egg marketing standards, eggs must be marked with the producer code (issued to producers upon registration) to identify and trace eggs, when they are sold as Class A or B, at public markets, or transported across EU Member State's borders (DEFRA, 2020; European Commission, 2008a).[1]

In the UK, egg grading is governed by GB and Northern Ireland[2] (NI) legislation, and eggs are classified into two quality classes, A and B. Class A eggs are the highest quality eggs and are sold as shell eggs. Immediately after grading, they must be placed in packs and labelled with the best before date, along with other required information (DEFRA, 2020). Class B eggs are those that do not meet the quality thresholds of Class A eggs, or are Class A eggs that have been downgraded, and are typically used in the food industry for the production of egg products (BEIC, 2024a; European Commission, 2008a).

2.2.4.2. Cleaning and hygiene

In the UK, guidance on enforcement of hygiene regulations is provided by the FSA and Food Standards Scotland (FSS) (FSA, 2009a). The FSA matrix also requires robust cleaning and disinfection regimes to be in place. Requirements include maintaining poultry house, bird and egg storage cleanliness, controlling contamination arising from feed, ensuring water cleanliness, prevention of pest contamination, appropriate waste handling, appropriate control of pesticides and veterinary medicines and ensuring staff hygiene (FSA matrix, unpublished). Similar recommendations are

1 Certain specific exemptions apply to these requirements

2 EU legislation remains in force in NI after the UK exit of the EU

made by the Codex (Codex, 1976). DEFRA provide a list of approved disinfectants that states which product to use and the concentration of the disinfectant that must be used (DEFRA, 2021).

2.2.4.3. Storage

Eggs in the UK have a shelf life (best before date) of 28 days. Before reaching consumers, eggs should not be chilled to ensure temperature variations do not affect the quality and safety of the product (DEFRA, 2020).

2.2.5. Egg processing

Shell hen eggs are marketed for direct retail sale, whereas egg products undergo further processing and are mainly intended for the industrial preparation of a variety of foods (such as pastries, dairy products, sauces, dressings, sweets and pasta) (EFSA, 2005). According to the European Food Safety Authority (EFSA), the eggs used for further industrial preparation are often those which do not meet the specifications for whole eggs (out-of-grade or downgraded products e.g. cracked eggs) (EFSA, 2014c). There are many types of egg products, the most common of which are liquid, dried, frozen and cooked whole eggs, egg yolk and egg whites. A summary of the key steps in these processes are shown in Figure 3, and a more detailed summary of the steps in production of liquid and dried egg is shown in Figure 4.

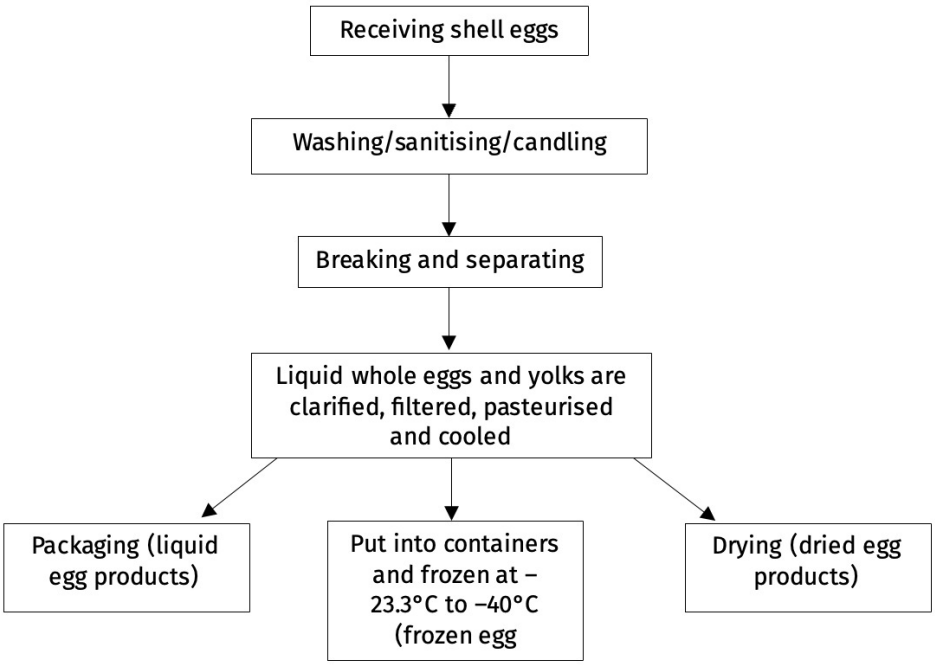

Figure 3. General overview of egg product processing [Created using information from BEPA (BEPA, 2024), USDA (USDA, 2015) and EEPA (EEPA, 2011)]

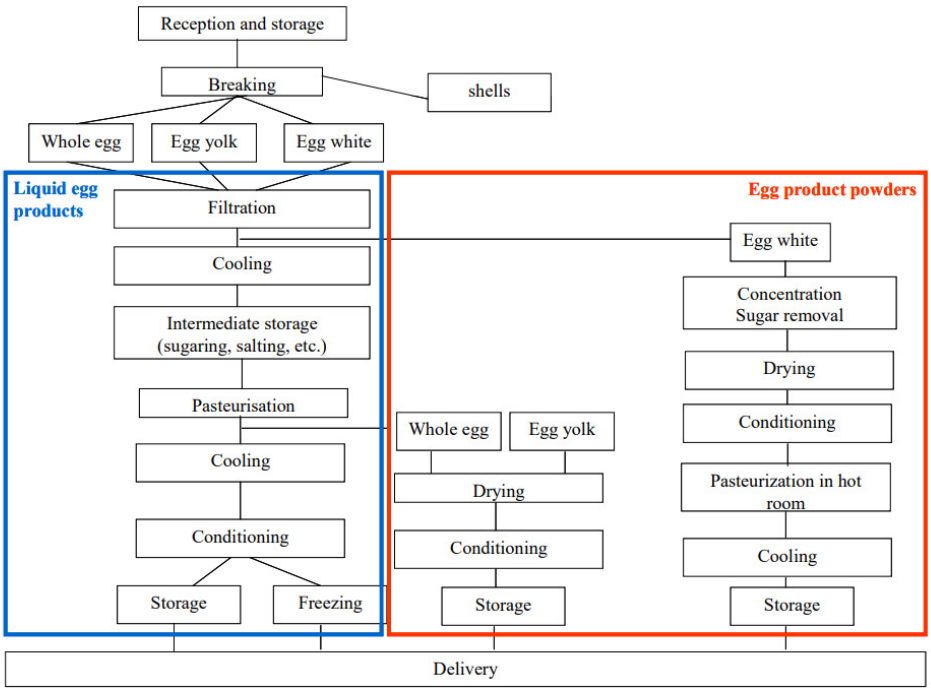

Figure 4. The major steps in the industrial production of egg products (EFSA, 2014c)

Many steps in the process are common across all egg production methods, these are detailed below.

2.2.5.1. Common steps in egg processing

Egg collection and transport

According to the British Egg Industry Council (BEIC), Lion Code egg producers and packers must adhere to specific regulations regarding collection and transport (see section 5.4.2). In particular, eggs should be transported to the packing centre within three working days of laying, necessitating at least two farm collections per week (BEIC, 2013). They must be stored at a consistent temperature below 20°C to prevent surface condensation. If eggs are collected more than 24 hours after laying, a cooling device is required to keep eggs at an even temperature below 20°C (BEIC, 2013). Lion Code and Laid in Britain state that dirty, cracked, or broken eggs must be removed promptly from the collection system and cannot be sold for human consumption (BEIC, 2013; Laid in Britain, 2021).

Washing

Contemporary egg washing machines employ pressure sprays, rotating brushes, and a device that spins the egg to enhance the contact between the egg and the brush, thereby reducing potential damage to the eggs (USDA, 2015). The washing water temperature is set to 30 - 40°C (Shanghai Beyond Machinery, 2024).

According to Reg. (EC) No 589/2008, eggs should not be washed or cleaned as this can cause damage to the egg cuticle and shell, which acts as a barrier to bacteria (European Commission, 2008a). In the EU, only those Member States (MSs) that have granted permission for this practice can market washed table eggs (EFSA, 2014c). However, egg washing before processing is permitted in the EU and GB (Reg. (EC) No 853/2004, Reg. (EC) No 589/2008), provided that the eggs are immediately broken after washing (European Commission, 2008a; European Parliament, 2004).

EFSA suggests that washing reduces the microbial load on the egg surface, particularly foodborne zoonotic pathogens, but it does not prevent egg-based disease caused by micro-organisms which are internally present in eggs (EFSA, 2005). Additionally, washing can damage the cuticle of the eggs, supporting increased contamination within the egg, and increasing moisture loss (EFSA, 2005).

Candling

Candling is a technique that employs a bright light to detect and eliminate flawed eggs. This process involves mechanically spinning the eggs multiple times in front of a bright light to inspect their internal quality (Codex, 1976). The main objective of candling is to discard dirty, cracked, or unsuitable eggs prior to the crucial breaking step in shell egg processing (USDA, 2015).

Breaking and separating

Eggs used for processing should have fully developed shells with no breaks. Reg. (EC) No 853/2004 states that cracked eggs can only be used if they are delivered directly to the manufacturing site, where they must be broken as soon as possible to eliminate microbiological hazards, and that if processing is not carried out immediately after breaking, liquid egg must be stored either frozen or at less than 4°C. This storage period must not exceed 48 hours (European Parliament, 2004).

According to Reg. (EC) No 853/2004, eggs must be broken individually, and methods such as centrifugation or crushing, which were previously allowed, are now prohibited due to the high microbiological risk (European Parliament, 2004). The breaking process also includes separation of the yolk and albumen. EFSA states that the effectiveness of separation is influenced by factors including the storage temperature of the eggs, the freshness of the eggs, the type of machinery used and the rate at which the eggs are broken (EFSA, 2014c).

Reg. (EC) No 853/2003 states that eggs other than those of hens, turkeys or guinea fowl must be handled and processed separately, and that all equipment must be cleaned and disinfected before processing of hens', turkeys' and guinea fowls' eggs is resumed (European Parliament, 2004).

Shell removal and filtration

The “Handbook of Egg Science and Technology” states that egg products are filtered to increase homogeneity and to remove eggshell debris (Mine, Guyonnet, et al., 2023). EFSA recommend that any shell debris remaining in the egg product should be immediately removed by sieving and filtration to prevent contamination and ensure complete homogenisation of the egg products (EFSA, 2014c). Reg. (EC) No 853/2004 states that the quantity of remaining eggshell, egg membrane, and any other particles in the egg product must not exceed 100 mg/kg of egg product (European Parliament, 2004).

Pasteurisation

According to the Codex, pasteurised liquid egg products should be cooled rapidly immediately after pasteurisation and refrigerated (Codex, 1976). EFSA states that exceptions are made for egg whites intended for drying (which are pasteurised post-drying) and for salted egg yolks (as refrigeration would increase yolk viscosity, hindering the pasteurisation process) (EFSA, 2014c).

Pasteurisation requirements for liquid whole eggs can vary by country. European heat treatments typically involve temperatures of 65 - 68 °C for 5 - 6 minutes for whole eggs and egg yolks. The United States of America (USA) requires a lower temperature of 60°C for at least 3.5 minutes (Lechevalier, Guérin-Dubiard, et al., 2017). EFSA state that egg whites undergo milder treatments (55 – 57 °C for 2 – 5 minutes) due to their higher heat sensitivity (EFSA, 2014c).

Storage and transport of egg products

Egg products are conditioned at consistent temperature prior to storage and delivery. EFSA recommend that the storage and delivery temperature of pasteurised liquid egg products should not exceed 4°C (EFSA, 2014c). The shelf life depends on the product type and packaging: two or three days at 4°C for bulk-packaged liquid egg products for the food industry, and up to sixty days for small packages for catering establishments, or consumers in some countries. EFSA also suggest that dried egg products and those with high sugar or salt content are generally recommended to have a shelf life of several months at ambient temperature (EFSA, 2014c).

2.2.5.2. Liquid egg production

Figure 4 shows the steps in typical production of liquid egg.

According to the British Egg Processors Association (BEPA), eggs with shells are usually; washed, rinsed, sterilised, candled, broken, separated automatically and checked for quality and flaws. The liquid egg product is then filtered, usually pasteurised, and packaged (BEPA, 2024).

If not used immediately in further processing, the liquid egg products must be refrigerated for storage and transport. BEPA state that whole eggs and yolks can be stored for two to six days at 4.4°C, egg whites can be stored for two to six days at 7.2°C, depending on the microbial quality of the product (BEPA, 2024).

According to the European Egg Processors Association (EEPA), there are two critical control points (CCPs) in liquid egg product processing. The first CCP is filtration and transfer (after breaking and/or before pasteurisation and/or before packaging), where there is a risk of physical hazards, in particular the presence of shell in the product or other foreign particles. This is addressed via visual examination of the filter. The second CCP is heat treatment and cooling, due to the potential of pathogenic microorganisms surviving. For this CCP, the control parameters are time and temperature of the heat treatment, in order to obtain at least 7 $\log_{10}$ reduction of *Salmonella* Enteritidis for egg yolk and whole egg product (EEPA, 2011).

2.2.5.3. Dried egg production

Figure 4 shows the steps in typical production of dried egg.

According to BEPA, eggs with shells are usually; washed, rinsed, sterilised, candled, broken, separated automatically and checked for quality and flaws. The liquid whole eggs and yolks are then clarified, filtered and pasteurised before drying. Glucose is normally removed from egg whites before drying to preserve the white colour and stabilise the product (BEPA, 2024).

The United States Department of Agriculture (USDA) states that two main methods are used for drying; spray drying (atomised liquid egg product is sprayed into a stream of hot air) and pan drying (egg whites are dried on pans to produce a flake-type or granular material). Spray drying is much more common, as it extends product shelf life, whereas pan drying is generally restricted to confectionary production (USDA, 2015).

Additional substances may be added to the dried egg to improve its properties, e.g. sugar or salt. This ensures the dried egg does not solidify, and sodium lauryl sulphate may be added to egg white to ensure aeration on reconstitution (BEPA, 2024).

BEPA recommend that the dried egg products should be cooled and stored at <10^{o}C and kept sealed to prevent moisture ingress. Reconstituted egg should be stored at <10^{o}C, and used within four days (BEPA, 2024).

During dried egg product processing, there are three CCPs according to EEPA. One CCP is the drying of egg powders where there is a potential for contamination or survival of pathogenic microorganisms. The parameter

for control at this stage is the humidity of the powder with the aim to achieve a_w<0.7. The next CCP is for the packing of egg powders, where there is a risk of inclusion of foreign bodies. The monitoring procedure involves sieving and metal detection. The remaining CCP is pasteurisation of powders where there is a microbiological risk of the survival of pathogenic organisms. The parameters to control for this stage are the time and temperature of the heat treatment (EEPA, 2011).

2.2.5.4. Frozen egg products

According to BEPA, eggs with shells are usually; washed, rinsed, sterilised, candled, broken, automatically separated and checked for quality and flaws. The liquid whole eggs and yolks are then clarified and filtered, before freezing at –23.3 - –40°C (BEPA, 2024).

Whole eggs are often mixed with sugar or salt to prevent gelation during freezing and thawing. Whipping agents such as triethyl citrate can be added to egg white to improve whipping, and citric acid can be added to yolk or whole egg products to limit greening of the yolk (BEPA, 2024).

BEPA suggest that frozen eggs can be stored at <–12.2°C for many years, but once defrosted should be stored at 4.4°C - 7.2°C and used within three days (BEPA, 2024).

As the production of frozen egg products is the same as production of liquid egg with a freezing step, the CCPs are as outlined in section 2.2.5.2.

2.2.5.5. Cooked egg products

Cooked egg products may be produced from shell eggs, or from other egg products such as dried or liquid egg, and includes omelettes, scrambled egg and hard-boiled eggs.

These egg products are produced via industrial cooking processes. BEPA state that omelettes and scrambled eggs are packed into sealed containers, whereas hard boiled eggs are peeled then packed in a preservative solution of sodium citrate and 0.1% sodium benzoate or potassium sorbate to inhibit mould growth (BEPA, 2024). The cooked egg products should be stored either frozen or refrigerated, dependant on the manufacturer's instructions (BEPA, 2024).

2.2.5.6. Preserved eggs

Preserved eggs are a speciality in Asian countries, such as China, and modified traditional processing methods are often used to produce them. In China, fresh raw eggs are pickled in an alkaline solution that contains, salt, tea and metal ions such as copper, iron and zinc. The process takes place at room temperature and lasts for more than 40 days (Xue, Han, et al., 2022). Metals such as lead oxide used to be added to preserved

eggs to assist with the gelation of the egg, however this practice has been banned in China due to health concerns associated with lead (Xue, Han, et al., 2022).

2.3. Consumption

2.3.1. Consumption estimates of EEPs in the UK

Chronic and acute consumption estimates for egg 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 (Gov UK, 2013, 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 the data used is 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[3] data for foods containing ≥ 5% egg, including consumption of both whole eggs (e.g. boiled or fried eggs) and composite products containing EEPs (e.g. quiche, omelette and cake). While composite products are out of scope of this risk profile, this data is considered more representative of UK EEP consumption pattern. In addition, HMRC trade data (2019-2024) shows that that over 60% of EEPs imported into the UK are egg products rather than whole eggs, with egg products predominately used for onward processing into composite foods (HMRC, 2024a).

NDNS and DNSIYC food codes (and their definitions) used to estimate consumption are listed in Appendix I. Consumption estimates using these food codes show that infants (4-18 months) are the highest chronic consumers of eggs on a per kg bodyweight per day basis, consuming 1 g/kg/bw/d (mean) and 4.2 g/kg bw/d (97.5 percentile). Regarding acute consumption, again on a per kg bodyweight per day basis, the highest consumers are also infants (4-18 months) who consume 3.1 g/kg bw/d (mean) and 11 g/kg bw/d (97.5th percentile).

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3 Chronic consumption is calculated by taking the average amount of food/nutrient consumed per day by each person during the total survey period, while acute consumption is calculated by taking the highest amount of food/nutrient consumed in a day by each person during the survey period (EFSA, 2011c).

For consumption in g/person/day when comparing with the average weight of a medium or large egg (53g-63g and 63g-73g, respectively), high consumers (97.5th chronic) are estimated to eat 1-2 eggs per day depending on age group (BEIC, 2024b).

2.3.2. Consumer behaviour

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 NI (FSA, 2019). In the survey 75% of respondents reported eating cooked eggs at least once per week, including 8% reporting that they eat them every day. 86% of respondents reported never eating raw or uncooked eggs. No information on egg products was included within the report.

The DEFRA Family Food Dataset for UK Household Purchases in 2021 – 2022, shows that an average of 2 eggs were purchased per person per week in UK households. This is much lower than the UK consumption estimates provided from the NDNS and DNSIYC (Appendix I). This may be due to the reporting of purchasing rather than direct consumption or related to the averages taken for the DEFRA Family Food Dataset.

According to the exposure assessment in the FSA '*Salmonella* risk profile of UK-produced hen shell eggs', which used industry data, the consumption of eggs per person per year in 2021 was estimated to be 202 (FSA, 2023b).This has increased from 195 per person per year in 2016 and differs to the data reported from the DEFRA Family Food Dataset. This may be due to averages taken as part of the DEFRA Dataset per household.

2.4. Trade

2.4.1. UK Exports

Non-hatching eggs are traded under the trade codes 040721, 040729, 040790, 0408 and 350211 (as defined in section 2.1). UK EEPs export data was extracted from the UN Comtrade database (United Nations, 2024). The UK exports EEPs to over 75 countries, however 98.84% of total exported EEPs from the UK are imported by 15 countries.

A total of 137,821 tonnes (t) were exported from the UK 2016-2022. The majority (49,7000 t) were exported to the Netherlands, representing approximately 36% of the total export volume measured between 2016

and 2022. The second largest volume of exports was to Ireland (43,952 t, 32% of volume), followed by France (17,552 t; 13% of volume).[4] The 15 highest recipients of UK EEPs exports are summarised in Appendix II.

2.4.2. UK Imports

Import data from His Majesty's Revenue and Customs (HMRC) shows that between 2016 and 2022 the UK imported a total of 458,934 t of EEPs, representing an average of approximately 65,562 t of EEPs per year (HMRC, 2024a). Of all imported EEPs approximately 70% are egg products rather than whole eggs.

The top three countries that the UK imported most EEPs from were Netherlands (55.9%), Ireland (11.8%) and Germany (6.6%). Data on the 15 countries the UK imported the largest volume of EEPs from is presented in Appendix II.

2.4.3. Global Trade

Global export data was extracted from the UN Comtrade global database using the commodity codes listed above (section 2.4.1) for the period 2016-2022 (United Nations, 2024).

The top five countries exporting eggs globally between 2016 and 2022 in the order of the highest trade volume were India (17,000,280 t), Netherlands (3,649,581 t), Türkiye (1,772,048 t), Poland (1,748,527 t) and Malaysia (1,299,403 t). Data is presented in Appendix II.

3. Hazard identification

3.1. Methodology used for identifying hazards that can be found in EEPs

A systematic literature review method was followed for the data collection in relation to the identification of hazards that can be found in poultry EEPs. The process followed the PRISMA guidelines on data collection (PRISMA, 2020). Data synthesis and statistics were not in scope for this work.

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4 There are differences between the data reported by importing third countries and the UK export data resulting from trade asymmetries, hence these figures are based on the third country import figures, as these are considered more accurate. There are many potential causes of asymmetry, which may include differences in methods, valuation, and partner country assignment (HMRC, 2024b).

The primary question asked during the searches was “What hazards are found in poultry eggs or egg products that may pose a risk to human health?”.

Publications were included if they met any of the following criteria with respect to EEPs:

- Contained information on prevalence of human health related hazards
- Reported on results of surveillance or monitoring
- Risk assessments or exposure assessments discussing hazards

Publications falling within any of the categories below were not included:

- Method development studies that did not include a surveillance component
- Experimental studies in food or feed that involved artificial inoculation of the samples
- Articles discussing the effectiveness of policies on hazards elimination or control
- Articles discussing authentication of organic products
- Articles reporting on non-human health related hazards
- Articles reporting on interventions to control hazards in animals
- Articles that did not discuss incidence in any form
- Articles that were not accessible

To note, some of these papers were still considered for later stages in the work, e.g., for hazard characterisation or exposure pathways.

For certain hazard groups such as allergens and biocides the criteria were further defined as follows:

- Allergenicity of EEPs themselves was not in scope, although it is discussed briefly in later sections of this report. However, information on allergenic proteins from different species that can be found in EEPs were in scope

- Biocides approved for use in the food industry for cleaning and disinfecting purposes. It is expected that misuse of the products is the main way in which residues can be found in the food commodities. For this reason, the scope of the searches was broadened to cover experimental studies on how such substances can be transferred into EEPs

3.2. Literature review strategy

3.2.1. Database searches

A comprehensive search was conducted across EBSCO, Pubmed, Scopus and Springer using an FSA internal tool that can search all 4 databases simultaneously (FSA, 2024c). The databases were searched for publications between January 2000 and June 2024.

The search terms were structured so that the articles returned would be limited to incidence of human health related hazards that can be found in poultry EEPs. An example of how such a search term was used can be found below. Not all the terms were necessarily used in all searches.

Example of search terms:

[poultry AND egg* AND hazard AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption OR human health) NOT (eggplant OR parasite)]

More details on the search terms can be found in Appendix III. Searches were conducted for general hazards and for each of the relevant hazard groups as identified and discussed in the following sections of this report.

3.2.2. Article selection process

All articles returned by the searches were scanned for relevance to the scope of the risk profile. An article was included when:

1. The title or abstract included the word “egg”
2. After reading the abstract, the inclusion criteria described above were satisfied.

3.3. Creating the long hazard list

The long hazard list consisted of any hazard that was identified either via the literature reviews or FSA and FSS incidents and outbreak data or alert information included in the FSA Risk Likelihood Dashboard (RLD), Food

Akai or the FERA horizon scanning tool (FERA, 2024; FoodAkai, 2024; FSA, 2024e). EU and UK reports on monitoring levels of veterinary medicines and pesticides were also included.

3.3.1. Results of the literature review

Full articles included in step 3.2.2 were accessed and scanned for information on hazard incidence in EEPs. Once a hazard was identified as reported in eggs it was added to the long list of hazards, allocated a unique ID and grouped under one of the following hazard groups:

1. Agricultural contaminants (mycotoxins and plant toxins)
2. Allergens
3. Biocides
4. Environmental contaminants
5. Feed additives (added to the feed for purposes other than medicating the animals)
6. Food additives
7. Metals
8. Microbiological
9. Microplastics
10. Pesticides
11. Process contaminants
12. Radiological
13. Veterinary medicines

3.3.2. Food Safety Alerts

The FSA Risk Likelihood Dashboard which contains information on food alerts from the UK, Australia, Japan, FDA and EU (Rapid Alert System for Food and Feed (RASFF)) was scanned for alerts raised in relation to EPPs between January 2019 and June 2024. Any unique hazards identified were added to the long hazard list.

Food Akai and the FERA horizon scanning tool data were also scanned in the same way for the period January 2019 to June 2024 (FERA, 2024; FoodAkai, 2024).

3.3.3. FSA and FSS Incidents

FSA records for incidents and outbreaks involving EEPs since January 2013 and FSS records for incidents and outbreaks between January 2019 and June 2024 were scanned for unique hazards that were used to generate the long hazard list.

3.4. Shortlisting hazards for characterisation

The hazard longlist was refined prior to hazard characterisation to focus resources on hazards where there is evidence of concern in relation to EEPs. Hazards that are banned in the UK, were highlighted but not characterised as an assessment had led to the ban and no further information could be added at present. Hazards were also not taken forward for characterisation when it was concluded that not enough information was currently available to complete the task.

The shortlisting was conducted using the criteria in Table 2. In the event of any ambiguity during the shortlisting of a hazard, expert judgement was used to determine inclusion.

Table 2. Shortlisting criteria

Step	Criteria	Response	Action
1	Is the hazard a concern for human health?	No	Exclude
		Yes	Include
2	Has the hazard caused illness in humans, associated with the consumption of eggs?	No	Go to next step
		Yes	Include
3	Has the hazard been reported in alerts associated with EEPs?	No	Go to next step
		Yes	Include
4	Is the hazard controlled in eggs by regulation in the UK or EU? Is it regulated in poultry feed and specifically in feed intended for laying hens?	No	Go to next step
		Yes	Include
5	Is the hazard banned in the UK?	No	Go to next step
		Yes	Exclude
6	Is the hazard a concern primarily as a foodborne hazard?	No	Exclude
		Yes	Go to next step
7	Can EEPs be a primary food vehicle that leads to human exposure?	No	Exclude
		Yes	Include

Step	Criteria	Response	Action
Overall	Do we have enough information to characterise the hazard?	No	Exclude
		Yes	Include

To note for food additives, if they were approved under Reg. (EC) 1338/ 2008 for use in EEPs specifically they were excluded from further characterisation as they are expected to be found in the products they are approved for (European Parliament, 2008).

3.5. Hazard identification results

3.5.1. Long hazard list

3.5.1.1. Literature searches

The literature searches produced 1399 hits (after duplications removed). Of those, 1216 articles contained the word “egg” in the abstract. Articles that did not contain the word “egg” but instead contained the word “foods” or “foodstuffs” were checked to ensure relevant articles were not discounted, and 9 extra articles were selected. At the abstract scan stage 209 were considered to be relevant, although the full article content was not accessible for 32 of those publications. The rest were taken forward to the full paper assessment stage as shown in Figure 5. These papers fed into the long hazard list alongside the alert, incident and outbreak data and reports from regulatory sources such as EFSA, FAO etc . A total of 135 unique hazards were included in the long list.

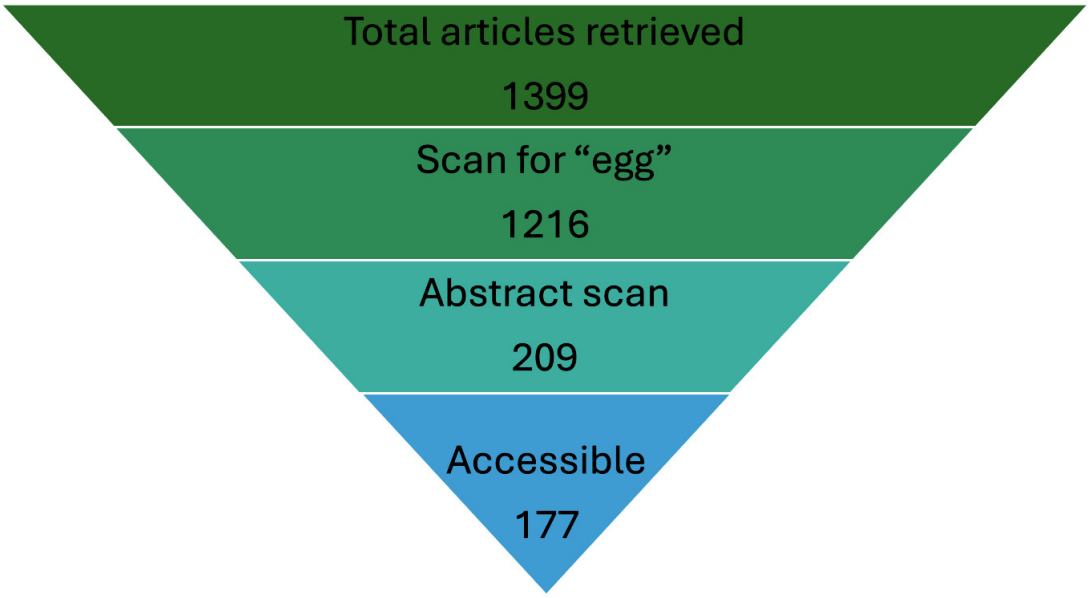

Figure 5. Number of articles that progressed through the four stages of selection and were used for generating the long hazard list

3.5.1.2. Outbreaks, Incidents and alerts

Food safety alerts and FSA and FSS incidents were also scanned to confirm relevance. Composite products were not in scope for this risk profile and therefore any alerts/ incidents referring to hazards in composite products were not included in the long hazard list. This principle was applied to the extent that the product was adequately described in the notification.

Table 3 contains data on the FSA and FSS incidents (notifications about non-compliance instances) reported between 2013 and 2024, noting any that also qualified as outbreaks (human cases reported). FSA records for incidents and outbreaks involving EEPs since January 2013 and FSS records for incidents and outbreaks since January 2019. Records from the onset of recording until June 2024 were scanned for this information, as per section 3.3.3. Alert data for 2019-2024 is also included; this information is obtained from the FSA Risk Likelihood Dashboard as per section 3.3.2, it includes food alerts from the UK, Australia, Japan, FDA and EU (RASFF).

3.5.2. Agricultural contaminants

Nine agricultural contaminants were identified as potential hazards in eggs during the literature review. The hazard detected most commonly was mycotoxins, specifically aflatoxins and ochratoxin A (OTA).

Aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2) are mycotoxins produced by fungi of the genus *Aspergillus* which are found especially in areas with hot and humid climates (EFSA, 2020b). OTA is produced by various fungi of the genus *Aspergillus* and *Penicillium* (EFSA, 2020b).

Several studies investigated the levels of aflatoxins and OTA in food of animal origin including eggs (Adegbeye, Reddy, et al., 2020; Keutchatang, Tchuenchieu, et al., 2022; Omar, 2021; L. Wang, Zhang, et al., 2018). Other mycotoxins, including fumonisins, patulin T2/HT2 and zearalenone, were discussed in papers relating to mycotoxins in food, however no specific evidence of detection in eggs was reported. One alert for mycotoxins in eggs was identified, however the nature of the mycotoxins was not specified.

Maximum legal limits for aflatoxins in poultry feed are set in GB and NI under regulations GB 2015/255 and 2002/32/EC respectively (European Parliament, 2002; Gov UK, 2002, 2015c). Other toxins, including OTA are recommended to be kept below specific limits in poultry feed in EU (2006/576/EC) (European Commission, 2006).

Table 3. Outbreaks, Incidents and alerts 2013-2024

Hazard name	Hazard group	Incidents (n)	Products reported in incidents	Outbreaks (n)	Incident occurrence (%)	Outbreak occurrence (%)	Alerts	Products reported within alerts (number of alerts)	Alert occurrence (%)
Salmonella	Pathogenic Micro-Organisms	44	Laying flock/ eggs (41), liquid eggs (3)	3	67	100	227	Eggs/ laying flock (205), Egg powder (11), Liquid egg (10), Cooked eggs (1)	91
Listeria	Pathogenic Micro-Organisms	0	NA	0	0	0	11	Eggs (1), Cooked eggs (8), other processed eggs - spicy quail eggs (2)	4
Clostridium botulinum	Biotoxins (other)	1	Laying flock/ eggs (1)	0	2	0	0	NA	NA
Cyromazine, Fipronil†	Pesticide Residues/ Biocides/ Veterinary Medicine Residues	2	Eggs (2)	NA	3	NA	1	Eggs (1)	0.4
Coccidiostats Lascolid, Enrofloxacin, Decoquinate, AOZ, Doxycycline, Flubendazole, Didecyl-methylammonium chloride	Veterinary Medicine Residues	8	Eggs (8)	NA	8%	NA	7	Eggs - including quail (5 - including 2 for quail), liquid pasteurised eggs (1), cooked eggs (1)	3
Dioxins, sulphites, fumes from diesel generator, elevated PH, formaldehyde	Environmental contaminants	5	Eggs (4), pickled eggs (1)	NA	6%	NA	4	Eggs (4)	2
Mycotoxins	Agricultural	1	Eggs	NA	1%	NA	0	NA	NA

Hazard name	Hazard group	Incidents (n)	Products reported in incidents	Outbreaks (n)	Incident occurrence (%)	Outbreak occurrence (%)	Alerts	Products reported within alerts (number of alerts)	Alert occurrence (%)
	contaminants								
Unauthorised hydrogen peroxide	Food additives & flavourings	5	Eggs (1), liquid eggs (4)	NA	6%	NA	0	NA	NA
Total	NA	66	Majority in laying flock or whole eggs	NA	NA	NA	250	Majority in laying flock or whole eggs	NA

†This incident involved the use of fipronil as a biocide

In addition to mycotoxins, evidence was found in the literature review that pyrrolizidine alkaloids (PAs) can be present in eggs (P. P. J. Mulder, López, et al., 2018). PAs are toxins exclusively biosynthesised by plants to provide a defence against herbivores. (EFSA, 2011a; FERA, 2014).

The information from the alerts, literature review, and regulations on poultry feed was sufficient to indicate that certain toxins should be subject to hazard characterisation, specifically aflatoxins, OTA and PAs will be characterised.

3.5.3. Allergens

There are 14 regulated allergens which must be declared if present in food. One of these is eggs, and hence any food containing eggs or egg products could pose a risk to allergic individuals (FSA, 2014). However, the allergenicity of EEPs themselves is out of scope for this profile, as it relates to the inherent properties of the proteins in the egg (Caubet & Wang, 2012), rather than a hazard which may be introduced to the egg or egg product.

Allergens could be introduced in EEPs either intentionally or unintentionally due to cross-contamination in the supply chain. The only allergen identified in the literature review or alerts was sulphur dioxide (sulphites), with alerts raised due to insufficient labelling. Under Reg. (EC) 1169/2011 sulphur dioxide must be declared as an allergen if the levels are above 10 mg/kg or 10 mg/litre (calculated in terms of the total sulphur dioxide (SO_2)) (European Parliament, 2011; Gov UK, 2011).

Sulphur dioxide will not be characterised in this context, as while allergens in general are a concern to consumers, there is no information that indicates insufficient labelling of allergens is a particular concern in EEPs when compared to other commodities.

Sulphur dioxide is authorised as a food additive in GB and NI (see section 3.5.6 for discussion).

3.5.4. Biocides

Biocides are substances which are intended to control harmful organisms via chemical or microbiological action (HSE, 2024b). Limited information was found in the literature review to indicate the presence of biocides in eggs.

In a review of the disinfectant usage in egg production in the UK, around 11 biocides or groups of biocides were identified, but levels of biocides in eggs were not reported (Wales et al., 2021).

Hydrogen peroxide was involved in an incident in the UK that affected egg products. Hydrogen peroxide is approved in assimilated Reg. (EC) 2015/1730 (European Commission, 2015; Gov UK, 2015a) in UK and NI for use in several biocidal product types (PT), including PT3 – veterinary hygiene disinfectants, and PT4 – food and feed disinfectants (HSE, 2024h, 2024d).

Hydrogen peroxide used in aseptic packaging evaporates before filling with food and no residues in food are expected (ECHA, 2015). Disinfected distribution systems for drinking water are also flushed before being refilled with drinking water. Subsequently, no MRLs are required for hydrogen peroxide as a biocidal product because it is not persistent, no systemic health effects are observed and because of its high reactivity (ECHA, 2015). As such, hydrogen peroxide has not been characterised.

Two pesticides identified in eggs, fipronil and chlorate, also have biocidal uses and residues detected in eggs are likely to have arisen from biocidal uses, so these chemicals have been characterised as biocides.

3.5.5. Environmental contaminants

The literature review identified several environmental contaminants associated with EEPs. The majority of these contaminants are persistent organic pollutants (POPs), which are defined as 'organic substances that persist in the environment, accumulate in living organisms and pose a risk to our health and the environment' (ECHA, 2024).

In the literature review, the most commonly identified hazards were dioxin and dioxin-like substances (polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and dioxin-like and non-dioxin-like polychlorinated biphenyls (PCBs) (BfR, 2010; Castellani, Manzoli, et al., 2021; EFSA, 2012c; Hoang, Traag, et al., 2014). They are predominantly present in the environment as a result of industrial processes (COT, 2010). Levels of dioxins and dioxin like PCBs are regulated in EEPs in GB and NI (GB 1881/2006) (EU 2023/915), and alerts have been raised in the UK and the EU for multiple instances of detection in eggs (European Commission, 2023a; Gov UK, 2006).

Per and polyfluorinated substances (PFAS) have been detected in eggs (DTU National Food Institute, 2023; Zafeiraki, Costopoulou, et al., 2016). 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 (COT, 2022a). Levels of four PFAS are regulated in eggs in the EU (NI) in Reg. (EC) 2023/915 (European Commission, 2023a).

Polychlorinated naphthalenes (PCNs) are a group of 75 chemicals of the class of chlorinated polycyclic aromatic hydrocarbons (EFSA, 2024f), some of which (PCN2-PCN8), are considered persistent organic pollutants (POPs)

under the Stockholm Convention (EFSA, 2024f). FERA investigated contaminants in specialty (non-chicken) eggs for sale in the UK, and detected PCNs in all of the samples (FERA, 2017a). EFSA concluded that eggs and egg products are a major contributor to PCN in the EU diet (EFSA, 2024f).

Organophosphate esters (OPEs) (also known as organophosphates (OPs)) have been detected in eggs (D. Li, Zang, et al., 2020). OPs are a group of chemical compounds widely used in pesticides, veterinary and human medicines, biocides, and more in recently fire retardants (COT, 1999, 2019). A review paper looking at OPE levels in food globally found levels in animal products, including eggs, were generally significantly lower than non-animal products (J. Li, Zhao, et al., 2019), and a study in the UK showed concentrations of OPEs in eggs were the lowest of all food groups (Gbadamosi et al., 2022).

Melamine has also been detected in poultry eggs (Alizadeh, Hosseini, et al., 2023). Melamine is used mainly in the synthesis of resins for manufacturing (WHO, 2008). It is also a metabolite of the pesticide cyromazine (EFSA, 2010c). Maximum legal levels for melamine are set in all foods in GB and NI under assimilated Reg. (EC) 1881/2006 and Reg. (EC) 2023/915 (European Commission, 2023a; Gov UK, 2006).

Limited information was also found in the literature review about the presence of chlorinated paraffins (CPs) in eggs (Ding, Zhang, et al., 2021). EFSA undertook a risk assessment for CPs which found fish, and liver and fatty tissue of mammals to have significantly higher levels than eggs (EFSA, 2020c).

The information from the alerts, literature review, and regulations was sufficient to indicate that certain environmental contaminants should be subject to hazard characterisation, specifically dioxins and dioxin-like substances, PCBs, PFAS, PCNs, and melamine.

3.5.6. Food additives

Food additives are substances which are added to food to perform a specific technological function, exerting an effect on a food. They include colours, stabilisers, preservatives and sweeteners (FSA, 2024b). The definition of a food additive is given in retained Reg. (EC) No 1333/2008 as "*any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food, whether or not it has nutritional value, the intentional addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result, in it or it's by-products becoming directly or indirectly a component of such foods*" (European Parliament, 2008).

Limited information was found in the literature review to indicate food additive residues may be present in egg and egg products.

One paper was identified which showed that benzoic acid, potassium sorbate, sodium benzoate, sodium sorbate, sorbic acid and sulphur dioxide/sulphites were detected in samples of egg products (D. Li, Zang, et al., 2020). All of the food additives detected in the study are approved preservatives in processed foods in UK under assimilated Reg. (EC) 1333/2008 with the exception of sodium sorbate (European Parliament, 2008; Gov UK, 2008).

Alerts due to undeclared sulphur dioxide were identified for preserved duck eggs, quail eggs in vinegar, and in eggs (unspecified) due to insufficient labelling as sulphur dioxide is an allergen (see section 3.5.3).

The permissible additives have not been considered in the hazard characterisation. Sodium sorbate has not been considered in the hazard characterisation as there is very limited evidence of presence in eggs, and no evidence to suggest that egg is a primary vehicle for this hazard.

3.5.7. Feed additives

Feed additives are defined under Reg. (EC) 1831/2003 as substances which are deliberately added to feed to perform functions such as meeting nutritional requirements, improving feed quality, animal performance and productivity (European Parliament, 2003). Results were found in the literature review for feed additives with cyromazine, lasalocid, maduramicin, monensin, narasin, nicarbazin, salinomycin and semduramicin reported in egg and egg products.

Cyromazine is an insecticide (also a pesticide or a veterinary medicine for some animals other than poultry), it has not been considered in the hazard characterisation for feed additives as there is very limited evidence of presence in eggs, and no evidence to suggest that egg is a primary vehicle for this hazard. Cyromazine is not authorised for use in poultry GB or NI (European Commission, 2024b; FSA, 2023a).

The remaining feed additives are all antiprotozoal agents - coccidiostats and histomonostats, used for the treatment of poultry coccidiosis (an intestinal infection) and histomoniasis (an infection of the liver and cecum) (ACAF, 2007). Antiprotozoal agents are predominately regulated as feed additives in the UK, although some are also regulated as veterinary medicines (European Commission, 2009c, 2009b; Gov UK, 2009b, 2009a). For consistency they are considered together with veterinary medicines in the hazard identification and hazard characterisation.

3.5.8. Metals

Heavy metals such as lead, arsenic, cadmium and mercury are present naturally in the environment (EFSA, 2024d). Human activities such as farming, industry or pollution can increase the levels of metals in the environment. Contamination of the food chain by metals might occur from the environment or during food processing and storage (EFSA, 2024d).

The literature search indicated that a range of metals, including mercury (Hg), antimony (Sb), arsenic (As), cadmium (Cd), lead (Pb), copper (Cu), nickel (Ni), chromium (Cr), manganese (Mn) and selenium (Se) may be present in egg and egg products. Several studies show metals including Pb, Cd, As, Hg, Cu, Ni and Cr are present in eggs (Iqbal et al., 2023; Kabeer, Hameed, et al., 2021; Salar-Amoli & Ali-Esfahani, 2015; Zergui et al., 2023).

A number of metals (lead, cadmium, mercury, arsenic, tin) are controlled in a range of commodities with prescribed maximum levels (MLs), however there are no MLs for metals in eggs (GB 1881/2006) (EU 2023/915) (European Commission, 2023a; Gov UK, 2006).

The information available was sufficient to indicate that metals in eggs should be subject to hazard characterisation. Arsenic, cadmium, chromium, mercury and lead were identified for hazard characterisation based on evidence of their presence in eggs and their higher toxicological concern (Tchounwou, Yedjou, et al., 2014).

In addition, copper and selenium were identified for hazard characterisation as they can pose a human health risk at certain levels, and specific concerns related to their presence in eggs have been identified. Selenium is regulated in animal feed in Reg. (EU) 2022/1459 (European Commission, 2022a) and eggs are a significant contributor to human exposure (EFSA, 2024c). Copper is used as a plant protection product (PPP) which has been implicated in eggs in alerts (EFSA, 2023b).

3.5.9. Microbiological hazards

Several microbiological hazards were identified in the literature review. *Salmonella* was the most frequently reported in a large number of papers and identified in the highest number of incidents and alerts for both *Salmonella* Typhimurium (1/195) and *Salmonella* Enteritidis (31/195) over the last 5 years. The Salmonella serovar was not always identified in the alerts. In 2016, the ACMSF undertook a risk assessment of *Salmonella,* in eggs and concluded that it was the microorganism, primarily Enteritidis, of most significant concern with respect to egg content contamination (ACMSF, 2016). EFSA concluded in 2014 that *Salmonella* Enteritidis was the only pathogen currently posing a major risk of egg-borne diseases in the

EU, with S. Tymphimurium rarely being associated with eggs in Europe (EFSA, 2014c). In the same report, EFSA concluded that S. Typhimurium may be of more relevance in ducks.

Listeria monocytogenes was also identified as a microorganism of concern in eggs in the literature review. EFSA report studies indicated the presence of *L. monocytogenes* in caged hen flocks and noted its ability to contaminate eggshells and its presence in liquid eggs at breaking plants (EFSA, 2014c). Other studies also show that *Listeria monocytogenes* are often present in egg breaking plants, for example one study showed that 8.5% of raw egg products were contaminated (Rivoal, Fablet, et al., 2013). Egg associated outbreaks of *L. monocytogenes* are not frequently reported, however, an outbreak in the USA in 2017-2019 resulted in multiple human cases and 1 death (CDC, 2020). The implicated product was hard boiled eggs intended for food processors and restaurants.

Campylobacter is also considered by EFSA to present a concern with regard to EEPs. They report studies indicating that *Campylobacter* can be present on egg shells as well as studies showing presence in raw egg products (EFSA, 2014c). *Campylobacter* are prevalent in many domestic animals including cattle, sheep and pigs but their main reservoir is live poultry, including chicken, ducks, geese, turkeys and ostriches (Sahin et al., 2002). Recent studies have reported a prevalence of *Campylobacter* on eggshells up to 94.6% depending on the housing of the birds (Casalino, Bozzo, et al., 2022; Gharbi, Bejaoui, et al., 2022).

For the other microbiological hazards identified, such as *Bacillus* spp, *Escherichia coli* and *Cronobacter sakazakii*, there was minimal information available in the literature review. As a result, the hazards were excluded from characterisation primarily based on eggs not being a primary food vehicle for human exposure. The only other microbiological hazards considered for characterisation was *Clostridium botulinum* and Avian Influenza. *C. botulinum* was implicated in an incident in the UK in which over 150 laying hens died, however there is no evidence of any transfer to egg and egg products for consumption. Regarding Avian Influenza, a recent FSA risk assessment indicated that poultry products represent negligible (chicken and turkey) to low (ducks and geese) risk and no further information has been available since the publication of this assessment (FSA, 2024d).

Therefore, *Campylobacter* spp, *L. monocytogenes*, and *Salmonella* spp are the microbiological hazards identified for characterisation in EEPs.

3.5.10 Microplastics

Plastic pollution has been widely recognised as a global environmental problem. However, the potential risks from exposure to smaller plastic particles i.e., micro- and nano-plastics in humans are yet to be fully understood (COT, 2021a). There is no international definition for microplastics (COT, 2021a; EFSA, 2016a). The Committee on Toxicity (COT) describes microplastics as *"synthetic particles or heavily modified natural particles with a high polymer content that are submicron-mm in size (0.1 to 5,000 µm or micrometres)"* (COT, 2021a). In Europe, European Chemicals Agency (ECHA) defines microplastics as *"particles containing solid polymer, to which additives or other substances may have been added, and where ≥ 1% w/w of particles have (i) all dimensions 0.1µm ≤ x ≤ 5mm, or (ii) a length of 0.3µm ≤ x ≤ 15mm and length to diameter ratio of >3"* (European Chemicals Industry Council, 2020).

Microplastics can be divided into two categories as: primary microplastics, intentionally produced in micro size for certain purposes (e.g., microbeads in cosmetics) and secondary microplastics formed in the environment due to fragmentation of larger pieces of plastic (e.g. plastic bags) (COT, 2021a). Secondary microplastics over the course of time can be fragmentated into smaller particles to form nanoplastics (EFSA, 2016a).

EFSA state that currently available data indicates presence of microplastics in seafood, beer, honey and table salt (EFSA, 2016a). No data was reported for eggs, even though eggs were targeted in their search terms (EFSA, 2016a).

One publication showed the average content of microplastics in hen eggs sampled to be 11.67 particles/egg, with most particles being spherical and 50-100µm in size. More microplastics were found in the egg yolk than the egg white, which the authors attribute to microplastics being lipophilic (Liu, Chen, et al., 2022).

No incidents related to microplastics in eggs were reported during the timeframe in scope, and microplastic levels are not regulated in eggs. Particulates in general are a potential risk to consumers although there is no information suggesting that eggs are 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 therefore a conclusion on consumer risk related to eggs could not be reached. Therefore micro/nano plastics were not characterised, but their presence in eggs cannot be ruled out.

3.5.11. Radionuclides

Radionuclides, also known as radioactive materials or radioactive isotopes, are unstable forms of elements that emit radiation as they undergo radioactive decay (Gov UK, 2024a). Natural radionuclides detected in eggs in Europe include, K-40, U-238, Ra-226, Pb-210, Po-210 and Th-228 (Cinelli, De Cort, et al., 2019).

Studies on radionuclide contamination in eggs have focussed on Ra-226 and Cs-137 as these are the most commonly identified types (Fathabadi, Salehi, et al., 2017; Shah & Abdeljawad, 2024). Ra-226 is a natural radionuclide formed in the U-238 decay series, and hence is present in many foods, drinking water and dust (which can be inhaled). Cs-137 is an artificial radionuclide, present in the environment as a result of authorised or accidental release from the nuclear power industry or weapons testing (Cinelli, De Cort, et al., 2019).

A study on levels of radionuclides following the Chernobyl incident showed Ba-140 and Li-140 were the main radionuclides detected in the shell after the chickens were fed with contaminated grass (Cosma, 2002).

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, to estimate the amount of radioactivity the public is exposed to. In the most recent report for 2022 eggs were shown in most cases to have levels below detection limits (CEFAS, 2022).

In summary some radionuclides have been detected at trace levels in eggs including those such as Cs-137 that are derived from nuclear discharge and weapons testing, and others that are present naturally.

No incidents related to radionuclides in eggs were reported during the timeframe in scope. Radionuclides in food are controlled under assimilated Council Reg. (Euratom) 2016/52, with levels for EEPs covered by ‘Other food except minor food’ (Gov UK). Radionuclides in general are a potential risk to consumers although there is no information suggesting that eggs are of particular concern when compared with other commodities. Therefore, radionuclides will not be characterised.

3.5.12. Pesticides

Pesticides include insecticides, fungicides and herbicides, which are used to control pests, weeds and diseases (HSE, 2024g).

The use of pesticides is widespread and varied. From the literature review, 28 pesticides were identified in eggs, with four (chlorate, chlordecone, cyromazine, and fipronil) specifically implicated in alerts, incidents and monitoring. Pesticide residues in food are controlled according to maximum residue levels (MRLs) in GB and NI (assimilated Reg. (EU) 396/2005) and there is evidence that pesticide residues may exceed MRLs in eggs (European Parliament, 2005; Gov UK, 2005). According to the 2021 UK quarterly surveillance results on pesticide residues in food, one non-compliant egg sample with an MRL exceedance was reported, giving a non-compliance rate of 0.76% (1 out of 132 egg samples) in 2021 (DEFRA, 2022a).

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

3.5.13. Veterinary medicines

Veterinary medicines products (VMP) are substances used for the treatment or prevention of disease, or altering physiological functions in animals (CEFAS, 2024). From the literature review, around 28 VMP residues (including those reported as feed additives) were detected in eggs.

In the feed additives section (3.5.7), those in scope are antiprotozoal agents - coccidiostats and histomonostats. These are predominately regulated as feed additives in GB and NI (under assimilated Reg. (EC) 124/2009), but some are also regulated as veterinary medicines in GB and NI (under assimilated Reg. (EC) 37/2010), and there is inconsistent reporting of incidents and alerts for these substances (European Commission, 2009c, 2009b; Gov UK, 2009b, 2009a). For consistency, both veterinary medicines and antiprotozoal feed additives are considered together in this section.

VMP residues in food and feed are controlled according to MRLs in GB (VMD, 2024b) and NI (European Commission, 2009c). The UK and EU undertake an annual monitoring programme for VMP residues in food. Non-compliance in eggs where levels of VMP residues exceeded the MRLs were reported.

The annual non-compliance rates for coccidiostats in the UK were between 0.0% - 0.61 % from 2019 to 2023, with an average of approximately 700 samples analysed per annum. For other VMPs, the annual non-compliance rates were between 0.0% - 0.072 % from 2019 to 2023, with an average of approximately 1,500 samples analysed per annum (VMD, 2024d).

According to the EU annual reports on VMP residues (2019-2021), the annual non-compliance rates for antibacterial substances in eggs were between 0.17-0.26%, with approximately 5,500 samples per annum. The non-compliance rates for anticoccidials in eggs from 2019-2021 were between 0.21 - 0.42% with approximately 5500 samples per annum (EFSA, 2024b).

Residues of a range of veterinary medicines can be detected in eggs. These may be at levels exceeding the MRL or they may be not authorised for use in laying hens or poultry. 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 unauthorised in eggs.

3.5.14. Hazards shortlisted for characterisation

The 135 unique hazards on the long hazard list were taken through the shortlisting process described in Table 2. A total of 22 individual hazards or hazard groups as shown in Table 4 were selected for characterisation.

Table 4. Hazards in eggs for characterisation

Hazard Group	Hazards for Characterisation
Agricultural contaminants	Aflatoxins, OTA, PAs
Biocides	Chlorate, fipronil
Environmental contaminants	Dioxins and dioxin-like substances, PCBs, PFAS, PCNs, melamine
Feed additives	Feed additives included with veterinary medicines
Metals	Arsenic, cadmium, chromium, copper, mercury, lead, selenium
Microbiological	*Campylobacter* spp, *Listeria monocytogenes, Salmonella* spp
Pesticides	Pesticide residues exceeding MRLs
Veterinary medicines and feed additives	Veterinary medicines and coccidiostats and histomonostats used as feed additives exceeding MRLs or not permitted for use in laying hens

4. Hazard characterisation

4.1. Agricultural contaminants

The agricultural contaminants shortlisted for characterisation are mycotoxins (aflatoxins, and OTA) and plant toxins (PAs). Conclusions on the concerns regarding the potential agricultural contaminant presence in EEPs are presented in section 4.1.4.

4.1.1. Aflatoxins

4.1.1.1. Hazard route

Aflatoxins are mycotoxins produced by two species of *Aspergillus*, a fungus found especially in areas with hot and humid climates (EFSA, 2024a). Humans can be directly exposed to aflatoxins through foods such as nuts and rice as a result of fungal contamination. Animals can be exposed through feed, leading to the presence of aflatoxins in products of animal origin (EFSA, 2020b).

Animal feeds such as extracted copra, peanut cake, sunflower cake, corn gluten, rice bran, cotton seed, palm kernel and soybeans were identified by EFSA as significant carriers of aflatoxins, in particular AFB1 in feed materials. The likelihood of contamination of the feed materials relates to the geographic origin (i.e., humidity and high temperature) (EFSA, 2004a). Aflatoxins do not bioaccumulate in fatty tissue, as such accumulation in the egg has only been identified under experimental conditions with extremely high aflatoxin concentrations in the feed. Under less extreme conditions, a carry-over into the eggs is unlikely (BfR, 2013).

A review paper was published by MacLachlan in 2011 to estimate the transfer of contaminants in animal feedstuffs to certain food products. The transfer factor was calculated by dividing residue concentration measured in the animal commodity of interest (in this case, eggs) to the residue concentration measured in the animal diet, including any contribution from ingested soil. Transfer factors for AFB1 from animal feeding stuffs into chicken eggs and quail eggs were reported as 0.00042 and 0.0005 respectively (MacLachlan, 2011).

4.1.1.2. Hazard characterisation

The International Agency for Research on Cancer (IARC) classified aflatoxins as Group 1 Carcinogens: Carcinogenic to humans (IARC, 2024). Aflatoxins are rapidly absorbed; distribution and accumulation is in the liver where the major metabolism and toxicity takes place (EFSA, 2020b). Aflatoxins can pass through the placenta in humans, and in experimental animals, metabolites of aflatoxins were found in the liver of foetus and mother (EFSA, 2020b).

Different potency for carcinogenesis were identified for aflatoxins, however due to insufficient data to derive cancer potency factors, EFSA assumed the carcinogenic potency of AFB1/2 and AFG1/2 to be similar to AFB1 (EFSA, 2020b). Both the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and EFSA did not consider it appropriate to establish a health-based guidance value (HBGV) due to genotoxic carcinogenicity (EFSA, 2020b; JECFA, 2016). EFSA derived a benchmark dose lower confidence limit (10%) ($BMDL_{10}$) value of 0.4 µg/kg based on hepatocellular

carcinoma incidence in rats. They adopted a margin of exposure (MOE) approach, which indicates that an MOE of 10,000 or higher would be of low health concern (EFSA, 2020b).

A summary of the levels of aflatoxin in EEPs identified in the literature, are given in Appendix V, with AFB1 detected at levels up to 168 µg/kg in whole egg (L. Wang, Zhang, et al., 2018). A study on prevalence, level and health risk assessment of mycotoxins in fried poultry eggs showed that the maximum level of AFB1 in the egg yolk was 1.45 µg/kg and in the egg white was 1.23 µg/kg (Omar, 2021), suggesting a similar distribution across the yolk and white.

No maximum level (MLs) have been set for aflatoxins in eggs and egg products. The MLs in assimilated Reg. 1881/2006 and Reg. (EU) 165/2010 for total aflatoxins (sum of AFB1, AFB2, AFG1 and AFG2) for specified foodstuffs (e.g. groundnuts, cereals) range between 4 - 15 µg/kg (European Commission, 2010; Gov UK, 2006).

4.1.2. Ochratoxin A

4.1.2.1. Hazard route

Ochratoxins are mycotoxins produced by various fungi of the genus *Aspergillus* and *Penicillium*, e.g., *A. ochraceus, and P. verrucosum* which grow in hot and humid areas. Humans can be directly exposed to OTA through food such as grains and dried fruit as a result of fungal contamination, or animals can be exposed through feed, leading to the presence of OTA in products of animal origin (EFSA, 2020b, 2020c). OTA can be found in modified forms. Due to the altered structures of the modified OTA, detection by the analytical methods aimed at the parent toxins may not be successful. However, these modified forms may contribute to the overall exposure and toxicity (EFSA, 2020c).

OTA is frequently present in the feed of food-producing animals (EFSA, 2020c). In the 2004 EFSA review, it was reported that chickens absorb approximately 40% of OTA after exposure, however later data included in the 2023 EFSA review indicated higher bioavailability (99% absorption) in laying hens (EFSA, 2004b, 2023d). Metabolites in poultry are mainly eliminated through excreta (EFSA, 2023d). Poultry species appear to eliminate OTA faster than monogastric mammalian species, resulting in a low OTA accumulation in the blood and tissues (EFSA, 2023d).

Transfer of OTA from feed to eggs is negligible (up to 2 mg OTA/kg of feed) and only occurs when OTA intake is very high (OTA at 10 mg/kg bw) (EFSA, 2023d). It was estimated that 0.11% of OTA in feed was transferred to eggs (EFSA, 2023d).

4.1.2.2. Hazard characterisation

IARC classified OTA as Group 2B: Possibly carcinogenic to humans (IARC, 2024). Kidney toxicity in different animal species and kidney tumours in rodents were reported with OTA exposure, and were selected as critical endpoints (EFSA, 2020d; JECFA, 2007). OTA is genotoxic both *in vitro* and *in vivo*; however, the mechanisms of genotoxicity are unclear. Direct and indirect genotoxic (e.g., oxidative stress) and non-genotoxic modes of action might contribute to tumour formation.

Due to uncertainty regarding the mode of action for kidney carcinogenicity, it is inappropriate to establish a HBGV and an MOE approach was applied by EFSA. For non-neoplastic effects, a $BMDL_{10}$ of 4.73 µg/kg bw/day was calculated from kidney lesions observed in pigs, and an MOE of 200 being of low health concern (EFSA, 2020c). For neoplastic effects, a $BMDL_{10}$ of 14.5 µg/kg bw per day was calculated from kidney tumours seen in rats with an MOE of ≥ 10,000 being of low health concern (EFSA, 2020c).

A summary of the levels of OTA in EEPs identified in the literature are given in Appendix V, with OTA detected at levels up to 2 µg/kg in the whole egg (Adegbeye, Reddy, et al., 2020; Keutchatang, Tchuenchieu, et al., 2022).

No MLs have been set for OTA in eggs and egg products. The MLs in assimilated Reg. (EU) 1881/2006 and Reg. (EU) 2022/1370 for OTA for certain foodstuffs (e.g. spices, cereals) range between 0.1 – 80 µg/kg (European Commission, 2022c; Gov UK, 2006).

4.1.3. Pyrrolizidine alkaloids

4.1.3.1. Hazard route

PAs are toxins exclusively biosynthesised by plants; more than 660 different PAs have been discovered. It has been estimated that approximately 6,000 plant species worldwide, may contain PAs such as *Asteraceae* (e.g., gordolobo yerba) and *Fabaceae* (e.g., borage) (COT, 2008; FSA, 2020). PA concentrations are expected to be higher when nutrient availability is low and increasing soil moisture might lead to higher PA-concentrations in the roots (Codex, 2014).

In the review by EFSA, bee derived products (e.g., honey) were the only foodstuffs of animal origin assessed, due to a lack of comprehensive studies for other animal products (EFSA, 2011a). PAs or their metabolites may indirectly contaminate eggs following exposure of poultry to PA-contaminated feed or if PA sources are present in forage fields. However, exposure to PAs from eggs is at a significantly lower level compared to plant-originated foodstuffs (e.g., herbs and spices) (EFSA, 2007b).

Based on the limited information, carry-over of PAs from animal feed into eggs was reported to be approximately 1% (EFSA, 2011a). Different PAs were shown to be transferred in different ratios into the eggs; this was investigated in a study by Eroksuz et al (2008), from which [EFSA] calculated transfer ratios of PAs into eggs between 0.22-1.08%, depending on the PAs (EFSA, 2011a; Eroksuz, Ceribasi, et al., 2008).

Different transfer ratios of PAs were reported in another feeding study in laying hens, using herbs with different PA profiles (P. Mulder, de Witte, et al., 2016). Overall transfer rates for the sum of PAs were estimated between 0.02% and 0.23%, depending on the type of PAs in the feed. The study also reported that PAs were mostly accumulated in yolk, due to the 10-day yolk formation compared to 1-day egg white formation at a later stage and steady-state transfer of PAs into eggs (P. Mulder, de Witte, et al., 2016).

4.1.3.2. Hazard characterisation

PAs have a common toxicity profile with the liver being the main target organ of toxicity. IARC has classified three PAs, lasiocarpine, monocrotaline and riddelliine, as Group 2B, 'possibly carcinogenic to humans' and other PAs as Group 3, "not classifiable as to its carcinogenicity to humans" due to the limited information available (Codex, 2014; IARC, 1987).

EFSA concluded that 1,2-unsaturated PAs may act as genotoxic carcinogens in humans based on the available knowledge and assessed the sum of 1,2-unsaturated PAs together, assuming equal potency. A $BMDL_{10}$ for excess cancer risk of 237 µg/kg bw/day for induction of liver haemangiosarcomas by riddelliine in female rats was calculated as the reference point for comparison with the estimated dietary exposure (EFSA, 2017a). EFSA recommended an MOE approach for cumulative chronic exposure levels of PAs, and determined that an MOE of 10,000 or higher, is of low concern from a public health perspective (EFSA, 2017a).

A study was conducted in Europe with a total of 1,105 samples collected. These comprised milk and milk products, eggs, meat and meat products, teas, and food supplements collected in supermarkets, retail shops, and via the internet. PAs were detected at 0.10–0.12 µg/kg PAs in 1% of egg samples (2 out of 205 egg samples) (P. P. J. Mulder, López, et al., 2018).

Reg. (EU) 2023/915 and assimilated Reg.(EU) 2020/2040 in GB has set MLs for 21 different PAs in food for plant origin (except pollen-based food supplements, pollen and pollen products) in a range of 1 – 1,000 µg/kg (European Commission, 2023a; Gov UK, 2020b). No MLs were defined for any food of animal origin, including eggs.

Directive 2002/32/EC specifies the MLs of contaminants in feed (European Parliament, 2002; Gov UK, 2002). No MLs were set specifically for PAs but Section VI specifies MLs for botanical impurities, such as weed seeds and unground and uncrushed fruits containing alkaloids, glucosides or other toxic substances separately or in combination (3,000 mg/kg).

4.1.4. Conclusion

Mycotoxins (aflatoxins, OTA) and PAs can contaminate feed and result in poultry exposure. Hot and humid climates are risk factors for aflatoxin and OTA formation in feed (EFSA, 2004a). PA concentrations in feed are expected to be higher when nutrient availability is low and increasing soil moisture might lead to higher PA-concentrations in the roots (Codex, 2014). Due to the metabolism and elimination of these agricultural contaminants by poultry, transfer from feed into eggs is limited. Generally experimental studies showed that, unless maximum levels in feed are exceeded, there is low concern for transfer into eggs. No MLs were set for mycotoxins or PAs in eggs.

There are concerns relating to genotoxicity and carcinogenicity for the specified mycotoxins and PAs, and they are generally assumed to have no safe threshold. Therefore, if aflatoxins, OTA or PAs are found to be present in eggs, there may be a concern for consumer health and further assessment would be required.

4.2. Biocides

The biocides that were shortlisted for characterisation were fipronil and chlorate. A conclusion section on biocides follows the individual hazard characterisation sections (4.2.14.2.2).

4.2.1. Fipronil

4.2.1.1. Hazard route

Due to its insecticidal properties, fipronil is also used as a veterinary medicine and a biocide. It is currently authorised as a veterinary medicine in GB and NI for the control of fleas in domestic animals, there are no approved uses on livestock, including chickens (VMD, 2024c). Fipronil is currently authorised as biocide in GB for use as an insecticide and acaricide (PT18) (HSE, 2024c). Residues of fipronil in eggs may also arise from the use of fipronil as an insecticidal pesticide, however it has not been approved as a pesticide in GB and the EU since 2018 (European Commission, 2016).

EFSA concluded that the residues of fipronil detected in eggs in the 2019 monitoring were as a result of illegal use as a biocide or veterinary medicine, rather than from pesticide usage (EFSA, 2021c). In 2017 there

was a large scale incident in which fipronil was detected in EEPs in over 45 countries, due to the illegal use of fipronil as a mite treatment for chickens (European Commission, 2018b).

4.2.1.2. Hazard Characterisation

Fipronil is toxic by oral, inhalation and dermal acute exposure. Adverse effects in the central nervous system, liver and thyroid were identified in short term studies. EFSA set an Acceptable Daily Intake (ADI)of 0.0002 mg/kg bw/day, and an acute reference dose (ARfD) of 0.009 mg/kg bw (EFSA, 2006).

Appendix VIII summarises the levels of fipronil detected in the literature and alerts. Levels of fipronil in food are controlled via pesticide MRLs under Reg. (EU) 396/2005, with a MRL of 0.005* mg/kg in place for eggs, where * denotes the MRL is set at the limit of quantification (LOQ) (European Parliament, 2005; Gov UK, 2005).

4.2.2. Chlorate

4.2.2.1. Hazard Route

Chlorate is a by-product or residue of chlorine based disinfectant usage in drinking water, irrigation, food processing and veterinary hygiene, which may lead to residues in foods, including eggs. (FERA, 2017b). Chlorine dioxide is currently authorised as biocide in GB for use as an disinfectant (PT02-PT05) (HSE, 2024c). Residues of chlorate in eggs may arise from the use of the herbicide sodium chloride, however this pesticide has not been approved in GB and the EU since 2008 (FERA, 2017b).

4.2.2.2. Hazard Characterisation

Chronic exposure to chlorate can inhibit iodine uptake, potentially leading to iodine deficiency, EFSA have set a Tolerable Daily Intake (TDI) of 3 µg/kg bw/day. Acute exposure can limit oxygen absorption from the blood leading to kidney failure. EFSA set an ADI of 36 µg/kg bw/day derived from a No Observed Adverse Effect Level (NOAEL) (EFSA, 2015a).

Appendix VIII summarises the levels of chlorate detected in the literature and alerts. Levels of chlorate in food are controlled via pesticide MRLs under Reg. (EU) 396/2005, with a MRL of 0.05 mg/kg in place for eggs (European Parliament, 2005; Gov UK, 2005). Chlorate MRLs are set at a level which accounts for the potential for food to come into contact with chlorate residues via routes such as drinking water or processing, and that contribution to the measured level from these sources should be taken into account (Reg. (EU) 2020/749) (European Commision, 2020; Gov UK, 2020a).

4.2.3. Conclusion

Cases of non-compliance of fipronil and chlorate have been detected in eggs (when compared to MRLs for these substances set under pesticide regulations) which may arise from their use as biocides. There are potential adverse effects which may result from exposure to residues of these substances. The presence of residues of these chemicals in eggs at levels exceeding the MRL, may require further action in the form of a risk assessment to determine the risk to consumer.

4.3. Environmental Contaminants

The environmental contaminants shortlisted for characterisation are dioxins and dioxin-like substances, PCBs, PFAS, PCNs and melamine. Conclusions on the concerns regarding the potential environmental contaminant presence in EEPs are presented in section 4.3.5.

4.3.1. Dioxins, dioxin-like substances and PCBs

4.3.1.1. Hazard route

Dioxins are a group of 75 PCDD and 135 PCDF related chemicals that occur naturally and are widely present in the environment, although mainly as unwanted byproducts of combustion and of various industrial processes (COT, 2010).

PCBs are not natural substances; they were globally manufactured and used until prohibition of manufacture in the late 1980s (EFSA, 2010a; WHO, 2019). PCBs can contaminate the environment from materials (e.g., paint) or waste sites containing PCBs (EFSA, 2010a). PCBs can be divided into dioxin like PCBs (DL-PCBs) which exhibit similar biological activity to dioxins, and non-dioxin like PCBs (NDL-PCBs).

PCBs, PCDDs and PCDFs are listed under the Stockholm Convention, as POPs (Stockholm Convention, 2019).

When released into the air, dioxins and DL-PCBs are deposited on plants and on soil, consequently contaminating both food and feed (Codex, 2018). Through transfer from animal feed, dioxins and DL-PCBs accumulate in tissues and can be excreted in fat-containing products such as milk and eggs (Codex, 2018; RIVM, 2019). In laying hens, dioxins and DL-PCBs may concentrate in the fat content of the egg yolk (Codex, 2018).

EFSA reported that the highest mean contamination level of NDL-PCBs was observed in fish and fish derived products followed by eggs in an analysis conducted from samples in northern Europe (EFSA, 2010a).

4.3.1.2. Hazard characterisation

Dioxins and DL-PCBs

IARC classified PCDDs, PCDFs and DL-PCBs as Group 1: Carcinogenic to humans (IARC, 1997, 2015). COT assessed dioxins and DL-PCBs in 2001 and concluded that the health effects most likely to be associated with low levels of exposure relate to the developing embryo/foetus and concluded that there is the potential for a range of adverse health effects. The 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. They considered this to be adequate to protect against other possible effects such as cancer and cardiovascular effects (COT, 2001).

EFSA re-evaluated dioxins and DL-PCBs in 2018 and proposed a reduction to the tolerable weekly intake (TWI), to 2 pg TEQ/kg bw (EFSA, 2018a). The COT performed a further assessment following the EFSA update and stated that while the re-assessment of dioxins is a necessary and important piece of work going forward, further review of dioxins will be an extensive and lengthy undertaking. In the meantime, COT has concluded it was not necessary to update their existing advice at this point and maintained current TDI of 2 pg/kg bw per day (COT, 2021b).

A survey by EFSA (2012) investigated the presence of the sum of dioxin and DL-PCBs in hen eggs and egg products, and found their presence with a maximum value of 11.96 pg WHO-TEQ/g (EFSA, 2012c). A summary of the levels of dioxin and DL-PCBs in EEPs identified in the literature are given in Appendix VI, with dioxins and DL-PCBs detected at levels up to 249.1 pg WHO-PCDD/F-PCB-TEQ/g fat (Hoang, Traag, et al., 2014).

Levels of dioxins and dioxin-like PCBs are controlled in EEPs in GB and NI in assimilated Reg. (EC) 1881/2006 and Reg. (EC) 2023/915 respectively. The MLs are 2.5 pg/g fat for the sum of dioxins (WHO-PCDD/F-TEQ) and 5.0 pg/g fat for the sum of dioxins and DL-PCBs (WHO-PCDD/F-PCB- TEQ) (European Commission, 2023a; Gov UK, 2006).

NDL-PCBs

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 (EFSA, 2010a). The German Federal Institute for Risk Assessment (BfR) assessed NDL-PCBs and found that NDL-PCB mixtures only have a low potential for acute toxicity (BfR, 2018b). However, the liver and the thyroid have been identified as the most sensitive target organs in animal experiments after long(er) term exposures with individual NDL-PCB congeners. A HBGV for

NDL-PCBs has not been established due to the insufficient toxicity data available. There is limited evidence in experimental animals for the carcinogenicity of some NDL-PCBs (IARC, 2015).

A survey by EFSA in 2010 found that NDL-PCBs were present in hen eggs and egg products at up to 16.7 µg/kg. Eggs were the second most contaminated food product category and 94% of hen eggs and hen egg product samples had NDL-PCB levels above the LOQ (EFSA, 2010a). A summary of the levels of NDL-PCBs in EEPs identified in the literature are given in Appendix VI, with NDL-PCBs detected at levels up to 218 ng/g fat (Squadrone, Brizio, et al., 2015).

Levels of NDL-PCBs are controlled in EEPs in GB and NI in assimilated Reg. (EC) 1881/2006 and Reg. (EC) 2023/915 respectively. The ML is 40 ng/g fat for the sum of NDL-PCBs. (European Commission, 2023a; Gov UK, 2006).

4.3.2. Melamine

4.3.2.1. Hazard route

Melamine is used mainly in the synthesis of melamine–formaldehyde resins for the manufacture of plastics, coatings, adhesives, and moulding compounds (dishware and kitchenware) (WHO, 2008).

Melamine can be present in food as a result of uses in food contact materials (FCMs), including articles made of melamine or melamine-formaldehyde plastics, coatings (EFSA, 2010c), adhesives or bamboo FCMs (COT, 2024b). Melamine may also enter the food chain indirectly from trichloromelamine which is used in sanitising solutions for food-processing equipment and food-contact articles (Codex, 2010).

Melamine in food or feed can be found at “baseline” levels, i.e., levels occurring indirectly from the approved uses of melamine or melamine precursors (Codex, 2010). It can also be found at “adulteration” levels, which refer to levels that result from the intentional, illegal addition of melamine or melamine–precursors directly to food and/or feed (Codex, 2010). Some melamine levels in eggs have been attributed to carry-over from adulterated animal feed (WHO, 2008). The deliberate addition of melamine to food is not permitted in Europe, the USA or in the UK.

Melamine can form as a metabolite from triazine-based pesticides/ herbicides, in particular cyromazine (Codex, 2010). Cyromazine can be also used as a veterinary medicine in some countries, and melamine might be present as an impurity in feed additives (e.g., Guanidino acetic acid (GAA) can contain up to 15 mg/kg melamine and up to 25 mg/kg of melamine and structurally related compounds) (Codex, 2010). As such, animal feed may contain melamine and result in carryover into products of animal origin including eggs (Codex, 2010).

4.3.2.2. Hazard characterisation

Melamine does not exhibit systemic toxicity, but is able to complex with other substances such as endogenous uric acid or substances related to melamine to form crystals in the urine, which cause kidney damage (EFSA, 2010c). Illegal adulteration of food and feed with melamine has resulted in illnesses and deaths of human infants, primarily as a result of kidney damage caused by crystals or stones in the urinary tract (EFSA, 2010c). In late 2008, approximately 300,000 infants in China were affected by infant formula containing melamine, including six confirmed deaths (EFSA, 2010c). Clinical signs included vomiting, fever, haematuria, dysuria, oliguria, anuria, high blood pressure, oedema and pain in kidney areas (WHO, 2008).

EFSA established a TDI of 0.2 mg/kg bw/day melamine derived from a $BMDL_{10}$ of 19 mg/kg bw/day (and by applying UF of 100) based on urinary bladder crystals observed in male rats, which was considered as adequate for the protection of infants (EFSA, 2010c). The same TDI was derived by the World Health Organisation (WHO) (WHO, 2008). Based on experimentally spiked feed (10 mg/kg melamine), transfer rates of melamine to eggs were calculated between 1.5% – 3.2% (EFSA, 2010c).

A summary of the levels of melamine in EEPs identified in the literature are given in Appendix VI, with melamine detected at levels up to 1.98 mg/kg in whole fresh egg (Shakerian, Khamesipour, et al., 2018).

Levels of melamine are controlled in EEPs in GB and NI in assimilated Reg. (EC) 1881/2006 and Reg. (EC) 2023/915 respectively. with a maximum level of 2.5 mg/kg in food, except where "*the maximum level does not apply to food for which it can be proven that the level of melamine higher than 2.5 mg/kg is the consequence of authorized use of cyromazine as insecticide. The melamine level shall not exceed the level of cyromazine*" (European Commission, 2023a; Gov UK, 2006).

Reg. (EU) 2017/2229 in EU and assimilated Reg. (EU) 2017/2229 in GB specifies the maximum content for melamine as 2.5 mg/kg for feed, except if feed contains the GAA additive, which is specified to contain melamine as impurity up to 20 mg/kg (European Commission, 2017; Gov UK, 2017). However, this is a specified use only for chickens for fattening but not laying hens.

4.3.3. Polychlorinated naphthalenes (PCNs)

4.3.3.1. Hazard route

The main source of PCNs is through industrial production and as a by-product of other industrial processes. PCNs are widely present in the environment and have been shown to be highly bio-accumulative.

Available data in feed and food show widespread occurrence in both (EFSA, 2024f). The most important exposure route of the general population is suggested to occur orally via foodstuffs (CHM, 2013).

Studies have shown that routes of exposure to PCNs for poultry are likely be via contaminated feed (C. Wang et al., 2022), or potentially through bedding materials in chicken housing (Fernandes, Lake, et al., 2023).

4.3.3.2. Hazard characterisation

Exposure to PCNs leads to several adverse effects including hepatotoxicity, neurotoxicity and immune response suppression along with endocrine disruption, leading to reproductive disorders and embryotoxicity (Fernandes, Kilanowicz, et al., 2022).

PCNs have similar mechanisms of toxicity to dioxin-like compounds (CHM, 2013; EFSA, 2024f). A number of short and medium term studies prove high short-term toxicity at relatively low concentrations (>3mg/kg) (CHM, 2013).

EFSA's risk assessment on PCNs in feed and food focused on hexa chlorinated napthalenes (hexaCNs) due to limited data on other PCN congeners. The haematological system, liver and thymus were identified as main targets for hexaCNs by EFSA as well as developmental effects (EFSA, 2024f). EFSA concluded that due to limitations in the data, the derivation of a HBGV was not appropriate and an MOE approach should be applied. EFSA proposed a $BMDL_{20}$ of 0.05 mg/kg bw/day based on a considerable decrease in the platelet count observed in rats. They considered that MOEs ≥ 2000 are sufficient to conclude that the current dietary exposure to hexaCNs does not raise a health concern (EFSA, 2024f).

A survey carried out by EFSA found that among the food categories in which hexaCNs contamination would be expected, the highest percentage of quantified data was found in the "eggs and egg products" category, with the highest mean concentration of 5.18 ng/kg (upper bound) reported for "whole eggs" (EFSA, 2024f). EFSA suggested this is due to the lipophilicy of PCNs and their tendency to concentrate in fatty foods (EFSA, 2024f).

A summary of the levels of PCNs in EEPs identified in the literature are given in Appendix VI, with PCNs detected at levels up to 20 ng/kg whole weight with the highest levels occurring in duck, goose and gull eggs (FERA, 2017a).

PCNs are not currently regulated under any specific GB or EU regulation for food or feed.

4.3.4. Polyfluorinated substances (PFAS)

4.3.4.1. Hazard route

PFAS are used in industrial applications and for production of consumer products. Many PFAS are environmentally long-lived and individuals are exposed to them through all environmental sources (COT, 2022b). A number of PFAS compounds are relatively easily soluble in water, therefore these compounds can easily spread via water and aerosols in the environment (BuRO, 2024). Food can become contaminated through contact with soil and water, via uptake through animal feed and water, through food packaging containing PFAS, or contact with processing equipment that contains PFAS (EFSA, 2020a).

In food, perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA) and their salts are found at the highest concentrations, compared to other PFAS types (European Commission, 2024c). PFAS may occur in eggs if the chickens ingest feed, water or soil contaminated with PFAS (BuRO, 2024). A study investigated the transfer of environmental contaminants including PFAS into hen eggs via poultry bedding. The highest PFAS contaminated bedding materials were shredded cardboard and dried paper sludge, and there was evidence for uptake of PFOS, and PFOA in chickens from this bedding (Fernandes, Lake, et al., 2023).

4.3.4.2. Hazard characterisation

In 2020 EFSA concluded that based on available studies in animals and humans, effects on the immune system were considered the most critical effect and equal potencies were assumed for the four PFAS assessed (PFOA, PFOS, perfluorononanoic acid (PFNA) and perfluorohexanesulphonic acid (PFHxS)) (EFSA, 2020e). A TWI of 4.4 ng/kg bw per week (0.63 ng/kg bw/day) was established from a $BMDL_{10}$ of 17.5 ng/mL for the sum of the four PFAS in serum based on epidemiological studies (EFSA, 2020e).

EFSA's approach was reviewed by the COT who raised concerns (e.g., uncertainties with the critical endpoint used and reservations with some of the modelling). The 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 (COT, 2022b).

Eggs were identified as one of the major contributors for PFAS in the diet, specifically for PFOS and PFOA (EFSA, 2020e). In 2020 EFSA estimated that eggs and egg products contributed up to 41% (mean, lower bound) of PFOS for infants' exposure and up to 40% (mean, lower bound) of PFOA for adults' exposure (EFSA, 2020e).

A summary of the levels of PFASs in EEPs identified in the literature are given in Appendix VI, with PFOA detected at levels up to 3.14 µg/kg in duck eggs (Qi, Zhou, et al., 2019).

Levels of PFAS are controlled in eggs in NI (EU 2023/915), with maximum levels of 1.0 µg/kg (PFOS), 0.3 µg/kg (PFOA), 0.7 µg/kg (PFNA), 0.3 µg/kg (PFHxS), 1.7 µg/kg (sum of PFOS, PFOA, PFNA, PFHxS) (European Commission, 2023a; Gov UK, 2006).

4.3.5. Conclusion

With the exception of melamine, the identified environmental contaminants included in this section are POPs, listed under the Stockholm Convention (Stockholm Convention, 2019). POPs become widely distributed throughout the environment (soil, water and air), they bioaccumulate and they are found at higher concentrations at higher levels in the food chain (Stockholm Convention, 2019). Therefore, exposure of poultry to POPs can occur through water, feed, soil and also from bedding materials used in husbandry and transferred into the eggs (Fernandes, Lake, et al., 2023).

For melamine, contamination in eggs may arise due to multiple pathways such from its pre-cursors e.g. GAA: and cyromazine or via its use in FCMs. Melamine is also associated with illegal adulteration in food and feed due to its ability to artificially increase the apparent protein content (Codex, 2010).

Toxicological effects of environmental contaminants vary and therefore further assessment would be required to determine whether a specific environmental contaminant detected in EEPs at a specific level, would be a risk to consumers.

4.4. Metals

The metals shortlisted for characterisation are arsenic, cadmium, chromium, copper, mercury, lead and selenium. Conclusions on the concerns regarding the potential metal presence in EEPs are presented in section 4.4.8.

4.4.1. Arsenic

4.4.1.1. Hazard route

Arsenic, in different inorganic and organic forms, can be present in the environment naturally, as well as anthropogenically through practices such as farming and industrial pollution (EFSA, 2009b). Inorganic arsenic in food and feed are generally found in the +3 or +5 oxidation state, present as thio complexes or as the oxo anions, arsenite and arsenate (EFSA, 2023g). Dimethylarsinic acid (DMA(V)) is by far the most abundant of small organic arsenic species in food (EFSA, 2024e).

Drinking water is one of the most significant sources of exposure to arsenic. Inorganic arsenic is naturally present at high levels in the groundwater of a number of countries (WHO, 2022a). Crops irrigated with contaminated water and food prepared with contaminated water are the main sources of arsenic exposure (EFSA, 2009b; WHO, 2022a).

The main contributors to overall dietary exposure to inorganic arsenic were considered to be rice, grains and drinking water (EFSA, 2023g). Inorganic arsenic is the predominant form found in meats, poultry, dairy products and cereal (IARC, 2012).

4.4.1.2. Hazard characterisation

Arsenic toxicity depends on its molecular form as inorganic arsenic is more toxic than the organic species. Toxicity of inorganic arsenic is well characterised, whilst there is less information available for organic arsenic.

EFSA has published a risk assessment of small organoarsenic species in food (EFSA, 2024e) which focussed on dimethylarsinic acid (DMA) and monomethylarsonic acid (MMA) (EFSA, 2024e) for which toxicological information is available.

With respect to inorganic arsenic, acute and subacute exposure can affect almost all physiological systems of the body (EFSA, 2023g). The health outcomes associated with chronic ingestion of inorganic arsenic include skin, bladder and lung cancer, skin lesions, developmental and neurodevelopmental effects, heart diseases, respiratory and kidney diseases, spontaneous abortion, stillbirth and infant mortality (EFSA, 2023g). “Arsenic and inorganic arsenic compounds” are classified as Group 1 carcinogens by IARC: carcinogenic to humans (IARC, 2012). Dimethylarsinic acid (DMA) and monomethylarsonic acid (MMA) acid are classified as Group 2B carcinogens by IARC: possibly carcinogenic to humans (IARC, 2012).

Inorganic arsenic is a genotoxic carcinogen and so no health based guidance values can be set (EFSA, 2023g; IARC, 2012). The COT noted that inorganic arsenic was an indirect genotoxin, which would have a threshold.

COT recommended that risk assessment is performed against the JECFA $BMDL_{0.5}$ of 3.0 µg/kg bw/day based on increased incidence of lung cancer. Considering the mechanistic data of genotoxicity by inorganic arsenic, COT concluded that a MOE of 10 was considered an appropriate level of concern (COT, 2023).

For small organic arsenic species, due to the incomplete toxicological data, EFSA has applied an MOE approach. EFSA has established a $BMDL_{10}$ of 18.2 mg/kg /bw/day for MMA(V) based on the gastrointestinal effects of diarrhoea in rats. An MOE of ≥ 500 was identified not to raise a health concern. A $BMDL_{10}$ of 1.1 mg/kg /bw/day for DMA(V) was established based on an increased incidence of urinary bladder tumours in rats. For DMA(V), an MOE of ≥10,000 was identified as of low health concern as EFSA considered DMA(V) to be genotoxic and carcinogenic. The mechanisms of genotoxicity and its role in carcinogenicity have not been fully elucidated although potential direct and indirect mechanisms have been suggested (EFSA, 2024e).

Occurrence data on inorganic arsenic by EFSA, showed that inorganic and organic arsenic levels in eggs and egg products were left-censored data (i.e., below the limit of detection [LOD] or limit of quantification [LOQ). Eggs were not a primary contributor to inorganic arsenic exposure from the data obtained from EU countries (EFSA, 2021a, 2023g, 2024e). The LOQ in EFSA's assessment was 0.01 mg/kg for inorganic arsenic (EFSA, 2021a, 2023g). No LOQ was reported for organic arsenic species (EFSA, 2024e).

In contrast to the EFSA data, arsenic levels in eggs reported in the literature were above the LOQ and are summarised in Appendix VII, with levels of up to 0.049 mg/kg detected in whole eggs (Chernikova, Pityurina, et al., 2020).

No ML of arsenic in eggs is established in GB or NI. However, MLs of inorganic arsenic for other commodities are between 0.01 – 0.25 mg/kg in Reg. (EU) 2023/915 (European Commission, 2023a) and between 0.10 – 0.3 mg/kg in assimilated Reg. (EU) 2015/1006 (Gov UK, 2015b).

4.4.2. Cadmium

4.4.2.1. Hazard route

Cadmium exposure is through food, water and air, however food is understood to be the main source of human exposure (COT, 2024a). The presence of heavy metals, including cadmium, in eggs is likely to result from industry and agriculture. This includes use of contaminated pesticides and fertilisers and irrigation of crops with contaminated water (Aljohani, 2023). Cadmium levels from the samples analysed in the EU showed that eggs and egg products were the food category that

contributed the least to the dietary exposure (EFSA, 2012a). However, the literature review indicated that cadmium has been detected in eggs and eggs products (see Section 4.4.2.2 for further detail).

4.4.2.2. Hazard characterisation

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 (COT, 2022c). Cadmium and cadmium compounds are classified as a Group 1 Carcinogen: Carcinogenic to humans by IARC (IARC, 2012). A report by the European Chemicals Bureau stated that there is no evidence to show that cadmium causes cancer through the oral route of exposure (JRC, 2008).

The critical adverse effect for cadmium is kidney damage. Therefore, JECFA and EFSA have derived a TWI of 25 µg/kg bw/week based on changes in kidney function, for the protection of possible kidney damage later in life (EFSA, 2009a; JECFA, 2007).

Cadmium levels in eggs reported in the literature are summarised in Appendix VII, with levels of up to 0.013 mg/kg detected in whole eggs (Salar-Amoli & Ali-Esfahani, 2015).

There are no regulatory levels for cadmium in eggs, however the MLs for other food groups (plant originated) range between 0.01 – 1 mg/kg (poultry meat: 0.05 mg/kg) in Reg. (EC) 2023/915 in EU and in assimilated Reg. (EC) No 1881/2006 (European Commission, 2023a; Gov UK, 2006).

4.4.3. Chromium

4.4.3.1. Hazard route

Chromium can enter the food chain via the different environmental pathways (e.g., water or soil), either because of its natural presence or emission from anthropogenic activities. It is used in a wide variety of processes including alloy production, and is present in a wide range of products such as; ceramics and glass, fungicides, pigments and especially in stainless steel (COT, 2018a).

The presence of heavy metals including chromium in eggs is likely to result from industry and agriculture, including use of contaminated pesticides and fertilisers, irrigation of crops with contaminated water (Aljohani, 2023).

Food preparation with chromium containing materials (e.g., processors, utensils) could represent an additional source for the presence of chromium in food. Exposure to the more toxic Cr(VI) is primarily through drinking water, although some exposure occurs through food (EFSA, 2014d).

4.4.3.2. Hazard characterisation

Chromium is most commonly found in two oxidation states, either chromium (III) (Cr(III)) or chromium (VI) (Cr(VI)). The most prevalent natural form of chromium is Cr(III) and food is considered to be a source of Cr(III) which is an essential micronutrient (COT, 2018a). The toxicity of chromium is dependent on the speciation of chromium. Although long term respiratory exposure to Cr(VI) can cause lung cancer, the IARC has concluded that there is not sufficient evidence to support that Cr(VI) ingested via food and water is a carcinogen. Both Cr(III) and (VI) can cause other non-carcinogenic chronic effects on the liver and kidney and in the blood (COT, 2018a).

EFSA established a TDI for Cr(III) of 300 µg/kg bw/day, based on the NOAEL from sub-chronic and long-term toxicity in rats. Based on their assessments, EFSA concluded that dietary exposure to Cr(III) would be considered unlikely to result in cancer in humans (EFSA, 2014b).

Regarding Cr(VI), for carcinogenic effects, ESFA derived a $BMDL_{10}$ of 1.0 mg/kg bw/day for combined adenomas and carcinomas observed in the small intestines of male and female mice, with an MOE of ≥10,000 being of low concern (EFSA, 2014d). For non-carcinogenic effects EFSA have determined an MOE of 100, which would indicate a low concern for human health and derived:

- $BMDL_{10}$ value of 0.11 mg/kg bw/day for adverse effects in duodenum and,
- $BMDL_{05}$ of 0.2 mg/kg bw/day for adverse haematological effects

In a 2014 review, EFSA determined the mean concentration of chromium from eggs as 22 µg/kg (LB) and 29 (UB) µg/kg (EFSA, 2014d). Levels of chromium in egg and egg products, were mostly lower than other food or drink categories (EFSA, 2014d).

In contrast to the EFSA data, chromium levels in eggs reported in the literature are summarised in Appendix VII, with levels of up to 0.24 mg/kg detected in whole eggs (Salar-Amoli & Ali-Esfahani, 2015).

There are no regulatory levels for chromium in food, however the WHO have derived a guideline value of 0.05 mg/L in water (WHO, 2020b).

4.4.4. Copper

4.4.4.1. Hazard route

Copper can be used as a PPP and fertiliser, and as a result it can also contribute to the concentration of copper in soil (EFSA, 2023b). Due to the homeostatic control of copper uptake from soil by plants, short-term applications of copper to plants may have limited impact on the detected levels. However in the longer-term, due to increasing concentrations in soil over time, there is likely to be increased copper uptake by crops (EFSA, 2023b). Additionally, copper can be present in drinking water due to leaching from copper plumbing (FWR, 2017). Copper can be also used as a feed additive in poultry (EU 2018/1039; EU 2022/1459) (EFSA, 2016b; European Commission, 2018a, 2022a). As a result of, concentrations from crops (when used as a feed) and the use as an additive in poultry feed, copper is expected to be present in the eggs.

A study by Kabeer et al., sought to investigate the relationship between heavy metal contamination in feed, water and eggs. Researchers concluded that, increased heavy metals levels in eggs, including copper was a result of exposure of poultry to contaminated feed and water (Kabeer, Hameed, et al., 2021).

4.4.4.2. Hazard characterisation

Copper has a tight homeostatic regulation in the body, which is critical for the prevention of copper toxicity. The development of chronic copper toxicity is dependent on copper homeostasis and its tissue retention (EFSA, 2022b).

Adverse health effects at higher levels include an increase in systolic blood pressure and impaired metabolism of other nutrients. At high excess, there are irreversible metabolic changes and in a worst case can result in death (COT, 2018c). The most critical effect of copper toxicity is liver injury due to accumulation. Copper retention is the critical pathway leading to toxicity and if intakes are not reduced, copper accumulation will occur in the liver resulting in hepatoxicity and extrahepatic toxicity (COT, 2018c; EFSA, 2022b). Based on the liver retention of copper, EFSA in 2022 established a copper Upper intake Level (UL) of 5 mg/day (at which no retention is expected) and an ADI of 0.07 mg/kg bw (EFSA, 2022b).

Eggs and egg products contribute 1–11% of the dietary copper intake of European populations (EFSA, 2016b).

Copper levels in eggs reported in the literature and alerts are summarised in Appendix VII, with levels of up to 8.5 mg/kg detected in whole duck eggs (Salar-Amoli & Ali-Esfahani, 2015).

Regulatory levels for copper in food are set under assimilated Reg. (EC) 396/2005 (European Parliament, 2005; Gov UK, 2005); the MRL for copper compounds in eggs is 2 mg/kg, based on their use as pesticides. The maximum content of copper in complete feed additives is 25 mg/kg for poultry. This maximum content includes copper already present in feed (e.g. due to natural occurrence or use of pesticides) and copper added as feed additive to meet the nutritional requirements of the animals (assimilated Reg. (EU) 2018/1039) (European Commission, 2018a; Gov UK, 2018).

4.4.5. Lead

4.4.5.1. Hazard route

Lead is an environmental contaminant which occurs both naturally and through human activities such as mining, smelting, etc. (EFSA, 2010b; WHO, 2023b). Drinking water delivered through lead pipes or pipes joined with lead solder may contain lead. However, measures have been taken to regulate levels of lead in pipes in Europe since the 1970s, which had a considerable effect in reducing exposure (EFSA, 2010b).

Farm animals including poultry, can be exposed to lead through feed and water contamination, and also from contaminated soil (FSA/VLA, 2024). For instance, in a case study, higher concentration of lead was reported in eggs collected from a farm close to mining area compared to commercially available eggs (Sartorius, Johnson, et al., 2022). Another study reported higher levels of lead in chickens that were exposed to lead-based paint in their environment (Trampel, Imerman, et al., 2003).

EFSA calculated the relative lead contribution of different food groups to total lead exposure. They considered individual consumption figures of food groups and mean lead concentrations in food groups. EFSA considered cereals, vegetables and tap water to contribute most to dietary exposure to lead for most European countries (EFSA, 2010b). The relative contribution of lead exposure from eggs, compared to the overall lead exposure (lower bound) was estimated as 0.13 in the GB and the highest contribution was observed in Poland (0.23). Lead levels in 11.4% of 615 analysed egg samples were above the LOD (EFSA, 2010b).

4.4.5.2. Hazard characterisation

The toxicity of lead differs according to whether it is in organic or inorganic form; organic lead is more toxic than inorganic lead (ASTDR, 2023). However, the dominant environmental exposure is to inorganic lead, while exposure to organic lead has predominantly been via occupational settings. Public Health England (PHE) (now the UK Health Security Agency) states that lead is a non-threshold contaminant and therefore may cause adverse health effects following exposure to any concentration (PHE,

2021). Exposure can lead to a wide range of serious adverse health effects. The most typical early symptom of lead poisoning, especially in occupational exposure or other high-level intakes of lead is colic (EFSA, 2010b). The most prominent symptoms are abdominal pain, nausea, vomiting and anorexia (EFSA, 2010b). 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 (EFSA, 2010b). The most critical chronic effects are developmental neurotoxicity in children/ unborn fetus; cardiovascular effects and nephrotoxicity in adults (EFSA, 2010b; PHE, 2021). In children, absorption of lead is considered higher and they appear to be more sensitive than adults (EFSA, 2010b).

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 (FSA, 2009b). For risk assessment of 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/day for cardiovascular effects (EFSA, 2010b). In all cases an MOE of >1 was an indication that any risk from this exposure is likely to be small (but not such that it could be dismissed as of no potential concern), with an MOE of >10 being sufficient to ensure no appreciable risk. Because toxicity depends on total exposure to lead from all sources, it is important to consider combined exposures from food, water, and non-dietary sources (EFSA, 2010b).

Levels of lead of up to 0.21 mg/kg have been detected in eggs as reported in the EFSA review (EFSA, 2010b). Lead levels in eggs reported in the literature are summarised in Appendix VII, with levels of up to 0.35 mg/kg detected in whole eggs (Salar-Amoli & Ali-Esfahani, 2015).

There is no ML for lead in eggs in assimilated Reg. (EC) No. 1881/2006 and Reg. (EC) 2023/915 (European Commission, 2023a; Gov UK, 2006). However, the ML for lead in poultry meat (excluding offal) is set at 0.10 mg/kg. Noting the exposure to lead from different sources and the absence of a threshold for adverse health outcomes, any exposure to lead from eggs will add to cumulative exposure and is therefore undesirable.

4.4.6. Mercury

4.4.6.1. Hazard route

Mercury is an environmental contaminant which occurs both naturally and from anthropogenic sources. After release into the environment, it undergoes complex transformations and cycles between atmosphere, land and aquatic systems (European Commission; COT, 2018b; EFSA, 2012b).

Mercury can be found in three chemical forms: (1) elemental or metallic mercury (Hg(0)), (2) inorganic mercury (mercurous (Hg_2^{2+}) and mercuric (Hg^{2+}) cations) and (3) organic mercury (e.g., methylmercury) (EFSA, 2012b).

Methylmercury is the most common form in the food chain and exposure to methyl mercury occurs mostly via diet (European Commission; EFSA, 2012b). Mercury can be also found in feeding stuffs (EFSA, 2008b). Levels of mercury reported in feeding stuffs were reported to EFSA above the ML of 0.1 mg/kg, mostly for "unspecified feeds and raw materials" (10.9% occurrence) during 2002 – 2006 (EFSA, 2012b). Average and maximum concentrations of total mercury in complete feeding stuffs for poultry were below the ML during these years (EFSA, 2012b). Mercury (as total) was detected in eggs, ranging from 0.6 – 6.3 µg/kg (mean LB and P95, respectively) (EFSA, 2012b). The literature review indicated that mercury has been detected in eggs (see Section 4.4.6.2 for further detail).

4.4.6.2. Hazard characterisation

The toxicity of mercury differs according to whether it is in organic, inorganic, or metallic form. The forms of mercury differ in their effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes (WHO, 2017a). Organic mercury, 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 (COT, 2018b). In their risk assessment, the COT concluded that the EFSA HBGV was appropriate: a TWI for methylmercury of 1.3 µg/kg bw/week (expressed as mercury), which is based on neurodevelopmental adverse effects after prenatal exposure (EFSA, 2012b). In 2012, EFSA adopted the provisional TWI (PTWI)of 4 µg/kg bw/week established by JECFA in 2010, for inorganic mercury, based on an increase in relative kidney weight observed in rats (EFSA, 2012b; JECFA, 2010).

Mercury levels in eggs reported in the literature are summarised in Appendix VII, with levels of up to 17.47 mg/kg detected in whole eggs (Aendo, Garine-Wichatitsky, et al., 2022).

There is no ML for mercury in eggs in assimilated Reg. (EC) No. 1881/ 2006 and Reg. (EC) 2023/915 (European Commission, 2023a; Gov UK, 2006). However, as exposure to mercury can come from different sources, any additional exposure to mercury will add to cumulative exposure and is therefore undesirable.

4.4.7. Selenium

4.4.7.1. Hazard route

Selenium can enter the food chain via the different environmental compartments (e.g. soil, water), either because of natural presence or emission from anthropogenic activities. It is an essential micronutrient, and food can be enriched with selenium. (EFSA, 2022d). Selenium can be also used as a fertiliser and as a feed additive for poultry (EU 2022/ 1459) (European Commission, 2022a). Taken altogether, concentrations from crops and being used as an additive in poultry, selenium is expected to be distributed into eggs.

4.4.7.2. Hazard characterisation

In the diet, selenium is mainly present in organic compounds, as L-selenomethionine and L-selenocysteine, with lower amounts in the inorganic form (e.g., selenate) (EFSA, 2022d). High intakes of selenium will result in selenosis (selenium poisoning) (EFSA, 2022d). Acute selenosis is characterised by symptoms including hypotension and tachycardia, gastrointestinal effects, pulmonary oedema, neurologic abnormalities, delirium and coma. Chronic selenosis includes symptoms such as brittle nails, brittle hair, alopecia, neurological abnormalities and decreased cognitive function (EFSA, 2022d).

An UL of 255 µg/day (3.64 µg/kg bw/day) for adults was derived from a lowest-observed-adverse-effect-level (LOAEL) of 330 µg/day based on alopecia (men, ≥ 50 years), an early sign of selenium toxicity. In 2022, EFSA highlighted that based on available intake data, adult consumers are unlikely to exceed the selenium UL of 255 µg/day, except for regular users of food supplements containing high daily doses of selenium or regular consumers of Brazil nuts (EFSA, 2022d). ULs of selenium in infants, children and adolescents were based on the UL of adults, adjusted for the body weight, as EFSA reports that there is no indication from the literature that children may be more susceptible than adults to selenium toxicity (EFSA, 2022d).

In 2024, EFSA reported that where poultry were fed at the maximum authorised level in animal feed, their eggs were identified to be a relatively high POAO source of selenium (EFSA, 2024c). Levels of 0.327 mg/kg fresh matter (FM) of inorganic selenium and 0.366 mg/kg FM of organic selenium were measured in eggs, exceeded only by liver and offal of all species. Based on the exposure assessment from food of animal origin, EFSA concluded that when complete feeds were supplemented at about 0.2 mg/kg feed (with total selenium ≤ 0.5 mg/kg feed), the adult UL was met or exceeded for all population groups (except elderly and very elderly), suggesting a potential concern for consumer safety.

There are no MLs for selenium in food and feed, however selenium is regulated in complete animal feed with a maximum content of 0.5 mg/kg in the EU (NI) under Reg. (EU) 2022/1459 (European Commission, 2022a).

4.4.8. Conclusion

A range of metals may contaminate eggs, and dietary exposure to metals, in particular heavy metals, may be a human health concern. As there are multiple sources of exposure to heavy metals due to their wide occurrence in environment and food, any significant additional exposures, for example from contaminated eggs, is undesirable as it could contribute to the overall background exposure in the UK population.

The toxicity of different metals varies, and they have been detected in eggs at varying concentrations. Therefore, a risk assessment would be required to determine the risk to consumers from contamination of EEPs with a specific metal at a particular concentration, especially those metals which have no threshold regarding safety, due to their high toxicity (e.g., lead, arsenic). No MLs for heavy metals are in place for eggs, however a number of heavy metals have been reported in eggs above the LOQ and at levels that would exceed relevant regulatory levels in other similar commodities where they are set. Although this should not be taken to confirm a risk from eggs without further assessment.

Copper and selenium are not heavy metals but may be present in eggs due to their authorised uses as PPPs and feed additives. These metals have a lower toxicity than heavy metals but may present a human health concern dependent on the level of presence. Further assessment would be required to determine whether these metals if detected in eggs at a specific level, would be a risk to consumers.

4.5. Microbiological hazards

The microbiological hazards shortlisted for characterisation were *Salmonella* spp, *Campylobacter* spp, and *Listeria monocytogenes*. Conclusions on the concerns regarding the presence of microbiological hazards are presented in section 4.5.4.

4.5.1. Salmonella

The genus *Salmonella* contains two species, *S. enterica* and *S. bongori*. Of those, *Salmonella enterica* serovars Enteritidis (SENT) and Typhimurium (STM) (non-typhoidal serovars) are the main types that are transmitted via food consumption (WHO, 2018b). References to *Salmonella* in this section encompass both non-typhoidal serovars -SENT and STM – unless a serovar is specified.

Salmonella spp growth conditions can be found in Table 5. The pH and a_W in the internal parts of the egg as described in section 2.2.3, are within the range that permits the growth of *Salmonella* spp. However, for such growth to occur other conditions such as temperature, oxygen and salt level also need to be favourable.

Table 5. *Salmonella* spp growth conditions (ICMSF, 1996)

Salmonella	Minimum	Optimum	Maximum
Temperature (^{O}C)	5.2	35-43	46.2
pH	3.8	7.0-7.5	9.5
a_W	0.93	0.99	-

Salmonella spp are readily destroyed by pasteurisation temperatures. This is affected by the food matrix, however, for example in low a_W foods, such as peanut butter, the survival of *Salmonella* spp at 70 °C is increased (Beuchat, Komitopoulou, et al., 2013). Dried egg products fall within this low a_W food category. The minimum water activity that permits growth of *Salmonella* spp is 0.93 however cells are able to survive in dried foods for extended periods of time (Beuchat, Komitopoulou, et al., 2013).

4.5.1.1. Hazard route

In 2022 in the UK, *SENT* was most frequently isolated from chickens compared to other animals, whilst *STM* was most frequently isolated from pigs (APHA, 2023). A list of the most commonly isolated serovars and phage types can be found in a report by the Animal and Plant Health Agency (APHA) (APHA, 2023). These patterns are likely to be different in different parts of the world, and they can affect the types of mitigations required, as transmission routes may differ. For example *STM* is the most prevalent serovar in hens in Australia (Moffatt & Musto, 2013; WHO, 2018b), whereas *SENT* is the most commonly found serovar in hen environments in other parts of the world (Whiley & Ross, 2015). However, *STM* has been associated with outbreaks in duck eggs in the EU (EFSA, 2014c).

There are two mechanisms whereby eggs can become internally contaminated with *Salmonella*; primary and secondary contamination.

Primary contamination (vertical transmission) occurs when *Salmonella* contaminates an egg during its formation. *SENT* is the serotype most associated with egg contamination by this means, due to its genetic makeup that enhances its ability to colonise the ovary and oviduct of laying hens (EFSA, 2014c). Although, *STM* has also shown ability to colonise the internal organs of the hen or invade into the egg albumen and yolk (EFSA, 2014c).

Secondary contamination (horizontal transmission) occurs when *Salmonella* contaminates the surface of an egg after its formation. This can be due to contact with contaminated surfaces, or contaminated feed and water, and insufficient cleaning of processing equipment and food contact surfaces (DEFRA, 2007). This contamination is facilitated by cracks on the eggshell. Such cracks can be caused by practices such as poor egg collection systems, and rapid cooling of eggs that may be practiced to slow down growth of any *Salmonella* which may be present (DEFRA, 2007; EFSA, 2014c).

Testing of UK shell eggs for *Salmonella* prevalence has not been conducted in recent years, however a 2003 FSA study found the prevalence of *Salmonella* (all serotypes) to be 0.34% (as reported in (FSA, 2023b).

Once in the egg, *Salmonella* needs to reach the yolk in order to grow and multiply. Migration of *Salmonella* from the albumen into the yolk depends on contamination dose, temperature, and age of the eggs (EFSA, 2014c). The growth rate of *Salmonella* within the egg environment depends on its location and is highly temperature dependent. *SENT* is unable to grow below 7°C, in egg albumen it cannot grow below 8°C and in egg yolk weak growth was observed at 10°C. Between 20 to 30°C, the growth of *Salmonella* is possible in all egg components. Overall, growth of *Salmonella* is faster in yolk than in albumen (EFSA, 2014c).

Sources of *Salmonella* introduction on farms are varied, evidence suggests that contaminated feed and water, pests such as rodents and insects, and introduction of infected hens, can cause flock contamination (FSANZ, 2013).

Salmonella naturally infects and colonises chickens, with conflicting studies failing to identify the key risk factors (likely due to the number of variables). However suggested risk factors include flock size, with larger flocks more likely to be infected with *Salmonella*; farm size, with larger farms less likely to use deep clean production systems; and on-floor housing systems. These systems increase the likelihood of *Salmonella* prevalence (ACMSF, 2016).

The risk factors associated with each of the egg production steps as identified in the British Red Lion Eggs Scheme are detailed in the FSA risk profile of UK produced hen shell eggs (BEIC, 2013; FSA, 2023b) and summarised in Table 6.

Table 6. Risk factors influencing the levels of Salmonella in eggs and egg products as identified in the British Red Lion scheme and summarised in the FSA risk profile on salmonella in hen shell eggs.

Stage of supply chain	**Key risks**
On farm: Cage, Barn, Free-range including organic	• Aged flocks can have higher prevalence of *Salmonella* • Pests and wildlife can spread contamination within housed birds • Infected feed/bedding/water/farm staff • Introduction of infected birds/point of lay pullets • Introduction of *Salmonella* via visitors and equipment such as lorries, catcher crews and egg crates • Insufficient cleaning may allow contamination to persist • Production of Class B eggs by positive flock where there are other flocks on site not subject to restrictions
Transport of eggs to packing centre	• Transport trays contaminated with *Salmonella* • Incorrect temperature controls†
Processing and packaging: Grading machine, dirt detector, crack detector, UV system, Weighing, blood detector	• Areas where the eggs come into contact can transfer *Salmonella* for example, production line belts – this is more likely when the eggs are wet • UV will potentially decrease *Salmonella* contamination levels; therefore, the lack of this step may increase risk • Contaminated environment of packing centre • Cross contamination from infected staff
Eggs shipped to retail	• Temperature control failure†
Retail and consumer handling	• Increase in temperature† • Cross contamination in processes such as whisking, and contamination of surfaces • Raw egg products need to follow correct de-activation processes which may be difficult in-home kitchen • Handling and cross contamination of cooking surfaces where external contamination exists on egg shell

† Increase in temperature can lead to condensation on the eggshells, which can encourage internalisation of *Salmonella*

4.5.1.2. Hazard characterisation

With respect to observed cases of illness, the two most important serotypes, *SENT* and *STM* are transmitted from animals to humans across the world (Majowicz, Musto, et al., 2010). Globally, there are an estimated 93.8 million cases of gastroenteritis due to non-typhoidal *salmonella* infection each year, resulting in approximately 155,000 deaths, of which approximately 85% are estimated to be foodborne (Majowicz, Musto, et al., 2010). *S.* Enteritidis is considered the most important transovarian serotype concerning eggs and egg products, however, other serotypes which are not capable of transovarian transmission, such as *S.* Typhimurium, *S.* Heidelberg, and *S.* Infantis can also infect laying hens and contaminate eggs, to a lesser extent (EFSA, 2014c).

Infections by both *STM* and *SENT* are characterised by a self-limited gastroenteritis which is accompanied by symptoms including non-bloody diarrhoea, vomiting, nausea, headache and abdominal cramps (Zhang, Kingsley, et al., 2003). The onset of disease symptoms occurs after 6-72 hours (usually 12-36 hours) after ingestion of *Salmonella*, and illness lasts 2-7 days. The severity of *Salmonella* infections in humans varies depending on the serotype involved and the health status and age of the patient (Scallan, Hoekstra, et al., 2011).

Salmonellosis is generally an acute disease, however chronic illnesses can occur post-infection. It is estimated that 0.3% to 6.2% of cases can develop irritable bowel syndrome (IBS), referred to as post infectious IBS and around 5.8% can develop reactive arthritis (Keithlin, Sargeant, et al., 2015). According to UK Health Security Agency (UKHSA) data, between 2015 and 2019, a total of 954 outbreak related cases were confirmed cases of salmonellosis, associated with the consumption of eggs and/or egg products (FSA, 2023b). Non-typhoidal salmonellosis is classified as a serious hazard by the International Committee on Microbiological Standards for Foods (ICMSF); incapacitating but not life-threatening; sequelae infrequent; moderate duration (ICMSF, 2018).

Salmonella spp (primarily *SENT*) was the most frequently reported hazard in the hazard identification searches, and the primary cause of outbreaks associated with the consumption of eggs. Eggs and egg products were the primary vehicle of *Salmonellosis* outbreaks (26%) in the UK in the years 2015 – 2020 (DEFRA, 2023). Of those, 68% were associated with *S.* Enteritidis (FSA, 2023b).Eggs and egg products were the primary vehicle of *Salmonella* outbreaks (44%) in the EU in 2021 (EFSA, 2022a). Between 2017 to 2021, the prevalence of *SENT* in laying flocks in the UK, determined via national control programme (NCP) testing, was 0.19% (FSA, 2023b). In the EU, NCP results in 2022 determined an overall prevalence of *SENT* to be 0.15% in laying flocks, and an overall prevalence of *STM* to be 0.10% in laying flocks (EFSA, 2023f).

4.5.2. Campylobacter

4.5.2.1. Hazard route

Campylobacter spp growth conditions can be found in Table 7. The pH and a_w in the internal parts of the egg as described in section 2.2.3, are within the range that permits the growth of Campylobacter. However, for such growth to occur, other conditions such as temperature, oxygen and salt level also need to be favourable.

Table 7. Campylobacter spp growth conditions (ICMSF, 2018)

Campylobacter	Minimum	Optimum	Maximum
Temperature (^{O}C)	30	37-45	45
pH	4.9	6.5-7.5	9.0
a_w	0.987	0.997	-

Of the *Campylobacter species, C. coli* and *C. jejuni* account for over 95% of human infections (Park, 2002). *They* are prevalent in many domesticated animals, but their main reservoir is poultry (Sahin et al., 2002), as the body temperature of these animals (42^{O}C) and the amino acids in their gut create a favourable growth environment (ACMSF, 2019). A study in Italy showed that the prevalence of *Campylobacter* in laying hens to be up to 94.6% (in aviaries), with caged birds showing the lowest prevalence (86.7%) (Casalino, Bozzo, et al., 2022). The lower levels seen in caged birds was believed to be due to the lower exposure to faeces. Lower prevalence has also been reported when the cloaca and eggshells were sampled instead of faeces (Gharbi, Bejaoui, et al., 2022; Guyard-Nicodème, Anis, et al., 2023).

The BfR have reported that chicken eggs may transmit *Campylobacter* to humans if the eggs are visibly contaminated with chicken excrement, due to excrement adhering to the shell of chicken eggs during production and packaging (BfR, 2018a). Eggs visibly contaminated with faeces or any excrement are not allowed to be sold at retail, however this contamination may not be visible (Dorn-In, Daldrup, et al., 2024).

Campylobacter transmission to the birds via drinking water, feed, old litter, pets, other animals, insects, equipment and farm workers have been investigated and is believed to be the main route of exposure (ACMSF, 2005, 2019; Hakeem, Fathima, et al., 2022). However, some studies have shown that *Campylobacter* can be transmitted directly to the chicks or to the egg before reaching the chicks (pseudo-vertical transmission), although this route is still believed to have a minor effect (ACMSF, 2005, 2019).

Occurrence of *Campylobacter* on eggshells has been reported (Adesiyun, Offiah, et al., 2005; BfR, 2023; Messelhäusser, Thärigen, et al., 2011; Sabzmeydani et al., 2020). However, no reports were identified on the

organism being isolated from the albumen or yolk unless the eggs were cracked, artificially inoculated or put into contact with contaminated surfaces (Fonseca, Beletti, et al., 2014). Although the survival of the organism in artificially inoculated egg parts has been confirmed in some studies (Shane et al., 1986), the result could not be replicated in others (Paula, Fonseca, et al., 2009).

In a metanalysis on source attribution for campylobacteriosis, Fravalo et al. identified eggs (particularly raw eggs and mayonnaise) as significant risk factors for campylobacteriosis. The study proposed that if *Campylobacter* is present on the eggshell, it could contaminate the egg during cracking, posing a risk of infection when the egg is consumed undercooked (Fravalo, Kooh, et al., 2021). Dorn-In et al. artificially contaminated eggs with *C. jejuni*. They found cross-contamination in 68% of egg whites and 14% of egg yolk after separation, and consequently recommend avoiding the manual separation of egg white and yolk using the eggshell (Dorn-In, Daldrup, et al., 2024).

Risk factors that contribute to *Campylobacter* colonisation of poultry, include movement of birds on farms during depopulation, movement between broiler houses and transfer by staff were the three top contributing factors to *Campylobacter* occurrence (Adkin, Hartnett, et al., 2006). The size of the flock, the number of bird houses, the use of manure, and water coming from centralised water systems (Guerin, Martin, et al., 2007). While these studies looked at broiler farm practices the risk factors identified are likely to affect layer flocks when practices are similar. Climatic conditions may be an important risk factor, with hot climates favouring higher prevalence of *Campylobacter* and higher microbial load in the birds while colder climates are likely to have the opposite effect (ACMSF, 2005; Sibanda, McKenna, et al., 2018). However, this was not the case in Iceland (Guerin, Martin, et al., 2007).

4.5.2.2. Hazard characterisation

Campylobacter (mainly *C. jejuni* and *C. coli*) causes campylobacteriosis in humans, a leading cause of bacterial gastrointestinal illness in many countries (ICMSF, 2018). The most common clinical symptoms of *Campylobacter* infections include diarrhoea (frequently bloody), abdominal pain, fever, headache, nausea, and/or vomiting, with symptoms typically lasting 3 to 6 days (WHO, 2020a). In rare cases, campylobacteriosis can be the cause of long-term conditions such as the Guillain-Barre syndrome, rheumatological conditions (ACMSF, 2005).

In terms of severity, the ICMSF categorise *Campylobacter jejuni* as “Moderate, not usually life-threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort” (ICMSF, 2018). Moderate is the lowest category used by the committee.

Campylobacteriosis is the most commonly reported foodborne gastrointestinal infection in humans in the EU and has been so since 2007 (EFSA, 2022f). In 2021, 127,840 confirmed cases of human campylobacteriosis were reported in the EU (EFSA, 2022f). The results reported in 2021 by 16 member states (MS) for non-ready to eat food show that 'meat and meat products' (including poultry) was the most contaminated food category (EFSA, 2022f).

Outbreaks of campylobacteriosis are rare, with most cases being sporadic and commonly attributed to undercooked poultry or cross-contamination from raw poultry (ICMSF, 2018). Fresh poultry meat is the most frequent source of human *Campylobacter* infections (BfR, 2018a; ICMSF, 2018). A recall of chicken eggs due to presence of *C. coli* was reported by BfR in 2019 (FERA, 2024; FoodAkai, 2024). Although *Campylo*bacter outbreaks have been attributed to eggs, a direct link has not been established so far (ACMSF, 2016).

4.5.3. Listeria monocytogenes

4.5.3.1. Hazard route

Listeria monocytogenes is a species of facultatively anaerobic non-spore forming bacteria. Its growth conditions can be found in Table 8. The pH and a_W in the internal parts of the egg, as described in section 2.2.3, are within the range that permits the growth of *L. monocytogenes*. However, for such growth to occur, other conditions such as temperature, oxygen and salt level also need to be favourable.

Table 8. *Listeria monocytogenes* growth conditions (Yousef & Lado, 2007)

Listeria monocytogenes	**Minimum**	**Optimum**	**Maximum**
Temperature (^{O}C)	-1.5	30-37	45
pH	4.0	6.0-8.0	9.6
a_W	0.9	0.97	-

There are many reservoirs of *L.* monocytogenes, and unlike most other foodborne pathogens, they can live and grow in the natural environment without the need to grow within an animal host (Chasseignaux, Toquin, et al., 2001).

Poultry themselves can harbour *L. monocytogenes* and contaminate their environment (Rothrock, Davis, et al., 2017). This pathogen has been isolated from environmental samples from both broiler (Rothrock, Davis, et al., 2017) and layer farms (Ricke et al., 2023), including from samples such as from litter, dust, grass, feed, faeces and caecal content and cloacal swabs. The highest incidence was detected in faecal samples in both broiler and layer farms (Ricke et al., 2023).

Prevalence rates on eggshells has been found to be low (1.8 - 6%) (Ricke et al., 2023). In another study in Mexico, *L.monocytogenes* was isolated from 4.6% of eggshell samples. It has also been isolated from the eggshells of inoculated eggs and the population was found to decrease over storage for 6 weeks. The decrease was faster at 20^{o}C compared to 5^{o}C (Brackett & Beuchat, 1992).

The risk factors identified in broiler environments were related to hygiene and biosecurity (separation of clean and dirty areas, no pest control, staff visiting other broiler houses, presence of pets, type of feed and failure to remove faecal matter, etc) (Rothrock, Davis, et al., 2017). While layer rearing systems can differ significantly from broiler systems, such risk factors are likely to affect the prevalence of environmental pathogens such as *L.monocytogenes* in similar ways.

Environmental cross-contamination is a major issue with respect to *L. monocytogenes*, in particular when the egg is first cracked before downstream processing (Brackett & Beuchat, 1992). It can occur through direct contact with raw materials, personnel, aerosols and contaminated utensils, equipment, and other surfaces that may come into contact with food (FSANZ, 2013). Cross-contamination can occur at any step where the product is exposed to the environment, including processing, transportation, retail, catering and in the home. Therefore, *L. monocytogenes* is a pathogen primarily associated with ready to eat foods (FSANZ, 2013).

Because *L. monocytogenes* is a hazard which can be introduced into food products from the processing environment, the majority (83%) of alerts recorded in the FSA RLD (including RASFFs, UK, Canada and US FDA alerts) are related to egg products rather than shell eggs.

L. monocytogenes have been detected in raw liquid whole egg samples at a 17.4% prevalence before pasteurisation and 2.1% after (Rivoal, Quéguiner, et al., 2010). The contamination of the pasteurised products did not indicate that the pathogen survives pasteurisation, but rather post processing contamination. This is because the corresponding raw products were not found to contain the pathogen. A later study by the same authors showed no contamination in pasteurised eggs and an 8.5% of incidence in raw products (Rivoal, Fablet, et al., 2013).

In the context of egg products, risks of contamination post pasteurisation may come from the environment (for instance, due to improper cleaning and sanitation allowing *L. monocytogenes* to establish and form biofilms) or from employees inadvertently carrying *L. monocytogenes* on their person or clothing (USDA, 2020).

4.5.3.2. Hazard characterisation

Infection by *L. monocytogenes* is known as listeriosis. Various clinical manifestations are associated with *L. monocytogenes* infection, and these can be grouped in two categories: invasive and non-invasive listeriosis.

Non-invasive listeriosis typically occurs, is generally mild and manifests as diarrhoea, fever, headache and myalgia (WHO, 2018a). During a number of outbreaks, the majority of cases developed symptoms of gastroenteritis after a short period of incubation (Aureli, Fiorucci, et al., 2000). Non-invasive listeriosis has not been well studied as the clinical presentations do not typically warrant medical intervention and are therefore not reported (CDC, 2024). Non-invasive listeriosis is typically self-limiting and symptoms only last a few days (CDC, 2024).

In contrast, the symptoms of invasive listeriosis are severe, and include fever, myalgia (muscle pain), septicaemia, and meningitis with high mortality rates (WHO, 2018a). The incubation period is usually one to two weeks, but can vary from a few days to 90 (WHO, 2018a). According to one outbreak report in a tertiary care hospital, the incubation period was 3-4 days which was significantly shorter than other reports (Johnsen, Lingaas, et al., 2010).

Invasive listeriosis presents a particularly serious risk to pregnant women including unborn babies, people with weakened immune systems and elderly people, where it can cause very severe illness and death (De Luca, Donati, et al., 2015). The case fatality rate of invasive listeriosis is high, ranging from 20-30% (Mead, Slutsker, et al., 1999). Pregnant women infected with *L. monocytogenes* can experience miscarriage, stillbirth and premature birth, which while not typically fatal for the mother can be fatal for the fetus (Pezdirc, Hure, et al., 2012).

ICMSF classified listeriosis as serious hazard; incapacitating but not life-threatening; sequelae infrequent; moderate duration. No differentiation was made between invasive and non-invasive listeriosis (ICMSF, 2018).

Egg associated outbreaks of L. monocytogenes are not frequently reported, however, such an outbreak in the USA in 2017-2019 resulted in multiple human cases and 1 death. The implicated product was hard boiled eggs intended for food processors and restaurants (CDC, 2020).

4.5.4. Conclusion

Overall, microbiological hazards present a risk in EEPs, with *SENT* being by far the most frequently implicated in alerts and incidents. Enteric pathogens such as *Campylobacter* and *Salmonella* will naturally infect chickens if they are exposed, typically via contaminated feed, water, or from exposure to environmental sources, for instance wild animals or

insects. *Listeria monocytogenes* can also contaminate from this enteric route, however it also has the ability to persist in the environment, and can establish a presence in a manufacturing environment, where it can contaminate egg products.

Human health effects of these pathogens vary depending on exposure and consumer group. If these pathogens are found to be present in eggs, there may be a concern for consumer health and further assessment would be required.

4.6. Pesticides

4.6.1. Hazard route

Pesticides in the form of PPPs are applied to plants to control pests, weeds and plant diseases. As poultry feed contains cereal grains, cereal by-products and plant protein sources among other ingredients (FAO, 2024), there is potential for ingestion of pesticides through the diet. When hens consume contaminated feed, the pesticides or their metabolites may accumulate and can be distributed to eggs which is evidenced by animal metabolism and feeding studies (JMPR, 2023).

In addition, pesticides can enter eggs through environmental exposure of laying poultry, such as through contaminated soil. Field studies showed that raising hens in contaminated areas might lead to transfer of pesticides from soil to the eggs (Piskorska-Pliszczynska et al., 2019). According to the EU pesticide report 2021, the detected presence of the (now non-approved) pesticide chlordecone in chicken eggs relates to its persistence in the soil. Contamination may occur in chickens in open-cage farms when feed is placed in contact with the soil in areas where this active substance was previously used (EFSA, 2023e).

4.6.2. Hazard characterisation

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.

Pesticides are regulated in eggs by monitoring residue levels in relation to MRLs under assimilated Reg. (EC) 396/2005 (European Parliament, 2005; Gov UK, 2005). Where pesticides are used in accordance with good agricultural practice (GAP) this is unlikely to be of concern, as levels in poultry and eggs are expected to be below the MRL. Occurrence of a residue below the relevant MRL indicates that an unacceptable risk to consumers is unlikely. However, an exceedance of an MRL does not necessarily indicate a concern for consumer health, it is typically taken as a trigger for risk assessment or other enforcement action.

Appendix VIII summarises the pesticides detected in the literature and the highest levels reported. As the pesticide residues identified in the literature review were often not quantified and consistent reporting was not available, EU Pesticide Monitoring Reports, UK Pesticide Residues in Food (PRiF) Reports, and incidents and alerts data was used to identify potential pesticide residue MRL exceedances. Table 9 summarises the non-compliant pesticide residues that exceeded their MRLs in eggs and egg products in the EU and UK between 2019 and 2024.

Two of the pesticides identified in eggs also have biocidal and/or veterinary medicine uses, fipronil and chlorate (residue from chlorine-based disinfectants), and residues detected in eggs likely arose from these uses. Further discussion can be found in section 4.2.

4.6.3. Conclusion

Overall, a relatively small number of non-compliant cases due to pesticide residues have been detected in eggs.

The potential adverse effects that may result from exposure to residues of pesticides depends on the toxicological profile of the substance, the dose-response relationship and the level of exposure. The information available from EU and UK monitoring, alerts and incidents data, indicate that some pesticide residues may be present at levels above their respective MRLs. The presence of pesticide residues in eggs exceeding the MRL, or presence of a residue of a pesticide that is not authorised, may require further action in the form of risk assessment to determine the risk to consumer.

4.7. Veterinary medicines and feed additives

4.7.1. Hazard route

The deliberate addition of veterinary medicines and feed additives to animal feed is an important route for administering these substances to animals, in particular to animals intended for food production (Codex, 2019). Other application routes of veterinary drugs are also possible, such as via drinking water or injection (ACAF, 2007).

In GB antiprotozoal agents (coccidiostats and histomonostats) are permitted as feed additives but the use of antibiotics in feed additives is prohibited (FSA, 2024a). In some countries, in addition to treating infections, antibiotics are added to feed as growth promoters, although in the UK, it is illegal to use any antibiotic as a growth promoter (FSA, 2024b; WOAH, 2022).

Table 9. Incidents of pesticides reported from 2019 to 2024 in the EU and UK

Pesticide	Acute Reference Dose (mg/kg bw)	Acceptable Daily Intake (mg/kg bw/day)	Approval status in GB/NI (European Commission, 2024a; HSE, 2024a)	Codex MRL in eggs (Codex, 2024a)	Max. level reported in non-compliant egg samples (mg/kg)	Source of incidents (FSA, FERA, RLD, EU (EFSA, 2024b))	Remarks
Chlorate	0.036 (EFSA, 2015a)	0.003 (EFSA, 2015a)	Not approved GB and EU MRL of 0.05 mg/kg in eggs	Not available	0.115	EU report 2022 (EFSA, 2024i)	1 egg sample was found to have exceeded the MRL for chlorate. The total number of egg samples was not given in the report, hence the non-compliance rate cannot be estimated.
Chlordecone	Not available	Not available	Not approved GB and EU MRL of 0.02 mg/kg in eggs	Not available	0.292	EU report 2020 (EFSA, 2022e)	The report stated 8 out of 27 food samples found to have exceeded the MRL for chlordecone were from chicken eggs. The total number of egg samples was not given in the report, hence the non-compliance rate cannot be estimated.
Cyromazine	0.1 (EFSA, 2008a)	0.06 (EFSA, 2008a)	Not approved GB and EU MRL of 0.05* mg/kg in eggs	0.3 mg/kg	0.04	FSA (2021) PRiF quarterly reports 2021 (DEFRA, 2022a)	Based on the UK PRiF quarterly reports 2021, the estimated non-compliant rate was 0.76% in 2021 (1 out of 132 egg samples).
Fipronil	0.009 (EFSA, 2006)	0.0002 (EFSA, 2006)	Not approved GB and EU MRL of 0.005* mg/kg in eggs	0.02 mg/kg	0.07	EU report 2019 (EFSA, 2021c)	EU Pesticide Monitoring Report 2019 showed that 23 out of 31 samples detected with fipronil were from eggs. 18 out of 1,331 egg samples were considered non-compliant. Therefore, the estimated non-compliant rate was 1.4%.

* MRL is set at the limit of quantification (LOQ)

The unintended carryover of veterinary drugs from medicated feed to un-medicated feed at feed manufacturing facilities can be a source of contamination (Codex, 2019). It is also possible for a non-target animal to be given feed formulated for a target animal species, intentionally or accidentally.

In one study, lasalocid content in eggs was analysed. Lasalocid is a coccidiostat, which at the time of the study was not authorised for use in laying birds. Approximately 66% of the eggs analysed contained lasalocid at levels correlating to the concentration in the feed. Carryover of lasalocid from manufacture of medicated broiler and turkey feeds to unmedicated layer feed in local feed mills was identified as the possible source of the residues in eggs (Kennedy, Blanchflower, et al., 1996). Another study also concluded that unintentional and unavoidable carry-over of nicarbazin could affect laying hens, most-likely as the feed for chickens (for fattening) and laying hens is often prepared at the same mill (Codex, 2023).

A study has shown that ingestion of veterinary drugs such as coccidiostats by laying hens can lead to residues in eggs (Goetting et al., 2011). During egg development in poultry, precursors to yolk lipoproteins are produced in the liver and transported to the yolk follicles in the ovary. The veterinary drugs that deposit in the egg yolk rapidly accumulate during this time and can be present in successive eggs for 10 or more days following treatment. Following yolk maturation, the albumen is laid down and can also serve as a residue accumulation site. A variety of drugs left detectable residues in eggs laid days to weeks after the cessation of treatment (Goetting et al., 2011).

4.7.2. Hazard characterisation

The toxicity of veterinary medicine or feed additive 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. The potential adverse effects of veterinary medicine residues in food are broad, but include allergic reactions, nephrotoxicity, hepatoxicity, reproductive disorders, bone marrow toxicity and carcinogenicity (Bacanli & Basaran, 2019; Baynes, Dedonder, et al., 2016; Hosain et al., 2021).

Some of the antibiotics used in poultry can also be prescribed for human use, for example ciprofloxacin and ofloxacin which are used to treat serious infections in humans (MHRA, 2024). Overuse and misuse of antibiotics contributes to antimicrobial resistance, which leads to antibiotics becoming ineffective and infections becoming more difficult to treat (WHO, 2023a).

Veterinary medicine residues in food and feed are controlled according to MRLs in GB (VMD, 2024b) and NI (European Commission, 2009c). EU monitoring of VMP residues in live animals and animal products showed coccidiostats were reported to be non-compliant in 0.11% of the samples analysed, with highest occurrence in rabbit meat (0.87%) followed by eggs (0.42%) (EFSA, 2023c).

Appendix IX summarises the veterinary medicines and feed additives detected in EEPs, and the highest levels reported. Table 19 and Table 20 show the non-compliant cases of coccidiostats and veterinary medicine residues in eggs identified from the UK annual surveillance results on residues of veterinary medicines in food between 2019 and 2024 (up to 30 June), EU annual reports on VMP residues in food between 2019 and 2021, and other incident information sources such as RASFF (EFSA, 2024b), as well as residues identified in the literature.

Chloramphenicol and nitrofuran were identified in eggs via the literature review and alerts (EFSA, 2014a). Both are prohibited substances in food-producing animals in the EU and UK (European Commission, 2009c; VMD, 2024b). EFSA has concluded that there is no safe level of residues of chloramphenicol and nitrofuran or their metabolites in food that represents an acceptable risk to consumers (EFSA, 2014a, 2015b). Therefore, although chloramphenicol and nitrofuran metabolite AOZ have been found in eggs, they are prohibited substances and therefore are excluded for further assessment.

4.7.3. Conclusion

Residues of veterinary medicines and feed additives may be present in EEPs. Many residues detected in eggs were coccidiostats and histomonostats which are predominately regulated as feed additives in the UK, although some are also regulated as veterinary medicines.

The potential adverse effects that may result from exposure to VMPs and feed additives depends on the toxicological profile of the substance, the dose-response relationship and the level of exposure. The information available from EU and UK monitoring, alerts and incidents data indicate that some residues may be present at levels above respective MRLs. Additionally, residues of VMPs or feed additives 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 or feed additive in eggs which is not authorised or exceeds the MRL, may require further action in the form of risk assessment to determine the risk to consumer.

5. Hazard Prevention, Mitigation and Controls

5.1. Hazard Mitigation

Interventions designed to eliminate or reduce the amount of any given hazard present in EEPs can be applied at a number of stages throughout the production process; from the farm where the poultry feed grows, to the retail market for the final product. Such activities aim to either prevent the hazard from entering the EEPs or mitigating the hazard before the final product reaches the consumers. Mitigations that the consumers can take at home, such as cooking, are not discussed in this section, as they would be the same for domestic and imported EEPs and they are not in scope.

In the rest of this section, mitigations are discussed in the context of how hazards may enter the EEPs.

5.2. Hazards introduced during egg formation

Hazards that may enter the egg before it is laid include pathogenic microorganisms such as *Salmonella* Enteritidis and a number of chemical hazards. These two groups of hazards (microbial & chemical) are discussed separately below.

5.2.1. Chemical hazards

Chemical hazards that may enter the egg during its formation are taken up by the birds via feed, water or contamination in the farm environment (e.g. in soil or bedding). These hazards include mycotoxins, PAs, environmental contaminants, metals, pesticides and veterinary medicines.

Mitigation measures for chemicals in eggs and egg products are primarily related to the environment of the poultry farm and the poultry feed and water, as there are currently no identified mitigation measures in the egg, other than monitoring. Quality control plans can be used to address this, in the UK this includes setting sampling and testing frequencies for all feed ingredients and feeding stuffs (BEIC, 2013).

5.2.1.1. Animal feed & water

Poultry diets are formulated from a mixture of ingredients, including cereal grains, cereal by-products, fats, plant protein sources, and other nutrients (FAO, 2024). Agricultural contaminants, pesticides, veterinary medicines and feed additives primarily enter the eggs via this route.

The Codex "Code of Hygiene Practice on Good Animal Feeding" provides recommendations on prevention of contaminants in eggs, as improper procurement, manufacturing and handling of animal feed may result in the introduction of hazards into the eggs and egg products (Codex, 2004). This is expanded on in the FAO "Good practices for the feed sector guidance" which makes recommendations around feed ingredients, traceability, inspection and control and GMP as well as feed production (FAO, 2020).

In the Codex "General Standard For Contaminants And Toxins In Food And Feed", maximum levels of various chemical contaminants are specified in feed, including aflatoxins, and ochratoxin A, melamine and several metals (Codex, 1995). This standard specifies that contaminant levels should be as low as possible, achieved by following GAP and good manufacturing practice (GMP), with specific actions recommended. For example preventing contamination at source (e.g. by reducing environmental pollution) and applying measures to prevent marketing of contaminated feed for consumption.

5.2.1.1.1. Mycotoxins

The Codex Alimentarius recommend a number of measures for the reduction of mycotoxin contamination in cereals, including appropriate use of crop rotation, use of appropriate pesticides and ensuring grain is dried appropriately (Codex, 2003).

The FSA has produced two guidance documents regarding mycotoxins, specifically fusarium and ochratoxin A in cereals. Specific mitigations recommended are avoiding maize in crop rotation, use of fungicides and appropriate drying and grain storage (FSA, 2007a, 2007b).

The FAO have produced "On-Farm Mycotoxin Control in Food and Feed Grain", which provides guidance on; signs of mycotoxins and mould growth, factors that affect fungal growth, symptoms of mycotoxin poisoning in poultry, and how to prevent mould damage before, during and after harvest (FAO, 2007).

Bentonite (a type of clay) can be added to feed to bind with mycotoxins in the digestive tract, thereby reducing mycotoxin contamination of animal products (EFSA, 2011b). The maximum content of bentonite in feed is controlled by UK legislation (European Commission, 2013).

In GB and NI maximum permissible limits are set for certain aflatoxins in feed under regulations GB 2015/255 and 2002/32/EC respectively, and guidance values are set for OTA. The maximum permissible level of AFB1 in feed materials (based on a moisture content of 12%) is 0.02 mg/kg (European Parliament, 2002; Gov UK, 2002, 2015c). The upper guidance

value for ochratoxin A in cereals and cereal product feed materials (based on a moisture content of 12%) is 0.25 mg/kg, and for compound feed for poultry 0.1 mg/kg (European Commission, 2006).

Mitigation measures for toxins in EEPs are related to the poultry feed, as there are currently no identified mitigation measures in the egg, other than monitoring. Quality control plans can be used to address this, in the UK this includes setting sampling and testing frequencies for all feed ingredients and feeding stuffs (BEIC, 2013).

5.2.1.1.2. PAs

Codex Alimentarius has set out a code of practice to reduce PA contamination (Codex, 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 agents.

5.2.1.1.3. Pesticides

In the UK and EU, pesticides must be authorised before being placed on the market. Authorised uses must be supported with a satisfactory risk assessment which includes a consideration of potential levels in poultry and eggs and subsequent consumer exposure. Pesticides are required to be appropriately labelled with instructions for use and must be used in accordance with GAP (HSE, 2024f). In GB, the Health and Safety Executive (HSE) is responsible for MRLs for pesticides. An MRL is the maximum concentration of a pesticide residue in food of plant or animal origin that is legally tolerated when a pesticide is applied following good agricultural practice (assimilated Reg. (EC) 396/2005) (European Parliament, 2005; Gov UK, 2005). Where pesticides are used according to the conditions of authorisation, residues exceeding the MRL in eggs should not occur.

An import tolerance is an MRL set on imported food or feed to meet the needs of international trade. Where a commodity is treated with a pesticide at a higher rate internationally than in GB, and the commodity is imported into GB, an assessment of the risk and expected levels in the commodity must be made, with an import tolerance set if required (HSE, 2024e).

Globally, the majority of countries set their own national MRLs, but in addition Codex Alimentarius sets Codex maximum residue levels (CXLs) for pesticides which are internationally agreed food standards (Codex, 2024a).

The FAO “International Code of Conduct on Pesticide Management (the Code of Conduct)” serves as a voluntary framework for all public and private entities engaged in, or associated with, production, regulation and management of pesticides (FAO, 2014).

There are pesticide monitoring programmes globally, including in GB and EU, which monitor pesticide residues in a range of crops (DEFRA, 2022b; European Commission). The results of the monitoring programmes can be used to target further action.

For eggs specifically, Codex states that appropriate feed must be used so as not to introduce chemical hazards such as pesticide residues into eggs (Codex, 1976). In the code of practice for animal feeding, it is specified that feed ingredients must be within statutory levels for pesticides (Codex, 2004).

The EU Drinking Water Directive sets maximum allowable concentrations of 0.1 µg/L for any pesticide and 0.5 µg/L for total pesticides in drinking water, irrespective of toxicity (European Parliament, 2020). WHO guidelines also provide some recommendations for mitigations including system plans and process control measures (WHO, 2022b).

5.2.1.1.4. Veterinary medicines

In GB, the Veterinary Medicines Directorate (VMD) is responsible for MRLs for veterinary medicines. The MRL is the maximum allowed concentration of a residue in a food product obtained from an animal that has received veterinary medicine or that has been exposed to a biocidal product for use in animal husbandry. Where the veterinary medicine is applied to the animal at up to the maximum allowed dose rate, residues exceeding the MRL should not occur.

In GB, VMD carries out an annual surveillance plan to analyse samples from food producing animals for residues of authorised veterinary medicines, prohibited substances and various contaminants (VMD, 2024d). In addition, farm inspections on the use of veterinary medicines are conducted (VMD, 2023b). In the EU, the EMA has a similar role, and also undertakes surveillance (EMA, 2024). Codex has produced guidelines for implementing a regulatory assurance programme for use of veterinary drugs in livestock (Codex, 2009).

WHO has launched new guidelines on the use of medically important antimicrobials in food-producing animals, recommending that farmers and the food industry stop using antibiotics routinely to promote growth and prevent disease in healthy animals. These guidelines aim to help preserve the effectiveness of antibiotics that are important for human medicine by reducing their use in animals (WHO, 2017b).

As highlighted in section 4.7.1, cross-contamination between feed for target species containing between coccidiostats and histomonostats and feed for non-target species can occur during preparation at the same mill.

Codex guidance states that feed additives and veterinary drugs used in medicated feed, should be assessed for safety and used under stated conditions set by competent authorities (Codex, 2005). It advises clearly distinguishing between feed additives and veterinary drugs used in medicated feed, to avoid misuse. This can be considered critically important to prevent carry-over and cross-contamination of medicated feed with non-medicated feed for non-target species (Codex, 2005).

It is essential that levels of undesirable substances are sufficiently low in feed and feed ingredients, that their concentration in food for human consumption, including eggs is consistently below the level of concern. Overall to achieve this, below points needs to be taken into account:

- Following Codex guidelines, GMP (Codex, 2005)
- Regular monitoring and identifying coccidiostats and histomonostats in feed (European Parliament, 2002) and egg above the MRL (VMD; European Commission, 2009b)
- Usage according to recommended withdrawal times (European Commission, 2009a)
- Usage for species that it is only authorised for (VMD; European Commission, 2009c, 2009b, 2012; Gov UK, 2009a, 2012)
- Measures to prevent cross-contamination during manufacturing, storage, transport and usage (e.g., carry-overs in mills) (Codex, 1995, 2005, 2023).

5.2.1.2. Environmental

Contamination of eggs with certain chemicals can occur through the environment of the poultry farm. Environmental contaminants include dioxins, dioxin-like substances, PCBs, PFAS, and metals. For these chemicals, environmental exposure is the primary route of contamination, which in turn may contaminate the poultry feed and water (see section 5.2.1.1).

5.2.1.2.1. Environmental contaminants

Codex guidance on source directed measures to reduce chemical contamination of food, notes that pollution can result in the contamination of crops grown for feed and drinking water, and that appropriate measures for national authorities may be to (Codex, 2001):

- Control emissions of pollutants from industry

- Control emissions from energy generation and means of transportation
- Control the disposal of solid and liquid domestic and industrial waste
- Control the production, sale, use and disposal of certain toxic, environmentally persistent substances
- Ensure that before new chemicals are introduced, they have undergone appropriate testing to show their acceptability
- Replace toxic environmentally persistent substances with alternatives

Codex also recommend that the surroundings and environment of the poultry farm should be considered for possible sources of contamination including, previous uses of the land, presence of chemical contaminants and polluted surface water (Codex, 1976).To reduce the contamination of dioxins and PCBs in eggs, control measures at the feed level should be considered. Such measures may include (Codex, 2018):

- Identification of possibly contaminated areas in the feed supply ecosystem
- Identification of the origin of frequently contaminated feed or feed ingredients
- Monitoring the compliance of feed and feed ingredients with nationally established guideline levels or maximum levels, if available

The Stockholm Convention is a global treaty to protect human health and the environment from POPs. Of the POPs included, PFOS (a PFAS) and PCNs are targeted for elimination and the unintentional release of dioxins and PCBs must be minimised (Stockholm Convention, 2019).

EFSA determined PFAS transfer from feed to animal derived food, including eggs (EFSA, 2020e). As such, the European Commission has recommended further investigation in cases where MLs are exceeded in foodstuffs. This aims to determine the possible root cause of contamination, and to control feed, animal drinking water and the soil on which animals live, as well as undertake monitoring in food (European Commission). Measures can be taken to remove PFAS from drinking water (EEA, 2024).

Limited information is available with respect to the control or mitigations of PCNs or melamine in food or feed. EFSA reviewed the potential human health risks related to PCNs in food and feed, and made a recommendation

that the monitoring of levels should be undertaken, particularly where animals are raised on PCN contaminated soil or near other sources (EFSA, 2024f).

Maximum legal levels, set in regulation at a national level, as outlined in section 4.3, are another way that the levels of contaminants in food products can be controlled.

Maximum levels for metals in drinking water in the UK are specified in The Water Supply (Water Quality) Regulations 2016 (Gov UK, 2016b). WHO provide information on the standards of water safety and recommendations for mitigations, including system plans and process control measures (WHO, 2022b). With regard to drinking water specifically for livestock and poultry, FAO guidance is available which provides guideline upper limits for toxic substances including metals in livestock drinking water (FAO, 1985).

5.2.2. Microbiological hazards

Most microbiological hazards that can be found in eggs are likely to come into contact with the egg after it is laid. However, Salmonella, and especially *Salmonella* Enteritidis can contaminate the egg during formation within the animal's reproductive system. *Campylobacter* spp are believed to contaminate the egg surface when present in the egg environment. Contamination during the formation of the egg cannot be ruled out, albeit its effect is believed to be minor.

To mitigate hazards that colonise the birds, eradication and vaccination programmes, including for breeder flocks, are likely to be the most effective mitigation measures (OIE, 2022). All other mitigations discussed in section 5.3.2 can also support control efforts.

5.3. Hazards introduced after laying

5.3.1. Chemical

The main contamination route for chemicals in eggs after laying is during processing, where biocides may be used as disinfectants or insecticides.

5.3.1.1. Biocides

The Codex "Code of Hygiene Practice on Good Animal Feeding" states that cleaning programmes should minimise residues of detergents and disinfectants, and that machinery must be dried following wet cleaning (Codex, 2004).

Codex states that any pest control measures (which would include the use of biocides in Group 3: Pest control, e.g. PT18 insecticides and acaricides) should not result in unacceptable levels of pesticide residues in or on eggs and that properly designed pest control methods should be used (Codex, 1976).

For biocides used in animal husbandry which may leave residues in foods of animal origin, veterinary medicine MRLs are applicable, as set out in assimilated Reg. (EC) 37/2010, (European Commission, 2009c; VMD, 2024b). Where a biocide is currently or has previously been authorised as a pesticide in GB or EU (for example, fipronil and chlorate), then pesticide MRLs are applicable (assimilated Reg. (EC) 396/2005) (European Parliament, 2005; Gov UK, 2005).

5.3.2. Microbiological

From the hazards characterised *herein*, *Salmonella* Typhimurium's primary route into the egg is via contact with contaminated surfaces, *Listeria monocytogenes* are primarily linked to cross-contamination in manufacturing settings, and *Campylobacter* spp, tends to colonise the egg shells when they come into contact with surfaces where the pathogen resides, primarily in faeces.

Controls for microbiological hazards in eggs are predominantly concerned with the control of *Salmonella*. These controls are discussed in detail below, but they can equally be applied to control other microbiological hazards, such as *Campylobacter* and *Listeria monocytogenes.*

In the UK, assimilated Regulation (EC) 2073/2005 (European Commission, 2005) sets requirements for sampling plans, analytical methods and permitted levels of microbiological hazards in foodstuffs for *Salmonella* and *L. monocytogenes* that can be found in foodstuffs. The requirements for EEPs can be found in Table 10.

Table 10. Microbiological criteria for *Salmonella* and *L. monocytogenes* in EEPs as set in Reg. (EC) 2073/2005 (European Commission, 2005)

Food	Microorganism	Limit	Analytical reference method	Stage where the criterion applies
Egg products, excluding products where the manufacturing process or the composition of the product will eliminate the salmonella risk	*Salmonella*	Not detected in 25 g	EN ISO 6579-1	Products placed on the market during their shelf-life
Ready-to-eat foods containing raw egg, excluding products where the manufacturing process or the composition of the product will eliminate the	*Salmonella*	Not detected in 25 g	EN ISO 6579-1	Products placed on the market during their shelf-life

Food	Microorganism	Limit	Analytical reference method	Stage where the criterion applies
salmonella risk				
Ready-to-eat foods intended for infants and ready-to-eat foods for special medical purposes	*Listeria monocytogenes*	Not detected in 25 g	EN/ISO 11290-1	Products placed on the market during their shelf-life
Ready-to-eat foods able to support the growth of L. monocytogenes, other than those intended for infants and for special medical purposes	*Listeria monocytogenes*	100 cfu/g (5)	EN/ISO 11290-2	Products placed on the market during their shelf-life
Ready-to-eat foods able to support the growth of L. monocytogenes, other than those intended for infants and for special medical purposes	*Listeria monocytogenes*	Not detected in 25 g	EN/ISO 11290-1	Before the food has left the immediate control of the food business operator, who has produced it
Ready-to-eat foods unable to support the growth[1] of L. monocytogenes, other than those intended for infants and for special medical purposes	*Listeria monocytogenes*	100 cfu/g	EN/ISO 11290-2	Products placed on the market during their shelf-life

[1] Products with pH ≤ 4,4 or a_w ≤ 0,92, products with pH ≤ 5,0 and a_w ≤ 0,94, products with a shelf-life of less than five days shall be automatically considered to belong to this category. Other categories of products can also belong to this category, subject to scientific justification.

In contrast to chemical hazards, microbiological hazards can be mitigated in industrial settings via heat treatment such as pasteurisation (USDA, 2020). Most egg products are pasteurised to destroy bacteria, however shell eggs are not always pasteurised. Shell eggs may be cooked, but they can also be eaten in circumstances where they are not cooked or not thoroughly cooked. Pasteurisation requirements for liquid whole eggs can vary by country. European heat treatments typically involve temperatures of 65 - 68 °C for 5 - 6 minutes for whole eggs and egg yolks. Egg whites undergo milder treatments (55 – 57 °C for 2 – 5 minutes) due to their higher heat sensitivity (EFSA, 2014c).

Controls for *Salmonella* in egg products include heat treatments to provide at least a 5-log reduction of viable cells, as well as cooling and freezing to prevent the growth of cells (USDA, 2020). Post lethality handling and sanitation is also important, which should be considered in HACCP systems, including microbiological sampling and testing. Verification of adequate pasteurisation should also be conducted, via testing for presence of *Salmonella* spp. (USDA, 2020).

The Food Safety and Inspection Service (FSIS) of the USDA guidance recommends that the presence of *Salmonella* in finished products can indicate pasteurisation failure. which may mean other pathogens such as *Listeria* may also be present (USDA, 2020).

L. monocytogenes is an environmental organism, with a strong adherence ability and a biofilm former., This is likely to affect its resistance to eradication attempts and should be considered when cleaning programmes are designed at an industrial setting (Gonzales-Fandos et al., 2021).

Campylobacter are susceptible to drying, freezing, heating, disinfectants and acidic conditions (pH<4.7) (FSS, 2019). However, resistance to disinfectants increases by several days when the cells form biofilm structures (ACMSF, 2019). Freezing reduces the microbial load significantly and chilling at refrigeration temperatures also results in slow reduction in bacterial numbers (ACMSF, 2019).

5.3.2.1. *Salmonella*

A control programme for *Salmonella* Enteritidis and *Salmonella* Tymphimurium in breeding flocks of domestic fowl has been in operation in the UK since 1989 (DEFRA, 2008). Control advice is provided, including on-farm visits, by experts in Salmonella control when appropriate (DEFRA, 2008).

Salmonella can be mitigated at the farm via various controls, including use of live attenuated vaccines of *S.* Enteritidis and other *Salmonella* serotypes. Evidence suggests that vaccines, whilst not completely protective, are effective in reducing the overall rate of *Salmonella* infection; faecal shedding; ovarian transmission, and the within-flock prevalence in hens (ACMSF, 2016).

Additional mitigations at the farm include preventing access of domestic, wild and feral animals to places where hens can access, as these animals can naturally carry *Salmonella*. Feedstuffs and water supply should be compliant with the respective country's code of practice, as they can act as fomites to transmit *Salmonella* to hens. In addition, the environment should be kept clean, and surfaces disinfected; formaldehyde based disinfectants are most effective if organic matter is present (DEFRA, 2007).

The FSA matrix, which is used to assess industry schemes for effectiveness on *Salmonella* controls is discussed in section 2.2.4. The FSA matrix requires a number of controls for such schemes to be approved, including: biosecurity measures, pest control, cleaning and disinfection programmes on the farm, vaccination programmes for both breeding and laying flocks, limited use of antimicrobials to treat animal diseases, sampling and testing regimes throughout the production chain (from feed to the final product),

personnel training, recording of all activities and controls, documented temperature controlled environment, independent auditing of documentation and clear processes when Salmonella is detected.

The Codex "Code of Hygienic Practice for Eggs and Egg Products"(Codex, 1976) includes similar key mitigation measures:

- Environmental hygiene – ensuring the hazards in the production environment are minimised through measures such as waste management and pest control
- Flock management and animal health – ensuring the flock is in good health via means such as vaccination (where vaccines exist, such as for *Salmonella*), flock checking and veterinary treatment when required
- Hygienic production and handling – ensuring the establishment minimises exposure to hazards including via cleaning and disinfection, maintaining clean water, feed management and pest control
- Personnel considerations – including ensuring appropriate training, personal hygiene and good health
- Record keeping – ensuring traceability and accountability to verify the effectiveness of control systems.

Controls may differ depending on whether the type of prevalent *Salmonella* can be transmitted vertically or horizontally. For example, vertical transmission can be controlled with vaccination while for environmental transmission the source needs to be identified, and biosecurity measures may be more effective. Additionally, the ability of the pathogens to form biofilms should be considered when designing cleaning and disinfection regimes.

5.4. Hazard Controls

5.4.1. Import Conditions

EEPs can only be imported into the UK from countries that have market access approval and have an approved residue monitoring plan in accordance with EU Decision 2011/163 (GB) or Reg. (EC) 2022/2293 (NI) (European Commission, 2011, 2022b). Imported products must also be accompanied by appropriate health certificates based on the assimilated Reg. (EC) 2019/628 (European Commision, 2020).

5.4.2. Regulations applicable to the UK

Regulations relating to EEPs mainly concern general criteria such as: rules for public health requirements (including hygiene, microbiological criteria, contaminants regulations, additives regulations, use of antimicrobials). The regulations are mostly not specific to eggs but applicable to products of animal origin (POAO) more broadly.

There are also regulations and legislation specific to the majority of the hazards identified in this profile. Regulations in this section have been split into areas to which they relate e.g. hazard specific such as microbiological criteria or commodity (EEP) specific. Regulations noted in this section are in relation to both GB and NI, as EU legislation remains applicable to NI. Where Regulations fall under assimilated legislation, these may be the same. Where Regulations are relevant to NI only, this is noted in the first column of the table. Any Commission regulations noted in the table which are not noted as specific for the UK, GB or NI, will be applicable to all. Regulations with only UK, GB, Welsh or Scottish references are relevant only to these areas. Any Regulations referring to EU Exit are relevant to GB only.

Regulations listed and summarised in Table 11 are commodity (directly relating to EEPs) or hazard specific regulations which relate to EEPs. General food safety laws relating to all food, POAO generally or general feed controls have been excluded in order minimise the list and keep only those specifically relevant to EEPs.

6. Conclusions

This risk profile identifies and characterises the main hazards associated with shell eggs and egg products (EEPs) from domestic poultry species imported into the United Kingdom.

EEPs are consumed widely across the UK population, with over half of those surveyed consuming them; this is predominantly due to the inclusion of EEPs in a large number of products as well as the consumption of whole eggs. Infants are the highest chronic and acute consumers of eggs. Across all population subgroups, 97.5th percentile consumers eat the equivalent of 1-2 eggs per day.

The UK is active in the global trade of EEPs, exporting an average of 19,689 tonnes per year between 2016 and 2022. The largest importer of UK EEPs is the Netherlands, importing around 36% of the total. The UK imports an average of around 65,592 tonnes per year, with around 56% of these imported from the Netherlands. Of all imported EEPs approximately 70% are egg products rather than whole eggs.

Table 11. Commodity (EEP) specific or hazard specific regulations relating to EEPs

Regulation	Summary in relation to EEPs
Agricultural and environmental contaminants and metals	
Assimilated Regulation (EC) 1881/2006 – setting MLs for certain contaminants in food stuffs Assimilated Commission Regulation (EU) 105/2010 Assimilated Commission Regulation (EC) 856/2005	This Regulation sets MLs for certain contaminants in food stuffs, covering mycotoxins (aflatoxins, OTA, Fusarium toxins, patulin and citrinin, ergot sclerotia, ergot alkaloids); metals (lead, cadmium, mercury, inorganic tin and arsenic); 3-monochloropropane-1,2-diol (3-MCPD) and its fatty acid esters and glycidyl fatty acid esters; dioxins and PCBs; PAHs; melamine; erucic acid, hydrocyanic acid, tropane alkaloids, PAs; nitrates; perchlorate. Equivalent EU Regulations are noted elsewhere. Regulation (EU) 105/2010 amends Regulation (EC) 1881/2006 as regards OTA. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." Regulation (EC) 856/2005 amends Regulation (EC) 466/2001 (repealed by Regulation (EC) 1881/2006) as regards *Fusarium* toxins. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." Equivalent EU Regulations are noted elsewhere.
Commission Regulation (EU) 2023/915 – MLs for certain contaminants in food (Repealing Regulation (EC) 1881/2006) – relevant to NI only	This Regulation is relevant to NI only as it came into force after EU Exit and the transition period. It lays down the MLs for certain contaminants in food, covering mycotoxins (aflatoxins, OTA, patulin, deoxynivalenol, zearalenone, fumonisins, citrinin, ergot sclerotia and ergot alkaloids); metals (lead, cadmium, mercury, inorganic tin and arsenic); plant toxins (erucic acid, tropane alkaloids, hydrocyanic acid, PAs, opium alkaloids and Δ9-THC); processing contaminants (PAHs, benzo(a)pyrene, sum of 4 PAHs; 3-monochloropropane-1,2-diol (3-MCPD)and glycidyl fatty acid esters); halogenated POPs (dioxins, dioxin-like PCBs, non-dioxin-like PCBs; the perfluoroalkyl substances: PFOS, PFOA, PFNA and PFHxS); and other contaminants (melamine, nitrates).
Assimilated Commission Regulation (EU) 2019/1009 – use of fertilising products.	This Regulations lays down rules on the making available on the market of EU fertilising products and amending Regulations (EC) 1069/2009 and (EC) 1107/2009 and repealing Regulation (EC) 2003/2003. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EU) 2018/1039 – copper authorisation	This Regulation concerns the authorisation of Copper(II) diacetate monohydrate, Copper(II) carbonate dihydroxy monohydrate, Copper(II) chloride dihydrate, Copper(II) oxide, Copper(II) sulphate pentahydrate, Copper(II) chelate of amino acids hydrate, Copper(II) chelate of protein hydrolysates, Copper(II) chelate of glycine hydrate (solid) and Copper(II) chelate of glycine hydrate (liquid) as feed additives for all animal species and amends Regulations (EC) 1334/2003, (EC) 479/2006 and (EU) 349/2010 and Implementing Regulations (EU) 269/2012, (EU) 1230/2014 and (EU) 2016/2261. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI.
Allergens	
Assimilated Regulation (EU) 1169/2011 (for England and Wales) and Regulation (EU) 1169/2011 (for Northern Ireland) – food	This Regulation largely provides legislative framework around the provision of food allergen information and is often referred to as Food Information to Consumers or FIC. The FIC imposes a duty on food businesses to ensure that all mandatory food allergen information (relating to 14 substances listed in the FIC that are known to cause allergies) is accurate, available, and easily accessible to the consumer. The 14 allergens listed in Annex II of the FIC are recognised as the most common ingredients or processing aids that cause food allergies and intolerances. If a food contains or uses an ingredient or processing aid in the manufacture or preparation of the food derived from one of the substances or products listed in Annex II, and it is still present in the

Regulation	Summary in relation to EEPs
information to consumers (FIC).	finished product, information regarding the presence or use of the allergen must be provided to the consumer. All FBOs must declare the presence, whether for use as an ingredient or a processing aid, of egg in food. The EU equivalent is still in force which is relevant to NI.
Biocides	
The Biocidal Products Regulations 2001/880 – GB only	These Regulations have effect with a view, first, to enabling applications to be made for agreement that an active substance can be used in a biocidal product and, secondly, to authorising the placing on the market and use of biocidal products to which these Regulations apply. Equivalent EU Regulations are noted elsewhere.
Assimilated Commission Regulation (EU) 528/2012 - concerning the making available on the market and use of biocidal products	This Regulation harmonises the rules concerning the sale and use of biocidal products. In order to be allowed to be sold, all biocidal products require a permit. The active substances that they contain must be approved or included into Annex I of the regulation. The EU equivalent is still in force which is relevant to NI.
Microbiological hazards	
The Zoonoses Order 1989 The Zoonoses (Amendment) (England) Order 2021 The Zoonoses (Amendment) (Wales) Order 2021/192 The Zoonoses Amendment (Coronavirus) (Scotland) Order 2021/83	This Order, which revokes and re-enacts, with amendments, the provisions of the Zoonoses Order 1975, designates (as did the 1975 Order) organisms of the genus *Salmonella* and the genus *Brucella* for the purposes of section 29 of the Act. Equivalent EU Regulations are noted elsewhere.
Assimilated Commission Regulation (EU) 2016/429 – transmissible animal diseases Commission Regulation (EU) 2020/692 Assimilated Implementing Regulation (EU) 2019/626 Commission Regulation (EU) 2020/2235	This Regulation is on transmissible animal diseases. According to legislation.gov.uk "the introductory text is up to date with all changes known to be in force on or before 28 August 2024. There are changes that may brought into force at a future data. Changes that have been made appear in the content and are referenced with annotations". The EU equivalent is still in force which is relevant to NI. Regulation (EU) 2020/692 supplements Regulation (EU) 2016/429 as regards rules for entry, and the movement and handling after entry of consignments of certain animals, germinal products and POAO. It also repeals Regulation (EU) 2016/759. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI. Regulation (EU) 2019/626 concerns the lists of third countries or regions thereof from which consignments of certain animals and goods intended for human consumption are authorised for entry into GB from a food safety perspective in accordance with Regulation (EU) 2017/625. Regulation (EU) 2016/759 has been repealed by Regulation (EU) 2020/692. Equivalent EU Regulations are noted elsewhere.

Regulation	Summary in relation to EEPs
	Regulation 2020/2235 lays down the rules of application of Regulations (EU) 2016/429 and (EU) 2017/625 as regards model animal health/ official certificates for entry into the Union or GB. It repeals Regulation (EC) 599/2004, (EU) 636/2401 and (EU) 2019/628. According to legislation.gov.uk the Regulation "is up to date with all changes known to be in force before 27 August 2024. There are changes that may be brought into force at a future date". The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EC) 2160/2003 – detection and control of *salmonella* and other zoonotic agents Assimilated Commission Regulation (EU) 2010/200 Assimilated Commission Regulation (EU) 517/2011 Assimilated Commission Regulation (EC)1177/2006 Assimilated Commission Regulation (EC) 1237/2007	The purpose of this Regulation is to ensure the proper and effective measures to detect and control *salmonella* and other zoonotic agents at all relevant stages of production, processing and distribution. For this Regulation "there are outstanding changes not yet made" according to legislation.gov.uk. The EU equivalent is still in force which is relevant to NI. Regulation (EU) 2010/200 implements Regulation (EC) 2160/2003 and "there are outstanding changes not yet made" according to legislation.gov.uk. The EU equivalent is still in force which is relevant to NI. Regulation (EU) 517/2011 implements Regulation (EC) 2160/2003 and amends Regulations (EC) 2160/2003 and 2010/200. The EU equivalent is still in force which is relevant to NI. Regulation (EC) 1177/2006 implements Regulation (EC) 2160/2003 as regards requirements for the use of specific control methods in the framework of the national programmes for the control of *salmonella* in poultry. The EU equivalent is still in force which is relevant to NI. Regulation (EC) 1237/2007 amends Regulation (EC) 2160/2003 and Decision 2006/696/EC (Repealed by Regulation (EU) 2020/692) as regards the placing on the market of eggs from *Salmonella* infected flocks of laying hens. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI.
The Poultry (Seizure of Hatching Eggs) Order 1990- *Salmonella* – GB only	This Order empowers an inspector of the Minister of Agriculture, Fisheries and Food to seize and dispose of any hatching eggs (the eggs of domestic fowls, turkeys, geese or ducks intended for incubation) in order to prevent the spread of *salmonella* (article 3).
The Control of Salmonella in Poultry (England) Order 2007/3574 The Control of Salmonella in Poultry (Breeders, Layers and Broiler Flocks) (Scotland) Order 2009/229 The Control of Salmonella in Poultry Order (Wales) 2008/524 The Control of Salmonella in Poultry Scheme Order (NI) 2008/263	This Order revokes and remakes the Poultry Breeding Flocks and Hatcheries (England) Order 2007. The principal change is that it extends the sampling provision in the earlier Order to laying flocks of birds of the species *Gallus gallus*. It enforces Regulation (EC)1003/2005 (Repealed by Regulation (EC) 200/2010), Regulation (EC) 1168/2006 (Repealed by Regulation (EC) 517/2011) and Regulation (EC) 1177/2006. For this Regulation "there are outstanding changes not yet made" according to legislation.gov.uk. The Order also revokes and remakes the Control of Salmonella in Poultry (Scotland) Order 2008. This Order also revokes and remakes the Poultry Breeding Flocks and Hatcheries (Wales) Order 2007. Finally, this Order revokes and remakes the Poultry Breeding Flocks and Hatcheries Scheme Order (Northern Ireland) 2007.
Assimilated Commission Regulation (EC) 2073/2005 – microbiological criteria	This Regulation lays down the microbiological criteria for certain micro-organisms and the rules which must be followed by FBOs when implementing the general and specific hygiene measures referred to in Article 4 of Regulation (EC) 852/2004. This should also apply in particular to the health standards for foodstuffs laid down in Regulation (EC) 853/2004.

Regulation	Summary in relation to EEPs
for foodstuffs.	The EU equivalent is still in force which is relevant to NI.
Assimilated Council Directive 2003/99/EC - zoonoses	The purpose of this Directive is to ensure that zoonoses, zoonotic agents and related antimicrobial resistance are properly monitored. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation…no amendments have been made to this version." The EU equivalent is still in force which is relevant to NI.
Pesticides	
Codex Pesticides Residues in Food online database	This database contains Codex MRLs for Pesticides and Extraneous MRLs adopted by the Codex Alimentarius Commission up to and including its 46th Session (November 2023). Codex MRLs (CXLs) are internationally agreed food standards covering pesticide residues in or on food and feed.
The GB MRL statutory Register - PPPs	Following the UK's exit from the EU, GB MRLs are set by inclusion in a new statutory Register, implemented and updated by means of a database. This statutory Register includes MRLs and legal provisions set under EU Regulations before the end of the transition period that have been carried forward into domestic law. EU MRLs will apply in NI at the end of the transition period.
Assimilated Regulation (EC) 396/2005 – MRLs of pesticides food and feed of plant and animal origin	This Regulation is on MRLs of pesticides in or on food and feed of plant and animal origin and amending Directive 91/414/EEC. There are changes to the text of this Regulation on which haven't been incorporated into GB law. The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EU) 1107/2009 – placing of PPPs on the market Assimilated Commission Regulation (EU) 540/2011 Assimilated Commission Regulation (EU) 2017/409 The Plant Protection Product (EU Exit) Regulations 2019 – relevant to GB only	This Regulation concerns the placing of PPPs on the market. The EU equivalent is still in force which is relevant to NI. Regulation (EU) 540/2011 implements Regulation 1107/2009. According to legislation.gov.uk "there are outstanding changes not made to the Regulation. Those changes will be listed when the content opened. Any changes that have already been made to the legislation appear in the content and are referenced with annotations". Regulation (EU) 2017/409 approves the basic substance hydrogen peroxide in accordance with Regulation (EC) 1107/2009 and amends the Annex to Regulation (EU) 540/2011. According to legislation.gov.uk "there are currently no known outstanding effects for this Regulation" The Plant Protection Product Regulations make amendments to legislation in the field of pesticides, and in particular amending legislation relating to PPPs. Part 2 amends Regulation (EC) 1107/2009 concerning the placing of PPPs. Part 3 transfers functions from Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides. Part 4 makes consequential amendments, contains transitional provisions and savings, and revokes retained direct EU legislation. The EU equivalent is still in force which is relevant to NI.
Veterinary medicines and feed additives	
The Animals and Animal Products (Examination for Residues and Maximum Residue Limits) (England and Scotland) Regulations 2015/787 The Animals and Animal	These Regulations apply in relation to England, Scotland and Wales and revoke the statutory instruments listed in the Schedule, consolidating their provisions. The Regulations implement: a) Directive 96/22/EC concerning the prohibition on the use in stockfarming of certain substances having a hormonal or thyrostatic action and of beta-agonists and b) Directive 96/23/EC on measures to monitor certain substances and residues thereof in live animals and animal products and provide for the execution and enforcement of Regulation (EC) 470/2009 - laying down procedures for the establishment of residue limits of pharmacologically active substances in POAO and Regulation (EU) 37/2010 on pharmacologically active substances and their classification regarding MRLs in POAO.

Regulation	Summary in relation to EEPs
Products (Examination for Residues and Maximum Residue Limits) (Wales) Regulations 2019/569 The Animals and Animal Products (Examination for Residues and Maximum Residue Limits) Regulations (Northern Ireland) 2016/54	This is similar for Northern Ireland, and they replace provisions formerly contained in the Animals and Animal Products (Examination for Residues and MRLs) Regulations (Northern Ireland) 1998 and Amending Regulations. MRLs in GB aim to protect public health, substances used in veterinary medicines, on the basis of scientific assessment of the risk to consumers of those substances, are classified into three groups (allowed substances, prohibited substances, out of scope substances) and provided in the VMD document on MRLs in GB. Equivalent EU Regulations are noted elsewhere.
The Veterinary Medicines Regulations 2013/2033	These Regulations revoke and remake with amendments the Veterinary Medicines Regulations 2011. The Regulations make provision for the authorisation, manufacture, classification, distribution and administration of veterinary medicinal products. Equivalent EU Regulations are noted elsewhere.
Assimilated Commission Regulation (EU) 2019/6 on veterinary medicinal products	This Regulation repeals Council Directive 2001/82/EC. It provides the regulatory framework for the placing on the market, manufacturing, import, export, supply, distribution, pharmacovigilance, control and the use of veterinary medicinal products.
Assimilated Commission Regulation (EU) 37/2010 - pharmacologically active substances and their classification	This Regulation is on pharmacologically active substances and their classification regarding MRLs in foodstuffs of animal origin. The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EC) 470/2009 - procedures for the establishment of residue limits of pharmacologically active substances in foodstuffs of animal origin	This Regulations lays down rules on MRLs for pharmacologically active substances used in veterinary medicine, such as antibiotics, in food of animal origin – including meat, fish, milk, eggs and honey – in order to ensure food safety. In this regard, it sets out the procedures for establishing MRLs and the reference point for action* in cases where an MRL has not been calculated. According to legislation.gov.uk "there are outstanding changes not yet made to this Regulation". The EU equivalent is still in force which is relevant to NI.
Assimilated Regulation (EC) 124/2009 – setting MLs for the presence of coccidiostats or histomonostats in food resulting from the unavoidable carry-over from non-target feed Assimilated Commission	This Regulation sets MLs for the presence of coccidiostats or histomonostats in food resulting from the unavoidable carry-over of these substances in non-target feed. The EU equivalent is still in force which is relevant to NI. Regulation (EC) 124/2009 amends Regulation (EC) 124/2009. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation. Since IP completion day (31 December 2020 11.00 p.m.) no amendments have been applied to this version." The EU equivalent is still in force which is relevant to NI.

Regulation	Summary in relation to EEPs
Regulation (EU) 610/2012	
Commission Regulation (EU) 2022/1644 – supplements 2017/625 regarding pharmacologically active substances - relevant to NI only	This Regulation is relevant to NI only as it came into force after EU Exit and the transition period. This Regulation supplements Regulation (EU) 2017/625 with specific requirements for the performance of official controls on the use of pharmacologically active substances authorised as veterinary medicinal products or as feed additives and of prohibited or unauthorised pharmacologically active substances and residues.
Commission Regulation (EU) 2022/1646 - on specific content of multi-annual national control plans and specific arrangements for their preparation - relevant to NI	This Regulation is relevant to NI only as it came into force after EU Exit and the transition period. This Regulation is on uniform practical arrangements for the performance of official controls as regards the use of pharmacologically active substances authorised as veterinary medicinal products or as feed additives and of prohibited or unauthorised pharmacologically active substances and residues thereof, on specific content of multi-annual national control plans and specific arrangements for their preparation.
Radionuclides	
The Food and Feed (Maximum permitted levels (MPLs) of Radioactive Contamination) (Amendment) (EU Exit) Regulations 2019	These Regulations are made in exercise of the powers conferred by section 8 of the EU (Withdrawal) Act 2018 (c.16) in order to address failures of REUL to operate effectively and other deficiencies arising from the withdrawal of the UK from the EU. It is related to MPLs for radioactive contamination. Equivalent EU Regulations are noted elsewhere.
Assimilated Council Regulation (Euratom) 2016/ 52 - maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency	This Regulation sets out the maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency. The regulation repeals Regulations (Euratom) 3954/87, (Euratom) 944/89 and (Euratom) 770/90.
Food and feed additives	
The Animal Feed (Composition, Marketing and Use) (England) Regulations 2015 The Animal Feed	These Regulations, which apply in relation to England only, provide for the continuing enforcement or implementation of EU Regulations and Directives on feed safety, genetically modified feed, feed additives, the marketing and use of feed, undesirable substances (contaminants) in feed and feed for particular nutritional purposes; provide for ambulatory references to the EU instruments specified; prescribe offences and penalties for failure to comply with the Regulations; revoke or make consequential amendments to certain Regulations; and provide for periodic review of the operation and effect of these Regulations. The Welsh and Scottish equivalent regulations are also noted here.

Regulation	Summary in relation to EEPs
(Composition, Marketing and Use) (Wales) Regulations 2016 The Animal Feed (Scotland) Amendment Regulations 2017	Equivalent EU Regulations are noted elsewhere.
Council Directive 2002/32/EC – undesirable substances in animal feed –	This Directive sets MLs for undesirable substance in animal feed including aflatoxins. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation…no amendments have been made to this version." The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EC) 1831/2003 – feed additives (including drinking water) Assimilated Commission Regulation (EC) 429/2008	Regulation (EC) 429/2008 provides detailed rules for the implementation of Regulation (EC) 1831/2003 as regards the preparation and the presentation of applications and the assessment and the authorisation of feed additives. According to legislation.gov.uk "there are outstanding changes not yet made to this Regulation". The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation 183/2005 EC– feed hygiene	This Regulations lays down requirements for feed hygiene, including for drinking water. The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EU) 1060/2013 – authorisation of bentonite as a feed additive (mycotoxins)	This Regulation has set the maximum content of Bentonite in feed which is used for reduction of the contamination of feed by mycotoxins for all animal species. According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EC) 1333/2008 – food additives Assimilated Commission Regulation (EC) 1129/2011	This Regulation lays down rules on food additives used in foods The EU equivalent is still in force which is relevant to NI. Regulation (EC) 1129/2011 amends Annex II to Regulation (EC) 1333/2008 by establishing a list of food additives. According to legislation.gov.uk "there are outstanding changes not yet made to this Regulation") The EU equivalent is still in force which is relevant to NI.
Assimilated Commission Regulation (EC) 231/2012 – food additives	This Regulation lays down specifications for food additives listed in Annexes II and III to Regulation (EC)1333/2008. According to legislation.gov.uk "there are outstanding changes not yet made to this Regulation". The EU equivalent is still in force which is relevant to NI.
Commodity specific/ general	
Assimilated Regulation (EC)	This Regulation lays down detailed rules governing the marketing of eggs. These provisions cover quality characteristics to be met by eggs, as well as

Regulation	Summary in relation to EEPs
589/2008 – detailed rules governing marketing of eggs The Eggs (England) Regulations 2021 The Eggs (Wales) Regulations 2022/209 The Eggs (Amendment) (Scotland) Regulations 2021/460	packaging requirements, storage conditions, hygiene practices (egg washing systems), grading, marking, time limits, traceability. Equivalent EU Regulations are noted elsewhere. The Eggs Regulations amend Regulation (EC) 589/2008.
Commission Regulation (EU) 2023/2465 - regarding the marketing standards for eggs – relevant to NI only	This Regulation is relevant to NI only as it came into force after EU Exit and the transition period. This Regulation supplements Regulation (EU) 1308/2013 as regards marketing standards for eggs, and repeals Commission Regulation (EC) 589/2008.
Assimilated Commission Regulation (EC) 798/2008 – veterinary certification requirements for imports into GB and transit for poultry and eggs, including those of wild-game birds.	This Regulation lays down veterinary certification requirements for imports into and transit (including storage during transit) through GB of the following commodities: 1. poultry, hatching eggs, day-old chicks and specified pathogen-free eggs; 2. meat, minced meat and mechanically separated meat of poultry, including ratites and wild game-birds, eggs and egg products. It includes a list of third countries and makes provision for the specification for the purposes of this Regulation by the Secretary of State, with the consent of the Scottish Ministers (in relation to Scotland) and the Welsh Ministers (in relation to Wales), of territories, zones and compartments] from which the commodities may be imported into GB. Equivalent EU Regulations are noted elsewhere.
The Eggs and Chicks (England) Regulations 2009 The Eggs and Chicks (Wales) Regulations 2009 The Eggs and Chicks (Scotland) Amendment Regulations 2010	These Regulations revoke and replace the Eggs and Chicks (England) Regulations 2008. As in the 2008 Regulations, they make provision for the enforcement and execution of directly applicable marketing standards relating to eggs for hatching and farmyard poultry chicks and, to eggs in shell for consumption. They also make new provision for the enforcement of directly applicable controls for *Salmonella* serotypes with public health significance in relation to the marketing and use of eggs in shell for human consumption. These Regulations revoke and remake, with modifications, the Eggs (Marketing Standards) Regulations 1995 in so far as they apply to Wales. Similarly for Scotland Equivalent EU Regulations are noted elsewhere.
Assimilated Commission Regulation (EU) 2020/688 – animal health requirements for movements of terrestrial animals and hatching eggs	This Regulation supplements Regulation (EU) 2016/429 as regards animal health requirements for movements of terrestrial animals and hatching eggs**.** According to legislation.gov.uk "this version of this Regulation was derived from EUR-Lex on IP completion day (31 December 2020 11:00 p.m.). It has not been amended by the UK since then." The EU equivalent is still in force which is relevant to NI.

Regulation	Summary in relation to EEPs
Assimilated Commission Regulation (EC) 617/2008 – detailed rules for implementing Regulation (EC) 1234/2007 as regard marketing standards for eggs for hatching and farmyard poultry chicks	This Regulation lays down detailed rules for implementing Regulation (EC) 1234/2007 as regards marketing standards for eggs for hatching and farmyard poultry chicks. According to legislation.gov.uk "there are outstanding changes not yet made to this Regulation". The EU equivalent is still in force which is relevant to NI.
The Registration of Establishments (Laying Hens) (England) Regulations 2003 The Registration of Establishments (Laying Hens) (Wales) Regulations 2004 The Registration of Establishments Keeping Laying Hens (Scotland) Regulations 2003	These Regulations implement for England, Wales and Scotland Directive 2002/4/EC on the registration of establishments keeping laying hens, covered by Directive 1999/74/EC. The Regulations apply to sites keeping 350 or more laying hens. Equivalent EU Regulations are noted elsewhere.
Assimilated Council Directive 2002/4/EC – registration of establishments keeping laying hens.	This Directive covers registration of establishments keeping laying hens, covered by Council Directive 1999/74/EC. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation. Since IP completion day (31 December 2020 11.00 p.m.) no amendments have been applied to this version." The EU equivalent is still in force which is relevant to NI.
Assimilated Council Directive 1999/74/EC – minimum standards for the protection of laying hens	This Directive lays down the minimum standards for the protection of laying hens. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation. Since IP completion day (31 December 2020 11.00 p.m.) no amendments have been applied to this version." The EU equivalent is still in force which is relevant to NI.
The Egg Products Regulations 1993	These Regulations revoke the Liquid Egg (Pasteurisation) Regulations 1963 and the Liquid Egg (Pasteurisation) (Scotland) Regulations 1963 and implement in part Directive 89/437/EEC (repealed by 2004/41) as amended by Directive 89/662/EEC (repealed by Regulation 2017/625) and Directive 91/684/EEC (repealed by 2004/41) (collectively referred to as "the Directive") on hygiene and health problems affecting the production and placing on the market of egg products.
Assimilated Council Directive 2004/41 – placing on the market of certain POAO	This Directive repeals certain directives (including 89/437 and 89/662) concerning food hygiene and health conditions for the production and placing on the market of certain POAO intended for human consumption and amends directive 89/662/EEC and 92/118/EEC and decision 95/408/EC. According to legislation.gov.uk "EU Directives are published on this site to aid cross referencing from UK legislation. Since IP completion day (31 December 2020 11.00 p.m.) no amendments have been applied to this version.". The EU equivalent is still in force which is relevant to NI

Regulation	Summary in relation to EEPs
Assimilated Commission Implementing Regulation (EU) 2020/2235	This regulation sets the rules in relation to animal health certificates for entry into and movement within the UK of certain animals and POAO. It repeals Regulation (EC) No 599/2004, Implementing Regulations (EU) No 636/2014 and (EU) 2019/628, Directive 98/68/EC and Decisions 2000/572/EC, 2003/779/EC and 2007/240/EC. The EU version still applies to NI

Hazard identification

In the hazard identification phase, a range of over 100 individual hazards in EEPs was identified in the literature review and through incidents and alerts data. The hazards were attributed to one of 13 groups, encompassing allergens, chemical, microbiological, physical and radiological hazards. From this, the hazards for characterisation were shortlisted to 22 hazards or hazard groups using inclusion criteria and expert judgement.

No allergens, food additives, radiological contaminants or microplastics were characterised. For food additives this was because the those detected were approved in the UK or there was very limited evidence of presence in eggs. For allergens, microplastics and radiological contaminants there was no evidence that there was a specific consumer health risk relating to EEPs.

Microbiological hazard characterisation

Three microbiological hazards have been characterised in EEPs, *Campylobacter* spp, *Listeria monocytogenes* and non-typhoidal *Salmonella* (*Salmonella* Enteriditis & *Salmonella* Typhimurium). *Salmonella* Enteritidis was by far the most frequently reported and implicated in alerts and incidents across all of the hazards considered in this profile. As enteric pathogens, the primary exposure routes for *Campylobacter* and *Salmonella* are through contaminated feed, water, or from exposure to environmental sources. *Listeria* monocytogenes can also contaminate via this route, however it also has the ability to persist in the environment, and can establish a presence in a manufacturing environment, where it can contaminate egg products.

Human health effects of these pathogens vary depending on exposure and consumer group. If these pathogens are found to be present in eggs, there may be a concern for consumer health and further assessment would be required.

Chemical hazard characterisation

The agricultural contaminants, aflatoxins, OTA and PAs were characterised in EEPs; they can potentially contaminate feed resulting in poultry exposure. Aflatoxin and OTA formation in feed is linked to growth in a hot and humid climate. Conversely, PA concentrations are expected to be higher where nutrient availability is low and there is high soil moisture. Legal limits are in place for aflatoxins in feed in GB and NI.

Several environmental contaminants were identified in EEPs. POPs such as dioxins and dioxin-like substances, PCBs, PFAS and PCNs were taken forward for characterisation. POPs can bioaccumulate and can

contaminate plants and soil, and hence can be transferred to poultry via animal feed. Proximity to anthropogenic sources of these contaminants is likely to impact the levels detected in eggs. Levels of dioxins and dioxin-like substances and PCBs are controlled in eggs in GB and NI, and levels of PFAS are controlled in eggs in NI.

Melamine was also characterised. Melamine can be present in food due to use in FCMs and sanitising solutions. It can also be present in veterinary medicine residues, as a feed additive impurity or through illegal use. It is most likely present in EEPs due to transfer via feed, although contamination through other routes is possible. Levels of melamine are controlled in food and feed in GB and NI.

A range of metals may contaminate EEPs due to their presence in the environment and emissions from industrial processes. Proximity to anthropogenic sources of metals is likely to impact the levels detected in eggs. Copper has been detected in eggs primarily due to its use as a pesticide.

Pesticide, biocide, feed additive and VMP residues have been detected in eggs at levels exceeding the respective MRL for certain specific substances. Residues above the MRL may result from the misuse of approved substances or illegal use of banned or non-authorised-substances that used in layer farms or egg processing environments.

The aforementioned chemicals potentially pose a human health concern; the potential adverse effects depend on their toxicity and the levels present. Where they are detected in EEPs, either at levels exceeding a legal limit (where one is in place), or at any level associated with potential human health concerns, a risk assessment would be required.

Mitigation and controls

Key mitigations for the majority of the chemical hazards in scope include the location of the poultry farm away from areas of high environmental contamination. Feed and water monitoring ensures that they meet the relevant guidelines and legislation and are compliant with legal limits for contaminants such as pesticides and veterinary medicines. There are no mitigations for chemical hazards once in the egg.

For microbiological hazards, key mitigations include applying HACCP controls, vaccination and restricting exposure to wild birds. Unlike chemical hazards, there is scope to mitigate microbiological hazards in EEPs via cooking or pasteurisation. Measures to prevent cross-contamination at all stages of production and in particular during processing are also important.

Extensive regulations relating to EEPs are in place in GB and NI. These include overarching regulations predominantly concerned with general criteria such as rules for public health requirements (including hygiene, microbiological criteria, contaminants regulations, additives regulations, use of antimicrobials). Many of these regulations are applicable to POAO rather than eggs specifically. In addition, there are regulations and legislation specific to the majority of the hazards identified in EEPs.

7. Uncertainties and Knowledge gaps

The level of uncertainty was estimated according to the categorisation defined in the ACMSF report on risk representation (ACMSF, 2020). Justifications for the uncertainty assigned to each area of the risk profile are provided in Table 12.

Table 12. 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 not 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](ACMSF, 2020)

Knowledge gaps were identified during the review of information for this risk profile. As well as the uncertainty and justification, this section 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 accounts for the scope of this risk profile and the levels of uncertainty.

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Table 13. 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. Articles that did not include "egg" in the title or abstract were excluded, however if these articles instead contained the word "foods" or "foodstuffs" then they were checked to ensure relevant articles were not discounted. 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, 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 commonly found at higher concentrations in EEPs, or of known human health concern 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. Radiological contaminants or microplastics could not be characterised because of the data gaps identified. Other hazards (e.g. microbiological) are well-defined. Uncertainties exist around the route of transmission for *Campylobacter* spp. Prevalence of foodborne hazards may not be the same in all geographical areas. Global trends and specific issues by regions or countries were not discussed, unless the information was readily accessible. The scope of this risk profile is for risks associated with EEPs 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 practice 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. Knowledge gaps and 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.	Low
Legislation and control	Information on UK import, and domestic legislation was available, as was assimilated EU legislation as relevant to NI. However, regulations were predominantly concerned with general criteria such as rules for general food safety or POAO in general (as opposed to EEPs specifically) and there were often multiple regulations relating to the majority of the identified hazards (albeit still not often specifically in EEPs). As such, there was a large amount of legislation to summarise and hence it may be subject to human error by the potential omission of relevant legislation or in the interpretation of changes in legislation. It was not possible to summarise the legislation of all countries globally or all of the generic background food safety legislation. The focus was on legislation specific to EPPs, then the hazards identified and then finally general food safety or POAO legislation that related to EEPs but was not specifically to them.	Low/ Medium

Risk profile section	Notes on uncertainty (including impacts of knowledge gaps)	Uncertainty
	The impact of the noted knowledge gaps is considered to be low-medium, given that international trade in foods is reliant on mutually acceptable controls for generally recognised hazards and multiple complex food and feed safety laws.	
UK consumption patterns	Chronic consumption estimates for EEPs have been obtained using the DNSIYC and the NDNS for all age groups between four months and 95 years. Consumption estimates were made using food codes from these surveys, including recipes, which means that all foods containing eggs ≥5% were used. While this risk profile only includes the EEPs specified, this consumption data takes account of expected consumer behaviour – eggs are consumed in multiple ways. This is not a full risk assessment and so does not impact the risk profile, as consumer exposure is not estimated	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 changes in a short space of time. UN Comtrade data is 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. This often results in asymmetries between third country import data from the UK from UN Comtrade and UK HMRC export data to third countries. 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 to 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

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Appendices

Appendix I. UK consumption data

Food codes from the NDNS and DNSIYC used to estimate chronic and acute UK consumption of eggs:

Table 14. Chronic and acute consumption of eggs (with recipes, ≥5%)

Age group	Consumers (n)	Chronic				Acute				Respondents in population group (n)
		g/person/ day		g/kg bw/d		g/person/ day		g/kg bw/d		
		Mean	P97.5	Mean	P97.5	Mean	P97.5	Mean	P97.5	
Infants (4-18 months)	1231	10	40	1.0	4.2	32	110	3.1	11	2683
Toddlers (1.5-3yrs)	845	13	50	0.91	3.6	37	120	2.6	9.5	1157
4-10yrs	2061	14	56	0.54	2.4	39	130	1.6	6.0	2537
11-18yrs	2095	17	70	0.31	1.3	49	170	0.87	3.2	2657
19-64yrs	4186	26	100	0.35	1.3	70	210	0.92	2.8	5094
65+yr	1302	24	77	0.32	1.0	65	170	0.87	2.3	7690
16-49yrs (women)	2058	23	91	0.34	1.4	62	170	0.92	2.9	2556

Rounded to 2 significant figures

Appendix II. Trade data

UK Exports

Table 15. The 15 countries importing the largest volumes (tonnes) of eggs 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]
Netherlands	1795	5892	5415	8831	8465	11489	7813	**49701**	**36.06%**
Ireland	6528	7099	8272	8620	11012	441	1979	**43952**	**31.89%**
France	2016	3467	5179	3999	2285	477	129	**17552**	**12.74%**
Germany	1362	1950	1485	4384	1175	439	54	**10850**	**7.87%**
Israel	0	0	0	0	0	2681	335	**3017**	**2.19%**
Italy	38	292	78	994	871	281	0	**2553**	**1.85%**
Spain	11	80	364	1132	48	23	41	**1697**	**1.23%**
Denmark	204	156	80	149	59	973	26	**1647**	**1.20%**
China, Hong Kong SAR	101	186	279	313	294	272	0	**1446**	**1.05%**
Belgium	26	51	63	17	68	846	197	**1269**	**0.92%**
Poland	7	9	47	18	21	375	301	**778**	**0.56%**
Libya	0	0	0	650	0	0	0	**650**	**0.47%**
Saudi Arabia	207	55	44	181	0	0	0	**487**	**0.35%**
Romania	128	151	2	0	6	0	0	**288**	**0.21%**

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

UK imports

Global trade

Table 16. Imports of eggs to the UK in tonnes (t) and as a percentage (%) of the total, from 2016 to 2022 by exporting country

Country	2016 (t)[1]	2017 (t)[1]	2018 (t)[1]	2019 (t)[1]	2020 (t)[1]	2021 (t)[1]	2022 (t)[1]	Total (t)[1]	Total (%)[2]
Netherlands	47165	43584	36930	34017	32078	31187	31769	**256730**	**55.94%**
Ireland	5336	6184	4948	12026	4909	13093	7472	**53968**	**11.76%**
France	6594	5106	4291	4878	2614	2534	4441	**30458**	**6.64%**
Poland	1264	1449	1781	2928	4408	3370	8002	**23203**	**5.06%**
Germany	7222	4845	4847	2845	1234	1032	1017	**23042**	**5.02%**
Spain	2661	3363	2175	1733	2180	1490	3870	**17471**	**3.81%**
Belgium	2702	2344	2553	2613	1639	1009	4346	**17207**	**3.75%**
Italy	1303	2864	2373	2385	3393	1510	1506	**15334**	**3.34%**
Denmark	2872	1489	1376	1089	1303	967	717	**9813**	**2.14%**
Portugal	2659	1674	826	170	32	20	1	**5382**	**1.17%**
United States	252	156	198	359	289	273	184	**1710**	**0.37%**
Lithuania	0	0	34	55	1038	47	12	**1186**	**0.26%**
Finland	707	349	36	0	0	0	0	**1093**	**0.24%**
Czechia	0	281	84	222	27	0	0	**613**	**0.13%**
Austria	3	56	86	117	117	44	14	**436**	**0.09%**
Hong Kong	0	0	0	0	60	99	172	**331**	**0.07%**
Sweden	27	7	22	35	28	78	77	**276**	**0.06%**
Romania	0	4	25	127	25	18	43	**243**	**0.05%**
Latvia	0	0	0	43	0	27	89	**160**	**0.03%**
Canada	36	30	51	5	0	0	0	**122**	**0.03%**
China	19	0	3	55	17	0	0	**94**	**0.02%**
Norway	22	6	0	6	0	0	0	**34**	**0.01%**
Hungary	2	1	1	2	2	5	1	**15**	**0.00%**
Namibia	0	0	0	0	0	5	0	**5**	**0.00%**
Greece	0	0	4	0	0	0	0	**4**	**0.00%**
Iceland	0	2	0	0	0	0	0	**2**	**0.00%**

Country	2016 (t)[1]	2017 (t)[1]	2018 (t)[1]	2019 (t)[1]	2020 (t)[1]	2021 (t)[1]	2022 (t)[1]	Total (t)[1]	Total (%)[2]
Bulgaria	0	0	0	0	1	0	1	**2**	**0.00%**
Luxembourg	0	0	0	0	0	0	0	**0**	**0.00%**
Malta	0	0	0	0	0	0	0	**0**	**0.00%**
Slovenia	0	0	0	0	0	0	0	**0**	**0.00%**
Slovakia	0	0	0	0	0	0	0	**0**	**0.00%**
Total	80847	73795	62646	65710	55394	56809	63733	**458934**	**NA**

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

Table 17. The 15 countries importing the largest volumes (tonnes) of eggs 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]
India	32481	6666659	7588198	31449	3619994	21427	40073	**18000280**	**49.32%**
Netherlands	536058	516167	569403	502655	528348	595191	446759	**3694581**	**10.12%**
Türkiye	276242	337328	344614	252829	187473	187306	186257	**1772048**	**4.85%**
Poland	249148	296042	237275	257938	242855	195026	270243	**1748527**	**4.79%**
Malaysia	711798	102938	113891	100943	95450	103792	70591	**1299403**	**3.56%**
USA	143313	148122	141103	137013	140763	191689	118184	**1020188**	**2.80%**
Germany	152799	146443	131708	136837	115052	115735	115323	**913895**	**2.50%**
Spain	100574	116221	126153	139146	149247	111416	124036	**866794**	**2.37%**
China	98693	112707	99615	100842	101768	102778	141407	**757809**	**2.08%**
Singapore	166984	191208	643	370919	2134	1536	624	**734048**	**2.01%**
Ukraine	54448	92241	116007	143992	114860	50772	32541	**604862**	**1.66%**
Belgium	43757	73132	83365	117540	123647	82006	74545	**597991**	**1.64%**
Jordan	3160	312900	86550	43015	11073	9914	4005	**470618**	**1.29%**
Thailand	16674	16126	26794	18091	17622	21270	299330	**415907**	**1.14%**

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

Appendix III. Literature search terms used

Table 18. Search terms used in the FSA internal-developed literature search tool for hazard identification

Hazard groups	Search terms	Hits	Number of articles included
Agricultural contaminants	egg* AND poultry AND (toxin* OR mycotoxin*) AND (contaminant OR contamination OR contaminants) AND (hazard OR toxicity OR exposure)	30	26
Agricultural contaminants	egg* AND toxin* AND (contaminant OR contamination OR contaminants) AND (hazard OR toxicity OR exposure)	69	
Agricultural contaminants	egg* AND poultry AND (toxin) AND (contaminant OR contamination OR contaminants) AND (hazard OR toxicity OR exposure)	13	
Allergens	egg* AND (allerg* OR hypersens*) AND react	72	0
Biocides	Egg* AND (biocide* OR disinfectant*) AND food	92	2
Environmental contaminants	Egg* AND persistent organic pollutant* AND food safety	23	20
Environmental contaminants	Egg* AND environmental contaminant* AND food safety	51	
Environmental contaminants	poultry AND egg* AND environmental contaminant* AND (surveillance OR survey OR alert OR notification OR outbreak OR Incident) AND (food OR consumption)	6	
Food additives	(poultry OR duck OR goose OR geese OR fowl OR quail OR pigeon OR pheasant OR partridge OR ratite OR hen OR chicken) AND egg* AND additive* AND ("human health" OR exposure) NOT parasite* NOT eggplant	106	8
Food additives	poultry AND egg* AND additive* AND (surveillance OR survey OR alert OR notification OR outbreak OR Incident) AND (food OR consumption)	18	
Food additives	Egg* AND additive* AND food safety	146	
General	egg* AND poultry AND hazard* and contam*	121	33
Metals	egg* AND metal* AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption)	48	17
Metals	poultry AND egg* AND metal* AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption)	8	
Microbiological	poultry and egg* AND microbiol* AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption)	152	54
Microplastics	egg* AND (plastics* OR microplastics) AND (contaminant OR contamination OR contaminants) AND (hazard OR toxicity OR exposure)	45	3
Parasites	poultry AND egg* AND parasite* AND (surveillance OR survey OR alert OR notification OR outbreak)	63	4
Pesticides	Egg* AND pesticide* AND food safety	139	21
Pesticides	poultry AND egg* AND pesticide* AND (surveillance OR survey OR alert OR notification OR outbreak OR Incident) AND (food OR consumption)	15	
Pesticides	Egg* AND pesticide* AND food incident	6	
Process contaminants	egg* AND ("process contaminants" OR "production system" OR "production systems" OR "process contaminant") AND (hazard OR toxicity OR exposure)	72	3

Hazard groups	Search terms	Hits	Number of articles included
Process contaminants	Egg* AND process contaminant* AND food	78	
Radiological	egg* AND (radio* OR radiological OR radiation) AND (contaminant OR contamination OR contaminants) AND (hazard OR toxicity OR exposure)	116	9
Veterinary Medicines	poultry AND egg* AND vet* AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption OR "human health")	97	9
Veterinary Medicines	poultry AND egg* AND (drug OR "veterinary medicine*" OR residue*) AND (surveillance OR survey OR alert OR notification OR outbreak) AND (food OR consumption OR "human health")	138	

Appendix IV. Levels of radionuclides in eggs and egg products

Radionuclide	GB maximum levels in eggs (Bq/kg) (Gov UK, 2016a)	Codex guideline levels in eggs (Bq/kg) (Codex, 1995)	Levels detected in eggs (Bq/kg)	Reference
Ag-110m	NA	NA	<0.06 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Am-241	80	10	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
C-14	NA	10 000	45 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Co-60	1250	1 000	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Cs-134	1250	1 000	<0.04 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Cs-137	1250	1 000	0.06 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Cs-137	1250	1 000	1.25 (mean)	(Gembal, Czerski, et al., 2023)
Eu-155	NA	NA	<0.08 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
H-3	NA	10 000	14 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
I-129	2000	100	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
K-40	1250	NA	103.8 (maximum)	(Cinelli, De Cort, et al., 2019)
Nb-95	NA	NA	<0.36 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Pb-210	1250	NA	0.14 (maximum)	(Cinelli, De Cort, et al., 2019)
Po-210	1250	NA	1.47	(Giri, Jha, et al.,

Radionuclide	GB maximum levels in eggs (Bq/kg) (Gov UK, 2016a)	Codex guideline levels in eggs (Bq/kg) (Codex, 1995)	Levels detected in eggs (Bq/kg)	Reference
			(maximum)	2012)
Po-210	1250	NA	0.25 (maximum)	(Cinelli, De Cort, et al., 2019)
Pu-238	80	10	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Pu-239/ Pu-240	80	10	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Pu-241	80	NA	<0.45(mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Ra-226	1250	NA	0.065 (maximum)	(Gooniband Shooshtari, Deevband, et al., 2017)
Ra-226	1250	NA	2.354 (maximum)	(Fathabadi, Salehi, et al., 2017; Shah & Abdeljawad, 2024)
Ra-226	1250	NA	0.0553 (mean)	(Hosseini, Fathivand, et al., 2006)
Ra-226	1250	NA	0.1 (maximum)	(Asefi, Fathivand, et al., 2005)
Ra-226	1250	NA	3.2 (maximum)	(Cinelli, De Cort, et al., 2019)
Ra-228	1250	NA	0.087 (maximum)	(Asefi, Fathivand, et al., 2005)
Ra-228	1250	NA	3.5 (maximum)	(Cinelli, De Cort, et al., 2019)
Ru-106	1250	100	<0.33 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Na-35	NA	1 000	<0.05 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Sb-125	NA	NA	<0.12 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Sr-90	750	100	0.034 (mean)	(Environment Agency & Food Standards Agency, et al., 2023)
Th-228	NA	NA	1.7 (maximum)	(Cinelli, De Cort, et al., 2019)
U-238	1250	NA	0.0012 (mean)	(Hosseini, Fathivand, et al., 2006)

Radionuclide	GB maximum levels in eggs (Bq/kg) (Gov UK, 2016a)	Codex guideline levels in eggs (Bq/kg) (Codex, 1995)	Levels detected in eggs (Bq/kg)	Reference
U-238	1250	NA	0.0014 (maximum)	(Cinelli, De Cort, et al., 2019)

Appendix V. Levels of agricultural contaminants in EEPs

Agricultural contaminant	Level detected (µg/kg) (max. unless otherwise stated)	Reference
Aflatoxins	1.9	(Keutchatang, Tchuenchieu, et al., 2022)
Aflatoxins	0.21[a]	(Adegbeye, Reddy, et al., 2020)
Aflatoxins	0.41	(Afsah-Hejri, Jinap, et al., 2013)
Aflatoxin B1	1.1	(Keutchatang, Tchuenchieu, et al., 2022)
Aflatoxin B1	1.45 (mean)	(Omar, 2021)
Aflatoxin B1	0.07[b]	(Adegbeye, Reddy, et al., 2020)
Aflatoxin B1	0.4	(Akande, Abubakar, et al., 2006)
Aflatoxin B1	168	(L. Wang, Zhang, et al., 2018)
Pyrrolizidine alkaloids	0.12	(Azarikia et al., 2018)
Ochratoxin A[c]	0.018	(Zahoor ul, Khan, et al., 2012)
Ochratoxin A	2.0	(Keutchatang, Tchuenchieu, et al., 2022)
Ochratoxin A	0.77 (mean)	(Omar, 2021)

[a] Dosed with feed containing aflatoxin at 123 µg/kg (max. allowed content of AFB1 in compound feed for poultry is 20 µg/kg (Reg. (EC) 2015/255))

[b] Dosed with feed containing aflatoxin at up to 100 µg/kg (max. allowed content of AFB1 in compound feed for poultry is 20 µg/kg (Reg (EC) 2015/255))

[c] Dosed with feed containing OTA at up to 10 mg/kg

Appendix VI. Levels of environmental contaminants in EEPs

Environmental contaminant	Levels detected in eggs	GB max. levels in eggs (Gov UK, 2006)	Exceeded GB max. level	Reference
Dioxins	12.77 pg /g fat (max.)	2.5 pg WHO-PCDD/ F-TEQ /g fat	Yes	(Van Overmeire, Pussemier, et al., 2009)
Dioxins	23 pg /g fat (max.)	2.5 pg WHO-PCDD/ F-TEQ /g fat	Yes	(Van Overmeire, Pussemier, et al., 2006)
Dioxins	3.93 pg /g	2.5 pg WHO-PCDD/ F-TEQ /g fat	Yes	(Megson et al., 2011)
Dioxins	0.045 pg /g fresh weight (max.)	2.5 pg WHO-PCDD/ F-TEQ /g fat	Not comparable	(FSANZ, 2009)
Dioxins	2.5 pg /g fat (max.)	2.5 pg WHO-PCDD/ F-TEQ /g fat	No	(RIVM, 2019)
Dioxins	12.1 pg /g fat (max.)	2.5 pg WHO-PCDD/ F-TEQ /g fat	Yes	(BfR, 2011)
Dioxins	13.6 pg /g fat	2.5 pg WHO-PCDD/ F-TEQ /g fat	Yes	(BfR, 2010)
Dioxin-like PCBs	11.84 pg /g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(Van Overmeire, Pussemier, et al., 2006)
Dioxin-like PCBs	0.012 pg /g fresh weight (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Not comparable	(FSANZ, 2009)
Sum of dioxin and dioxin-like PCBs	2.31 pg /g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	No	(Kilic, Cakirogullari, et al., 2011)
Sum of dioxins and dioxin-like PCBS	18.9 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(Hoogenboom, Ten Dam, et al., 2016)
Sum of dioxins and dioxin-like PCBS	113 pg /g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(Squadrone, Brizio, et al., 2015)
Sum of dioxins and dioxin-like PCBS	249.1 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(Hoang, Traag, et al., 2014).
Sum of dioxins and dioxin-like PCBS	95.35 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(Van Overmeire, Waegeneers, et al., 2009)
Sum of PCDD/F and PCB	22.9 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(FERA, 2017a)
Sum of dioxin and dioxin-like PCBs	14.9 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	Yes	(BfR, 2010)

Environmental contaminant	Levels detected in eggs	GB max. levels in eggs (Gov UK, 2006)	Exceeded GB max. level	Reference
Sum of dioxin and dioxin-like PCBs	5.0 pg/g fat (max.)	5.5 pg WHO-PCDD/ F-PCB-TEQ /g fat	No	(RIVM, 2019)
Non-dioxin-like PCBs	80 ng/g fat (max.)	40 ng/g fat	NA	(Hoogenboom, Ten Dam, et al., 2016)
Non-dioxin-like PCBs	218 ng/g fat (max.)	40 ng/g fat	NA	(Squadrone, Brizio, et al., 2015)
Non-dioxin-like PCBs	51.3 ng/g fat (max.)	40 ng/g fat	NA	(Hoang, Traag, et al., 2014).
Melamine	1.3 mg/kg (mean)/ 1.98 mg/kg (max.)	2.5 mg/kg	No	(Mirza Alizadeh, Hosseini, et al., 2023)
Melamine	1.98 mg/kg (max.)	2.5 mg/kg	No	(Shakerian, Khamesipour, et al., 2018)
Melamine	0.03 mg/kg (mean)/0.16 mg/kg (max.)	2.5 mg/kg	No	(EFSA, 2010c)
Melamine	Egg powder: 4 mg/kg (max.) Dry whole egg: 4.6 mg/kg (max.) Albumen: 12 mg/kg (max.) Yolk: 0.48 mg/ kg (max.)	2.5 mg/kg	No*	(WHO, 2008)
Polychlorinated naphthalenes (PCNs)	20 ng/kg (max.) (duck, goose and gull eggs)	NA	NA	(FERA, 2017a)
Polychlorinated naphthalenes (PCNs)	0.62 ng/kg (max.)	NA	NA	(FSAI, 2010)
PFAS	1 µg/kg (Max.)	1.7 µg/kg (sum of PFOS, PFOA, PFNA, PFHxS) (NI only)	NA	(Clarke, Bailey, et al., 2010)
PFOA (Perfluorinated compounds)	Duck eggs: 0.214 µg/kg (mean) 3.138 µg/kg (max.)	0.3 µg/kg (NI only)	NA	(Qi, Zhou, et al., 2019)
PFOS (Perfluorinated compounds)	Duck eggs: 0.024 µg/kg (mean) 0.182 µg/kg (max.)	1.0 µg/kg (NI only)	NA	(Qi, Zhou, et al., 2019)

Appendix VII. Levels of metals in EEPs

Metal	Commodity	Level detected (mg/kg) (mean unless otherwise stated)	Reference
Arsenic	Hen eggs	0.049	(Chernikova, Pityurina, et al., 2020)
Arsenic	Hen eggs	0.008	(Salar-Amoli & Ali-Esfahani, 2015)
Arsenic	Hen eggs	Albumen: 0.065, Yolk: 0.107[a]	(Rana, Bera, et al., 2012)
Arsenic	Duck eggs	Albumen: 0.021, Yolk: 0.046[a]	(Rana, Bera, et al., 2012)
Cadmium	Hen eggs	0.0198	(Chernikova, Pityurina, et al., 2020)
Cadmium	Hen eggs	0.036	(Abdulkhaliq, Swaileh, et al., 2012)
Cadmium	Hen eggs	0.13	(Salar-Amoli & Ali-Esfahani, 2015)
Cadmium	Hen eggs	0.012 (max)[b]	(Aendo, Garine-Wichatitsky, et al., 2022)
Cadmium	Duck eggs	0.013 (max)[b]	(Aendo, Garine-Wichatitsky, et al., 2022)
Cadmium	Duck eggs	Albumen: 0.18, Yolk: 0.14	(Aendo, Netvichian, et al., 2018)
Cadmium	Eggs	0.002 (median)	(Malmauret, Parent-Massin, et al., 2002)
Cadmium	Hen eggs	Albumen: 0.42, Yolk: 0.48	(Hossain, Ahmed, et al., 2024)
Chromium	Hen eggs	0.24	(Salar-Amoli & Ali-Esfahani, 2015)
Chromium	Hen eggs	Albumen: 0.26, Yolk: 0.18	(Hossain, Ahmed, et al., 2024)
Chromium	Duck eggs	Albumen: 0.03, Yolk: 0.27	(Aendo, Netvichian, et al., 2018)
Copper	Hen eggs (poultry farm)	Albumen: 0.32, Yolk: 0.37	(Kabeer, Hameed, et al., 2021)
Copper[c]	Hen eggs	2.7	(Abdulkhaliq, Swaileh, et al., 2012)
Copper[c]	Hen eggs	3.13	(Salar-Amoli & Ali-Esfahani, 2015)
Copper[c]	Duck eggs	Albumen: 3.38, Yolk: 1.79	(Aendo, Netvichian, et al., 2018)
Copper[c]	Preserved eggs	2.68	(Fu, Liu, et al., 2014)
Copper	Salted eggs	1.76	(Fu, Liu, et al., 2014)
Copper[c]	Duck eggs	8.4 (single value)	RASFF (European Commission, 2023d)
Copper[c]	Preserved duck eggs	6.2 (single value)	RASFF (European Commission, 2023c)
Copper[c]	Duck eggs	6.5 (max)	RASFF (European Commission, 2023b)

Metal	Commodity	Level detected (mg/kg) (mean unless otherwise stated)	Reference
Copper[c]	Preserved duck eggs	8.1 (single value)	RASFF (RASFF, 2023)
Lead	Hen eggs (poultry farm)	Albumen: 0.83, Yolk: 0.88	(Kabeer, Hameed, et al., 2021)
Lead	Hen eggs	0.27	(Abdulkhaliq, Swaileh, et al., 2012)
Lead	Hen eggs	0.18	(Chernikova, Pityurina, et al., 2020)
Lead	Hen eggs	0.35	(Salar-Amoli & Ali-Esfahani, 2015)
Lead	Duck eggs	Albumen: 2.21, Yolk: 1.85	(Aendo, Netvichian, et al., 2018)
Lead	Preserved eggs	0.21	(Fu, Liu, et al., 2014)
Lead	Salted eggs	0.05	(Fu, Liu, et al., 2014)
Lead	Hen eggs	Albumen: 0.28, Yolk: 0.03	(Hossain, Ahmed, et al., 2024)
Lead	Hen eggs	Albumen: 0.06 (max), Yolk: 1.89 (max)[d]	(Sartorius, Johnson, et al., 2022)
Mercury	Hen eggs	0.07	(Salar-Amoli & Ali-Esfahani, 2015)
Mercury	Hen eggs	0.007	(Chernikova, Pityurina, et al., 2020)
Mercury	Hen eggs (free range)	Albumen: 7.44, Yolk: 3.18	(Gonzalez-Alvarez, Jaramillo, et al., 2023)
Mercury	Hen eggs	17.74 (max)[b]	(Aendo, Garine-Wichatitsky, et al., 2022)
Mercury	Duck eggs (free range)	60.63 (max)[b]	(Aendo, Garine-Wichatitsky, et al., 2022)

[a] Levels in eggs from area with contaminated water

[b] Levels in eggs produced in an area near a gold mine

[c] Levels exceed the MRL of 2 mg/kg for copper in eggs in GB and NI set under pesticide regulations (Reg. (EC) 396/2005)

[d] Levels in eggs produced in a mining area

Appendix VIII. Levels of pesticide residues in EEPs

Pesticide residue	Approval status in GB/NI (HSE, 2024a)	GB MRLs (mg/kg) (European Commission, 2024b)	Codex MRLs (mg/kg) (Codex, 2024a)	Maximum level reported in eggs (mg/kg)	Reference
Aldrin	Not approved	0.02	0.1	0.00012 (Salar-Amoli & Ali-Esfahani, 2015) 0.1154 (sum of aldrin/ dieldrin, fat) (Van Overmeire, Pussemier, et al., 2006)	(Salar-Amoli & Ali-Esfahani, 2015) (Van Overmeire, Pussemier, et al., 2006)
Beta-hexachloro cyclohexane	Not approved	0.01* (hexachlorocyclohexane)	Not available	Not specified	(EFSA, 2021c)
Bifenthrin	Not approved	0.01*	Not available	0.0167 (lipid weight) (Parente, Lestayo, et al., 2017) 0.00006 (Dallegrave, Pizzolato, et al., 2018)	(Parente, Lestayo, et al., 2017) (Dallegrave, Pizzolato, et al., 2018)
Bromide ion	Approved	0.05	Not available	2.8	(EFSA, 2021c)
Carbaryl	Not approved	0.05*	Not available	99	(Rai, Ahmad, et al., 2008)
Chlorate^	Not approved	0.05	Not available	0.115	(EFSA, 2024i)
Chlordecone^	Not approved	0.02	Not available	0.292	(EFSA, 2022e)
Chlorpyrifos	Not approved	0.01*	Not available	0.00028	(Dallegrave, Pizzolato, et al., 2018)
Copper compounds	Approved	2	Not available	Not specified	(EFSA, 2021c)
Cyhalothrin	Not approved	0.01	Not available	0.00004	(Dallegrave, Pizzolato, et al., 2018)
Cypermethrin	Approved	0.05*	0.01	6.408 (lipid weight) (Parente, Lestayo, et al., 2017) 0.00137 (Dallegrave,	(EFSA, 2024i) (Parente, Lestayo, et al., 2017) (Dallegrave, Pizzolato,

Pesticide residue	Approval status in GB/NI (HSE, 2024a)	GB MRLs (mg/kg) (European Commission, 2024b)	Codex MRLs (mg/kg) (Codex, 2024a)	Maximum level reported in eggs (mg/kg)	Reference
				Pizzolato, et al., 2018)	et al., 2018)
Cyromazine^	Not approved	0.05*	0.3	0.04	(FERA, 2024) (FSA, 2024e) (DEFRA, 2022a)
DDT	Not approved	0.05	0.1	0.076 (EFSA, 2021c) 0.06 (EFSA, 2024i) 0.00005 (Salar-Amoli & Ali-Esfahani, 2015) 5.25 (fat) (Van Overmeire, Pussemier, et al., 2006)	(EFSA, 2021c) (EFSA, 2024i) (Song, Lee, et al., 2019) (Salar-Amoli & Ali-Esfahani, 2015) (Van Overmeire, Pussemier, et al., 2006)
Dieldrin	Not approved	0.02	0.1	0.000015 (Salar-Amoli & Ali-Esfahani, 2015) 0.1154 (sum of aldrin/ dieldrin, fat) (Van Overmeire, Pussemier, et al., 2006)	(EFSA, 2021c) (Salar-Amoli & Ali-Esfahani, 2015) (Van Overmeire, Pussemier, et al., 2006)
Disulfoton	Not approved	0.02 (chicken eggs) 0.01* (duck, geese, quail eggs)	0.02	0.013	(Song, Lee, et al., 2019)
Endosulfan	Not approved	0.05*	0.03	0.0023 (Ketyam, Imsilp, et al., 2016) 0.00011 (Salar-Amoli & Ali-Esfahani, 2015)	(Ketyam, Imsilp, et al., 2016) (Salar-Amoli & Ali-Esfahani, 2015)
Ethoxyquin	Not approved	0.05	Not available	0.054	(EFSA, 2022e)
Fipronil^	Not approved	0.005*	0.02	0.07 (FSA, 2024e) 2.513 (Canton, Signorini, et al., 2022)	(EFSA, 2021c) (FERA, 2024) (FSA, 2024e) (Song, Lee, et al., 2019) (Canton,

Pesticide residue	Approval status in GB/NI (HSE, 2024a)	GB MRLs (mg/kg) (European Commission, 2024b)	Codex MRLs (mg/kg) (Codex, 2024a)	Maximum level reported in eggs (mg/kg)	Reference
					Signorini, et al., 2022)
Heptachlor	Not approved	0.02	0.05	0.00002	(Salar-Amoli & Ali-Esfahani, 2015)
Hexachlorobenzene	Not approved	0.01*	Not available	Not specified	(EFSA, 2024i) (EFSA, 2021c)
Lindane	Not approved	0.01*	0.001	0.00006	(Salar-Amoli & Ali-Esfahani, 2015)
Mephosfolan	Not approved	0.01	Not available	0.0045	(Pereira, Candido, et al., 2020)
Mercury	Not approved	0.01*	Not available	Not specified	(EFSA, 2021c)
Permethrin	Not approved	0.05*	0.1	0.328 (lipid weight) (Parente, Lestayo, et al., 2017) 0.0009 (Song, Lee, et al., 2019)	(Parente, Lestayo, et al., 2017) (Song, Lee, et al., 2019)
Phenothrin	Not approved	0.05*	Not available	0.91 (lipid weight)	(Parente, Lestayo, et al., 2017)
Pirimiphos	Not approved (pirimiphos-ethyl) Approved (pirimiphos-methyl)	0.01	0.01 (pirimiphos-methyl)	0.0045	(Pereira, Candido, et al., 2020)
Pyraclostrobin	Approved	0.05*	0.05	0.0045	(Pereira, Candido, et al., 2020)
Spiroxamine	Approved	0.05	Not available	0.0083	(Pereira, Candido, et al., 2020)

^Included for hazard characterisation as incidents or non-compliance have been reported

* MRL is set at the limit of quantification (LOQ)

Appendix IX. Levels of VMP and feed additive residues in EEPs

Table 19. Coccidiostats and feed additives found in eggs from the literature and monitoring

Coccidiostat	ADI (mg/kg bw/day)	UK Auth. of VMP in chickens (VMD)	GB Auth. in poultry feed (FSA, 2023a)	Max. content in mg/kg [a] [b]	GB MRL in eggs (µg/kg) [c]	Max. level reported in egg samples (µg/kg)	Source [d]
Clopidol	Not available	Not authorised	Not authorised	Not available	Not available	Not available	(Sin, Shen, et al., 2023)
Decoquinate ^	0.075 (EMEA, 2000)	Authorised for cattle and sheep (GB and NI)	Authorised – poultry for fattening	0.4 (laying birds and chickens reared for laying (> 16 weeks))	20 (European Commission, 2009b)	53.8 µg/kg ((FERA, 2024),(FSA, 2024e))	(EFSA, 2023c) (FERA, 2024) (FSA, 2024e)
Diclazuril ^	0.03 (EMA, 2014)	Authorised for cattle and sheep (GB and NI)	Authorised – poultry for fattening and laying	0.01 (laying birds and chickens reared for laying (> 16 weeks))	2 (European Commission, 2009b)	Not available	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b)
Lasalocid ^	0.005 (EFSA, 2017b)	No current authorisations	Authorised – poultry for fattening and laying	1.25 (chickens reared for laying (< 16 weeks) and turkeys (< 16 weeks)[f]	150 [@386980; @387112; @386898	1400 (VMD, 2022)	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b) (VMD, 2022) (VMD, 2021) (VMD, 2020) (FSA, 2024e)
Monensin ^	0.003 (EFSA, 2024g)	Authorised for cattle (GB and NI)	Authorised – poultry for fattening and laying	1.25 (chickens reared for laying (< 16 weeks) and turkeys (< 16 weeks) [f]	Not available	2.3 (VMD, 2020)	(EFSA, 2023c) (EFSA, 2022c) (VMD, 2020)
Narasin ^	0.005 (EFSA, 2018b)	No current authorisations	Authorised – poultry for fattening	0.7 (turkeys, laying birds and chickens reared for laying (> 16 weeks))	2 (European Commission, 2009b)	4.3 (VMD, 2023a)	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b) (VMD, 2023a) (VMD, 2020) (FSA, 2024e)
Nicarbazin ^	0.9 (JECFA, 2022)e	No current authorisations	Authorised – poultry for fattening and laying	1.25 (laying birds and chickens reared for laying (> 16 weeks))	300 (European Commission, 2009b)	Not available	(EFSA, 2023c)
Robenidine ^	Not available	No current	Authorised –	0.7	25	Not available	(EFSA, 2022c)

Coccidiostat	ADI (mg/kg bw/day)	UK Auth. of VMP in chickens (VMD)	GB Auth. in poultry feed (FSA, 2023a)	Max. content in mg/kg [a] [b]	GB MRL in eggs (µg/kg) [c]	Max. level reported in egg samples (µg/kg)	Source [d]
	(previously 0.055 mg/ kg bw) (EFSA, 2023a)	authorisations	poultry for fattening	(laying birds and chickens reared for laying (> 16 weeks)	(European Commission, 2009b)		
Salinomycin ^	0.005 (ARfD is also 0.005 mg/kg bw) (EFSA, 2024h)	No current authorisations	Authorised – poultry for fattening and laying	0.7 (turkeys, laying birds and chickens reared for laying (> 12 weeks)) [f]	3 (European Commission, 2009b)	9.5 (VMD, 2020)	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b) (VMD, 2022) (VMD, 2020) (FSA, 2024e) (FERA, 2024)
Semduramicin	0.00125 (EFSA, 2007a)	Not authorised	Authorised – poultry for fattening	0.25 (laying birds and chickens reared for laying (> 16 weeks)) [f]	2 (Gov UK, 2009a)	0.8	(Dorne, Fernández-Cruz, et al., 2013)
Toltrazuril ^	0.002 (EMEA, 1998b)	Authorised for species including poultry (GB and NI)	Not authorised	Not available	Not available	Not available	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b)

^ Incidents or non-compliance have been reported

[a] Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12 %

[b] Reg. (England) 2015/255, Regulation (EU) 2002/32, (European Parliament, 2002; Gov UK, 2015c)

[c] GB (VMD, 2024b) and NI (European Commission, 2009c)

[d] UK annual surveillance results, EU annual reports, FSA, FERA, Risk Likelihood Dashboard (RLD)

[e] ADIs of the two components of nicarbazin: Dinitrocarbanilide (DNC) – 0.2 mg/kg bw/day, 2-hydroxy-4,6-dimethylpyrimidine (HDP) – 0.08 mg/kg bw/day (EFSA, 2017c)

[f] For the period before slaughter in which the use of the coccidiostat is prohibited (withdrawal feed))

Table 20. Veterinary medicine residues identified from the literature and monitoring in eggs

Veterinary medicine	Acceptable Daily Intake (mg/kg bw)	UK Authorisation of veterinary medicines in chickens (VMD)	GB MRL in eggs (µg/kg) (VMD, 2024a)	Maximum Level reported in non-compliant egg samples (µg/kg)	Source of incidents †	Remarks (VMD, 2024a)
Chlortetracycline	0.003 (EMA, 1995)	Authorised	200	206.04	(Kodimalar, Rajini, et al., 2014)	
Ciprofloxacin ^	0.0062 (EMEA, 1998a)	No current authorisations	Not available	Not available	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b)	Not for use in animals from which eggs are produced for human consumption
Doxycycline ^	0.003 (EMA, 2015)	Currently authorised for a range of species including poultry (GB and NI)	Not available	1887 (FERA, 2024)	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b) (FERA, 2024)	Not for use in animals from which milk or eggs are produced for human consumption
Enrofloxacin ^	0.0062 (EMEA, 1998a)	Currently authorised for a range of species including poultry (GB and NI)	Not available	4236 (FERA, 2024)	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b) (FERA, 2024)	Not for use in animals from which milk or eggs are produced for human consumption
Florfenicol	0.01 (JECFA, 2021a)	Authorised	Not available	Not available	(D. Li, Zang, et al., 2020)	
Flubendazole ^	0.012 (EMEA, 2006)	Currently authorised for a range of species including poultry (GB and NI)	Not available	800	(FERA, 2024) (FSA, 2024e)	Codex set a MRL of 400 µg/kg for flubendazole in eggs (Codex, 2024b)
Lincomycin	0.03 (JECFA,	Authorised	50	25	(E. Kim,	

Veterinary medicine	Acceptable Daily Intake (mg/kg bw)	UK Authorisation of veterinary medicines in chickens (VMD)	GB MRL in eggs (µg/kg) (VMD, 2024a)	Maximum Level reported in non-compliant egg samples (µg/kg)	Source of incidents †	Remarks (VMD, 2024a)
	2021a)				Bahn, et al., 2012)	
Mantadine	Not available	Not authorised	Not available	Not available	(D. Li, Zang, et al., 2020)	
Ofloxacin ^	Not available	Not authorised	Not available	Not available	(D. Li, Zang, et al., 2020)	
Oxytetracycline	0.003 (EMA, 1995)	Authorised	200	479	(Olatoye & Kayode, 2012)	
Sulfadiazine (SDZ) ^	Not available	Currently authorised for a range of species including poultry (GB and NI)	Not available	Not available	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b)	Sulfonamides - Not for use in animals from which eggs are produced for human consumption
Sulfadimethoxine ^	Not available	No current authorisations	Not available	Not available	(EFSA, 2022c)	Sulfonamides -Not for use in animals from which eggs are produced for human consumption
Sulfamethazine (SMZ)	0.05 (JECFA, 2021b)	Not authorised	Not available	992 (sum of SDZ and SMZ)	(Sasanya, Okeng, et al., 2005)	
Sulfamethoxazole ^	Not available	Currently authorised for a range of species including poultry (GB and NI)	Not available	Not available	(EFSA, 2022c) (EFSA, 2021b)	Sulfonamides - Not for use in animals from which eggs are produced for human consumption
Trimethoprim ^	0.0042 (EMEA, 1997)	Currently authorised for a range of species including poultry (GB and NI)	Not available	Not available	(EFSA, 2023c) (EFSA, 2022c) (EFSA, 2021b)	Not for use in animals from which eggs are produced for human consumption

† UK annual surveillance results, EU annual reports FSA, FERA, Risk Likelihood Dashboard (RLD)
^ Incidents or non-compliance have been reported