Food Control 155 (2024) 110040

Contents lists available at ScienceDirect

Food Control

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

Preventing chemical contaminants in food: Challenges and prospects for safe and sustainable food production

Helen Onyeaka [a,*], Soumya Ghosh [b], KeChrist Obileke [c], Taghi Miri [a], Olumide A. Odeyemi [d], Ogueri Nwaiwu [a], Phemelo Tamasiga [e]

[a] *School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK*
[b] *Department of Genetics Faculty Fakulteit: Natural and Agricultural Sciences / Natuur- en Land-bouwetenskappe PO Box / Posbus 339, Bloemfontein 9300, South Africa*
[c] *Department of Physics, Renewable Energy Research Group, University of Fort Hare Alice 5700, Eastern Cape, South Africa*
[d] *Research Division, University of Tasmania, Australia*
[e] *Public Policy in Africa Initiative, Yaounde, Cameroon*

ARTICLE INFO

Keywords:
Chemical toxicants
Food contamination
Food safety
Diseases

ABSTRACT

Human exposure to chemical contaminants in food has resulted into various health related problems. To prevent and mitigate hazardous exposure to chemical contaminants in food, it is imperative to understand the sources and resultant health problems when exposed. The article, therefore, brings to light the issue of chemical contamination in food, which has become a growing concern due to its potential harm to human health. This is in line with the United Nations' sustainable development goal number three, which seeks a substantial reduction of illnesses from chemical contamination by 2030.

It covers a range of topics, including the various sources of chemical contamination, the health problems that can arise from exposure to these contaminants, and the presence of naturally occurring contaminants in food. The article emphasizes that the food production process, including processing, packaging, transportation, and storage, can greatly contribute to food contamination. The article suggests the appropriate legislative measures, along with strong surveillance and enforcement, that can help to reduce the amount of chemical contamination in food. To achieve this, the article advocates for the continued production of food with minimal chemical contamination.

There is a need to consider the economic impact of diseases caused by toxic chemical exposure in food, in line with global sustainability and best practices goals. Finally, the article suggests that by adopting best practices from around the world, we can help to bridge knowledge gaps and provide benefits to developing countries.

1. Introduction

Preventing chemical contaminants in food has been a major challenge for the food industry and regulators, as they pose risks to human health leading to a range of adverse effects, from mild symptoms such as headaches and nausea to more serious conditions, including birth defects, developmental disorders, and even cancer. Sources of these contaminants include the environment, food processing, storage, and pesticides. Even with efforts to prevent contamination, the issue persists. Factors such as climate change, globalization, and food manufacturing contribute to the increasing prevalence of chemical contaminants in the food supply. This highlights the need for a comprehensive approach to prevent chemical contamination in food that incorporates the latest technological innovations, sustainable agricultural practices, and effective regulations.

The documentation of food contamination dates back to around 8000 years ago, but with the advancements in agriculture and globalization, the rapid spread of contamination has become a major concern. The food industry is facing a significant challenge in protecting consumers from chemical toxicants in food. The complex food supply chain, referred to as a "supply web," makes it difficult to monitor and ensure the safety of the food we consume (Markus, 2015). The global nature of the food industry has made it imperative that strict legislative interventions and monitoring standards are put in place to prevent the spread of contamination. For instance, the European Food Safety Authority (EFSA) has grouped these chemicals as Common Assessment

---

* Corresponding author.
E-mail address: h.onyeaka@bham.ac.uk (H. Onyeaka).

https://doi.org/10.1016/j.foodcont.2023.110040
Received 18 April 2023; Received in revised form 8 August 2023; Accepted 11 August 2023

Group (CAGs) based on their chemical structures, physiochemical properties, hazard profiles and also assigned a lower tolerable daily intake (TDI) for each of these chemicals (EFSA, 2013; EFSA Scientific Committee et al., 2019) in food come from various sources including soil, environment, personal care products, disinfection by-products, water, air, packing material, and microbes. These toxicants can cause a range of health problems, from mild gastroenteritis to fatal hepatic, neurological, and renal problems (Rather et al., 2017). The presence of chemical contaminants in food or in concentrations higher than what is considered safe is a common cause of foodborne diseases and outbreaks (Carter & Blizard, 2016). A high degree of safety needs to be followed when there is substantial use of chemicals to meet the needs of communities around the globe. Of note are the two main concerns, which are the lack of scientific information to perform risk analysis and the lack of assessment of chemicals for, which data is available, especially in developing countries (United Nations, 2023).

The food and water we consume are both vulnerable to the infiltration of toxic chemicals. These chemicals can be both organic and inorganic and come from a variety of sources including the environment (da Araújo et al., 2016; Thompson & Darwish, 2019). There is growing recognition of the need to transition to a more sustainable food production system that not only meets the demand for food but also safeguards the health of consumers and the environment. This requires a collaborative effort between the food industry, government regulators, and scientific community to implement effective strategies to prevent chemical contamination in food. The prospects for safe and sustainable food production are promising, as advancements in food technology, risk assessment, and regulatory frameworks provide new avenues for ensuring the safety of the food supply. To protect consumers from chemical contamination in food, it is crucial that research continues to investigate how toxicants are transferred from the farm to the fork, particularly in underdeveloped countries.

The impact of chemical contaminants on human health is complex and multifaceted. The toxic effects of these substances can vary based on the dose of the contaminant and the individual's immunity to its toxic effects. Some pollutants, such as arsenic, mercury, and lead, have been linked to increased risk of certain types of cancer, including skin, liver, and stomach cancer, respectively (Lu et al., 2015; Zhao et al., 2014). Chemical contamination has been documented in a wide range of food products, including fish, vegetables, and seafood, and its potential health impacts on human health are well documented (Thompson & Darwish, 2019). There is no universally safe level of exposure to chemical contaminants, but acceptable exposure levels have been established for many contaminants, below which no toxic effects should be observed. The nature of the contaminant, the dose ingested, and the individual's biology all contributes to determining the toxic effects of exposure.

The increasing pollution of the environment as a result of industrialization has made chemical contamination of food an increasingly serious concern in recent years. Consuming food contaminated with pesticides or heavy metals can lead to gastrointestinal illnesses (Song et al., 2017). For example, a lead poisoning outbreak in Nigeria in 2010 resulted in the deaths of 400–500 children due to exposure to lead-contaminated food (Tirima et al., 2018).

Food scarcity in underdeveloped countries increases the risk of chemical contamination and digestive disorders, particularly for those reliant on aquatic food. Staple crops like wheat and maize are crucial for national diets but can also expose vulnerable groups to chemical contaminants in developing countries. In underdeveloped countries, transportation and logistics systems are inefficient in terms of reducing distances while transporting food (Wang et al., 2019). Chemical contamination of food has historically been connected to a lack of management systems or weaker public health interventions, which are associated with most areas in developing nations (Nerín et al., 2016). An overview of the knowledge gaps and best practices was performed, and these could lay the foundation for future studies. Accordingly, this review aims to provide a comprehensive summary of the existing knowledge regarding various chemical contaminants that have been historically and presently linked to food safety concerns. Its primary objective is to identify the ongoing sources of persistent chemical contamination in food and shed light on the potential health implications associated with exposure to such contaminants.

2. Chemicals contamination present in foods

The prevalence of chemical contamination in food continues to pose a significant threat to human health, especially to children who are more susceptible to its effects. This is due to the fact that they consume more food in proportion to their body weight, as well as their developing immune systems and limited dietary options (Environmental Protection Authority, 2017).

The level of risk from food contamination varies with the amount of food consumed and the chemical contaminant concentration in the food. These contaminants have been linked to health problems like cancer, developmental and neurological problems. To mitigate the health risks associated with food contamination, it is essential to take appropriate measures to minimize exposure to these chemicals through monitoring and controlling the sources of contamination. The most reported chemical contaminants in food include but are not limited to, heavy metals, pesticides, and mycotoxins.

2.1. Chemical contaminants present in food

2.1.1. Methylmercury

Methylmercury, a toxic form of mercury, is produced through the bacterial conversion of deposited mercury in water bodies (Guimarães et al., 2000). Fish is one of the common food sources of methylmercury. According to the Environmental Protection Agency (EPA), methylmercury is known to be neurotoxic and has detrimental effects on human development (Karagas et al., 2012; Lynch et al., 2011). Despite its negative effects, fish remains an important food source, particularly for infants and children, due to its high levels of beneficial omega-3 fatty acids. However, it is crucial to consider both the type of fish species and portion size as these factors affect both the levels of methylmercury and omega-3 fatty acids in the fish. To optimize the health benefits of fish consumption, it is important to consider these factors and regulate the rate of consumption.

2.1.2. Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are chemicals commonly used in industrial applications like electrical equipment, flame retardants, and paints but they persist in the environment and can accumulate in animal tissues, including food sources like fish and meat (Environmental Protection Agency, 2017). Studies have shown that exposure to PCBs is associated with a range of negative health effects, particularly in relation to neurological development (Adamse, Schoss, Theelen, & Hoogenboom, 2017; Boucher et al., 2009; Schantz et al., 2003; Wigle et al., 2008).

Although the levels of exposure to PCBs have declined in recent years, children are still exposed to low levels of these chemicals (Axelrad et al., 2009; Chmil et al., 2020; Patterson et al., 2009). More recently, PCBs are associated with several different disease conditions. It has been linked to endometriosis (Shirafkan et al., 2023) and Klimczak et al. (2023) highlighted that historical occurrence of polychlorinated naphtalenes still occur in humans from unintentional emissions obtained from thermal processes. To explore how PCBs can be reduced in the environment, Hassan et al. (2023) deduced from a review that the concentrations of highly-chlorinated PCB can be substantially reduced under the presence or absence of oxygen and that the decline was due to the degradation of congeners with one or more chlorine atoms.

However, exposure to PCBs can have varying effects on individuals and populations, influenced by factors like exposure dose and duration, as well as age and health. Other persistent chemicals, including dioxins, dibenzofurans, and organochlorine pesticides, are also present in animal foods and can increase overall exposure and associated health risks.

2.1.3. Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are a group of persistent organic pollutants (POPs) that are widely distributed in the environment and can accumulate in the fat tissue of various food items, such as fish, meats, poultry, dairy products, and even human breast milk (Rose et al., 2010; Schecter et al., 2010). These contaminants pose a risk to people of all ages, as exposure to PBDEs has been linked to several negative health effects, including disruption of the nervous and endocrine systems (Herbstman et al., 2010). Endocrine disruption has become an area of growing concern due to the potential for long-term impacts on human health, such as alterations in hormonal balances, developmental problems, and other serious health outcomes.

2.1.4. Bisphenol A (BPA)

The chemical bisphenol A (BPA) is a well-researched endocrine disruptor that interferes with the normal functioning of hormones. According to the National institute of environmental health sciences (2023), the primary source of exposure to BPA is through the diet and occurs when the chemical migrates from food and drink containers, especially when the containers are heated. The potential harm caused by BPA has raised significant concerns. The National Toxicology Program (2019) has reported that exposure to BPA during fetal development, infancy, and childhood may lead to negative effects on the brain, behaviour, and prostate gland.

Due to the uncertainty surrounding the safety of BPA, the US Food and Drug Administration (FDA, 2021) introduced legislation aimed at restricting or prohibiting the use of BPA in food containers and consumer products. This move reflects the need to address the public's concerns about the potential harm caused by BPA. Additionally, according to EFSA (2021) opinion regarding the re-evaluation of the risks of BPA in food and accordingly, a significant lower tolerable daily intake (TDI) of 0.04 ng/kg body weight/day has been recommended (Bisphenol A). The findings of the studies on BPA and its impact on human health (Diamanti-Kandarakis et al., 2009) highlight the importance of continued research and monitoring in this area.

2.1.5. Phthalates

Phthalates are a group of toxic chemicals that are commonly found in a variety of fatty foods, including dairy products, fish, seafood, and oils. Additionally, exposure to these chemicals in infants occur through the consumption of breast milk and infant formula, which can be contaminated with phthalates. The endocrine-disrupting properties of phthalates on human health has been the subject of numerous studies, for instance, studies by Main et al. (2006), Nassar et al. (2010), and Swan (2008). The findings of these studies indicate that phthalates can cause a range of reproductive and developmental effects in laboratory animals, which suggests that they may have similar effects in humans. These findings highlight the need for continued research into the effects of phthalates on human health and the importance of reducing exposure to these toxic chemicals, especially in vulnerable populations such as infants. Based on these studies, the EFSA has developed a group of TDI for low molecular weight phthalates such as diisononyl phthalate (DINP), di-butylphthalate (DBP), butylbenzylphthalate (BBP) and di-(2-ethylhexyl)phthalate (DEHP) due to their identical hazard profile with possible identical mode of action (EFSA et al., 2019).

2.1.6. Perchlorate

Perchlorate is a widely present chemical contaminant that has been found to exist in different forms of food and drinking sources in the United States. The sources of perchlorate include surface and groundwater (Kirk et al., 2007), human breast milk (Dasgupta et al., 2008), dairy products, vegetables, and other produce. The major concern regarding perchlorate is its ability to disrupt the normal functioning of the thyroid gland. The inhibition of iodide uptake by the thyroid glands leads to a reduction in the production of thyroid hormone which affects its function (Leung et al., 2014). This poses a significant health risk to pregnant women who consume food contaminated with perchlorate. The developing foetus is particularly vulnerable to the adverse effects of perchlorate exposure, making it imperative to monitor and control the presence of this chemical in the food supply. Given the serious implications of perchlorate exposure, it is important to be vigilant and take necessary measures to protect public health.

2.2. The threat of chemical food contamination: an age-old concern with contemporary implications

The food manufacturing industry is particularly vulnerable to contamination, both intentional and unintentional. Intentional contaminants may come from sources such as active packaging, economically motivated adulterants, and dietary ingredients (Lipp & Chase, 2015) while unintentional contamination may occur during food processing, storage, or due to the presence of contaminants in raw materials. With the potential for harmful effects on human health, it is crucial to address this issue and monitor and control the presence of chemical contaminants in the food supply. Fig. 1 visually represents the alarming reality of chemical food contamination in certain regions around the world.

Tables 1 and 2 in the report by Lipp and Chase (2015) illustrate past and recent chemical food safety issues. In the past (as shown in Table 1), arsenic was a major concern, while the current situation (as shown in Table 2) is dominated by plastics. In 2013, the US Centers for Disease Control and Prevention reported over 11,000 cases of foodborne illnesses, with metals and other chemical substances being identified as the primary contaminants (Callejón et al., 2015; Salter, 2014).

By examining historical and recent chemical food safety issues (Tables 1 and 2), we can gain insights into the geographical differences and major contrasts that influence these contamination events.

Table 1 highlights past instances of chemical food safety issues, revealing significant variations across different regions and time periods. Arsenic contamination was a prominent concern in the past, as demonstrated by events such as the Esing Bakery incident in Hong Kong (1857) and the arsenic-tainted sweets in Bradford, England (1858) (Lowe & McLaughlin, 2015; Perkins, 2021). These instances occurred during a time when food safety regulations were less stringent, and the understanding of contaminants and their effects was limited.

However, as we shift to the current era, Table 2 illustrates a different landscape of chemical food safety issues. Plastics have emerged as a dominant concern, as exemplified by cases like ethylene oxide-contaminated sesame seeds in Europe (2020) and plastic contamination in Butterball turkey products (2021) (Kowalska & Manning, 2022; U.S Department for Agriculture, 2021). This shift reflects changes in manufacturing processes, packaging materials, and the pervasive use of plastics in food production and distribution.

The contrasts between developed and developing countries are evident in these tables. Developed nations have made significant strides in regulating and mitigating chemical contamination in food, leading to a decline in certain historical issues. For instance, the Swill milk crisis in New York (1850) and the Minamata illness caused by mercury poisoning in Japan (1950) spurred stricter regulations and improved monitoring practices (Kennedy, 2021, pp. 9–22; Knox & Mayer, 2013).

On the other hand, developing countries often face unique challenges due to limited resources, inadequate infrastructure, and a lack of comprehensive regulatory frameworks. The Delhi 1998 oil poisoning incident in India, caused by edible mustard oil contaminated with Argemone mexicana seed oil, resulted in numerous deaths and hospitalizations (Sitaraman & Rao, 2019). These cases highlight the need for capacity-building efforts, knowledge transfer, and international collaboration to address chemical contamination in food effectively.

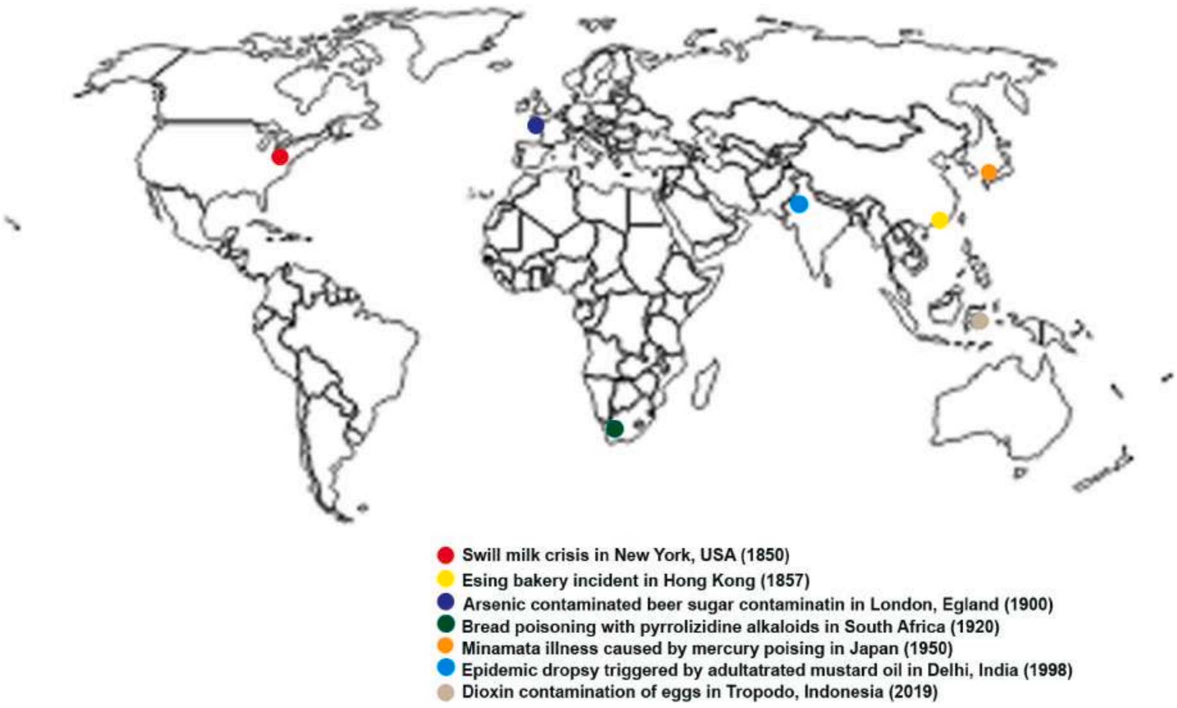

Fig. 1. Food contamination and crisis caused in some parts of the world.

Table 1
Historical chemical food safety issues.

Issue	Year	Reference
The Swill milk crisis in New York	1850	Kennedy (2021)
The Esing Bakery incident in Hong Kong	1857	Lowe and McLaughlin (2015)
Arsenic-contaminated beer sugar outbreak in London	1900	Montet and Dey (2018)
Bread poisoning with pyrrolizidine alkaloids in SA	1920	Wiedenfeld (2011)
Arsenic-tainted sweets in Bradford, England	1858	Perkins (2021)
Cadmium-contaminated rice irrigation water in Japan	1910–45	Aoshima (2022)
Minamata illness caused by mercury poisoning in Japan	1950	Knox and Mayer (2013)
Cooking oil contamination in Meknes, Morocco	1959	Segalla (2020)
Epidemic dropsy triggered by adulterated mustard oil	1998	Sitaraman and Rao (2019)
Clenbuterol-contaminated pork in Guangzhou, China	2009	Wang and Zhang (2011)

Table 2
Recent chemical food safety issues.

Issue	Year	Reference
Fipronil contamination of eggs in Europe	2017	Nayak et al. (2022)
Dioxin contamination of eggs in Tropodo, Indonesia	2019	Mihai et al. (2021)
Ethylene oxide-contaminated sesame seeds in Europe	2020	Kowalska and Manning (2022)
Bongkrek acid-contaminated corn noodles in Jixi, China	2020	Yuan et al. (2020)
Plastic contamination in Butterball turkey products	2021	(U.S Department for Agriculture, 2021)

In a broader context, it is essential to acknowledge the global nature of the issue. Food supply chains are increasingly interconnected, making contamination events in one region capable of impacting consumers worldwide. Furthermore, the nature of chemical contaminants is evolving, with emerging concerns such as plastic contamination posing new challenges that require innovative solutions.

By considering the geographical differences and major contrasts between developed and developing countries, we can gain a better understanding of the factors contributing to these food contamination events. It underscores the importance of comprehensive regulations, adequate surveillance systems, and knowledge-sharing initiatives to prevent and mitigate chemical contamination in food.

3. Sources of food contamination

To fully comprehend the sources of chemical contaminants in food, it is important to consider their origins. In some instances, the environment may play a role in the contamination of food (Smedley & Kinniburgh, 2002). Factors such as soil conditions, point sources and human activities can lead to the build-up of metals in the environment, with events such as mining potentially releasing chemicals like mercury and arsenic into the environment (Bortey-Sam et al., 2015). Other chemical toxicants such as lead, polychlorinated biphenyls (PCBs), and dioxins may also enter food through environmental sources.

The use of pesticides in agriculture may also contribute to the contamination of food (Lebelo et al., 2021). Additionally, the use of medications in both humans and livestock may also pollute waterways and pose a threat to human health through food consumption (Thompson & Darwish, 2019). Food packaging procedures may also be a source of food contamination, as chemicals from the packaging materials may “migrate” and contaminate the food. High-resolution mass spectrometry (HR-MS) has identified oligomers in plastics, food, and human blood (Schreier et al., 2023; Tsochatzis et al., 2021). It has been observed that oligomers can transfer from both newly produced and recycled plastic packaging materials into food (Tsochatzis et al., 2022). The influence of recycling technologies on the production, migration, and safety of oligomers in food and its packaging remains unclear as no specific information is currently available. These pollutants in food have the potential to cause both chronic and acute toxicity (Thompson & Darwish, 2019). Urban farms and gardens may also pose additional concerns due to the presence of metal pollutants (Kaiser et al., 2015).

Drinking water can also become contaminated (Enault et al., 2015), leading to the pollution of marine biota and the compromise of seafood for human consumption (Nelms et al., 2018). Those who consume a high amount of seafood may have elevated levels of these pollutants in their system. Occupational exposure may also play a role in human exposure to contaminants, such as lead, as workers in high-risk fields such as vehicle repair may inadvertently ingest lead after hand-to-mouth contact (Thompson & Darwish, 2019).

The presence of microplastics in food and its impact on ensuring food safety and sustainable production is a matter of great significance. These minuscule plastic particles, which come from different sources like degraded plastics, microbeads, and synthetic textile fibers, can enter the environment and eventually find their way into the food chain (Katare et al., 2021). Marine organisms can ingest microplastics, leading to their accumulation in seafood, while soil and crops can also become contaminated. The ingestion of microplastics raises concerns about potential health hazards due to their ability to carry other contaminants along with them.

The health implications of these chemical contaminations are broad, with findings from the literature indicating that mild gastroenteritis and syndromes related to the liver, kidneys, and nervous system may occur (Rather et al., 2017). The major sources of food contamination are found to be naturally occurring toxins, environmental pollutants, processing, packaging, preparation, storage, and transportation of raw food materials (Rather et al., 2017).

On the other hand, the way the foods are processed or cooked at high temperature, may lead to the formation of Maillard reaction products (MRPs) that could be toxic or beneficial to human health. MRPs are produced by the interaction with the reducing sugars and amino acids, which is a non-enzymatic browning reaction, leading to formation of various odour and brown colour (Hodge, 1953; Tamanna & Mahmood, 2015). The MRPs especially carboxy methyl lysine (CML) may cause diabetes and cardiovascular diseases while acrylamide acts as a carcinogen (Knecht et al., 1991; Meng et al., 1998; Tareke et al., 2000). Notably, MRPs such as melanoidins have been observed with antioxidative (Natella et al., 2002) and antimicrobial effect (Hiramoto et al., 2004). To circumvent this problem, there is an ever-increasing demand for the use of instant meal rather than traditional cooking. Notably, studies have shown that people consuming high amount of processed meat, pizza or snacks develop insulin resistance and metabolic syndrome compared to people having high intake of fresh vegetables and low processed food (Esmaillzadeh et al., 2007). Taking together, despite several known sources of food contamination, many remain unidentified, however, advancements in technology have made it easier to detect these sources, leading to the importance of continuous surveillance for food safety.

3.1. Naturally occurring chemical contaminants in food

The presence of natural chemical contaminants in food is a common occurrence. Raw food surfaces are naturally prone to contamination by a range of bacteria, viruses, parasites, and other pathogens. Sources of contamination can include soil, sewage, live animals, exterior surfaces, internal organs of meat animals, and food derived from diseased animals (Gallo et al., 2020; Rather et al., 2017). Although advancements in medicine have reduced the risk of contamination from diseased animals, other forms of chemical contamination, such as the accidental introduction of chemical substances in food or the use of antibiotics or chemicals in animal feed, continue to pose a threat to food safety (Martin & Beutin, 2011).

Parasites in food can also pose a significant risk to human health. These parasites can enter food products such as fruits, vegetables, and meat through irrigation water, excreta, soil, sewage, poor handling practices, or human handling (Rather et al., 2017). Food-producing livestock can also play a role in spreading parasites, as they can become infected and spread the parasites to the food they produce. Most of the living organisms present in food can produce toxins that are classified as natural toxins. Foodborne illnesses and outbreaks can be caused by several of these natural contaminants, with enteric diseases being transmitted via the fecal-oral route because of consuming contaminated food or ingesting free-living parasites from the environment (Rather et al., 2017). In conclusion, the presence of natural chemical contaminants in food poses a significant threat to human health and highlights the need for effective food safety measures and proper handling practices.

3.1.1. Mycotoxins

Mycotoxins are secondary metabolites (Li et al., 2023) and are naturally occurring harmful compounds that are produced by various fungi, particularly those belonging to the genera *Penicillium, Fusarium, and Aspergillus* (Zeidan et al., 2018). These toxins are produced when environmental factors such as moisture and temperature of the food become optimal for fungal growth. With the recent changes in weather patterns caused by climate change, the prevalence of mycotoxins in food crops has become a growing concern. As the environment becomes increasingly favourable for fungal growth, the risk of food contamination by mycotoxins also increases. This highlights the need for continuous monitoring and regulation of food crops to ensure that they remain free from these harmful compounds.

3.1.2. Marine biotoxins

Marine biotoxins are naturally occurring toxic substances produced by certain types of phytoplankton in the sea. According to a study by Peteva et al. (2018), the presence of these toxins is higher during the summer months. These toxins can cause a range of health problems in individuals who consume contaminated seafood. Example, domoic acid and its derivatives, which are neurotoxins, can cause amnesic shellfish poisoning, leading to digestive disorders and more severe neurological issues in elderly people. Another group of lipophilic toxins known as Diarrhetic Shellfish Poisoning, including azaspiracid, okadaic acid, and dinophysistoxins, can cause minor gastrointestinal symptoms like nausea, vomiting, diarrhoea, abdominal discomfort, chills, headaches, and fever. These symptoms can last for a few days (Peteva et al., 2018).

3.2. Food allergens

Food allergens are proteins or their derivatives that can cause abnormal immune system reactions. Egg and milk are common allergens, but allergies to shellfish, peanuts, and tree nuts can develop later in life and persist (Onyimba et al., 2021). Most foods can potentially cause an allergic reaction, with around 90% of reactions being triggered by peanuts, tree nuts, milk, soy, wheat, egg, crustaceans, fish, sesame, lupin, or molluscs (Durban et al., 2021). Food allergies range from minor gastrointestinal discomfort, skin rashes to life-threatening anaphylaxis and asthma. On the other hand, actual food allergies account for a small portion of the wide range of individualized allergic events to foods, which also includes food intolerances (Schussler et al., 2018). Vegetables and fruits such as apples, kiwi, and melons can also cause moderate allergic reactions (Vanga et al., 2018). Pollen-food syndrome, also known as oral allergy syndrome, is linked to primary allergies to pollen or latex (Kim et al., 2008) and causes symptoms usually restricted to the throat and mouth (Mastrorilli et al., 2019).

There is no cure for food allergies, and avoidance of allergenic foods is the only way to manage them effectively (Turnbull et al., 2015). Emergency treatments are available to address allergic reactions.

3.3. Unusual chemical contamination in food

The occurrence of unusual chemical contamination in food can be a result of both accidental and intentional causes. Intentional contamination can arise from sources such as economic adulterants or malicious intent. Food can also be used as a vector for delivering biological or chemical weapons, in which chemical agents are deliberately added to adulterate food matrices (Bruemmer, 2003; Shabani et al., 2022). The September 11, 2001, terrorist attack in the United States, for example, raised concerns about the safety of the country's food supply (Sobel et al., 2002; Spink & Moyer, 2011). In response to these concerns, new and sophisticated techniques have been developed both in the US and internationally to detect chemical agents that may contaminate food, including natural toxins, agrochemicals, heavy metals, and non-metallic ions (Khan et al., 2001; Meadows, 2004). The risk of chemical contamination in food is a widespread public health concern that affects individuals of all ages, races, genders, and income levels globally. Numerous studies have reported the presence of harmful chemical substances, such as mycotoxins, pesticides, antimicrobials, polychlorinated biphenyls and dioxins, polycyclic aromatic hydrocarbons, and metals in food and animal feed, leading to a range of health issues (Prüss-Ustün et al., 2011).

Similarly, the presence of chemical contaminants, such as melamine, in imported food is also a cause of consumer concern. Melamine is a nitrogen-based industrial chemical used in the production of melamine resins, and its presence in human foods and animal feed has raised alarm among consumers (Vail et al., 2007). Studies have reported that melamine-related compounds (cyanuric acid, ammeline, and ammelide) in animal feed caused animal illness and death, and high and continuous dietary exposure to melamine, in combination with cyanuric acid, can cause the formation of insoluble melamine cyanurate crystals in the kidneys of cats and dogs, resulting in renal failure (Andersen et al., 2008; Chan et al., 2008). Furthermore, the presence of melamine in meats consumed by humans can also pose a potential risk (Vail et al., 2007). In some cases, melamine contamination in infant formula milk has resulted in renal complications and death (Chan et al., 2008; Ingelfinger, 2008). In response to these incidents, regulatory agencies, such as the Food and Drug Administration (FDA), have developed and implemented monitoring methods, such as infrared spectroscopy, liquid and gas chromatography-mass spectrometry, to detect melamine and cyanuric acid in both domestic and imported milk-derived products (Andersen et al., 2008; Vail et al., 2007).3.6 Use of genetically modified crops.

The concept of "genetically modified" refers to the process of transferring genes across species using laboratory techniques such as gene insertion, DNA splicing, and cloning (Byrne, 2014). These techniques, collectively known as recombinant DNA technology, result in the creation of genetically modified organisms (GMOs), which are also referred to as bioengineered, genetically engineered, and transgenic crops or foods. Although the term "genetically modified" is sometimes perceived as ambiguous or confusing, it is important to note that many foods we consume have been genetically modified over generations through human selection for desirable qualities and domestication from wild species. However, crops or products produced through recombinant DNA technology are not allowed in organic production according to USDA standards for organic agriculture (Nandwani & Nwosisi, 2016, pp. 1–35).

Genetically modified crops were cultivated on 179.7 million hectares in 28 different countries in 2015, representing more than 10% of the world's arable land and seven times the size of the United Kingdom. United States, Argentina and Brazil are the leading producers of genetically modified crops. Although scientists are conducting controlled trials, no genetically modified crops are currently being produced commercially in the United Kingdom (The Royal Society, 2016). Only a few varieties of GMO crops are cultivated in the US, yet some of these GMOs represent a significant portion of the crop grown (e.g., corn, soybeans, canola, cotton, and sugar beets) (U.S. FDA, 2020). GMO soybeans ac-counted for 94% of all soybeans planted in 2018, while GMO corn and cotton accounted for 92% and 94%, respectively of all plants planted. GMO canola accounted for 95% of all planted canola in 2013, while GMO sugar beets accounted for 99.9% of all sugar beets produced in the same year. The majority of GMO plants are used in generating ingredients that are then used in many other food products, such as corn starch or sugar made from genetically modified sugar beets. The benefits of genetic modification (GM) in agriculture are numerous and well documented in the literature. Perez-Torrado et al. (2015) highlight that GM technology has the potential to increase agricultural yields, reduce pesticide use, improve the nutritional content and quality of food, lower the cost of food and drug production, enhance food security, provide resistance to pests and diseases, and offer medicinal benefits to a growing global population. Furthermore, crops have been engineered to mature faster and withstand environmental stresses such as salt, boron, aluminum, frost, drought, and others, allowing for their growth in otherwise inhospitable conditions. This technology has also been applied in the production of non-industrial (ornamental plants) and non-protein (bioplastic) products, as demonstrated by Mickelbart et al. (2015).

However, the consequences of altering a crop's natural state by the introduction of foreign genes are not fully understood. Phillips (2008) highlights the potential implications such as changes in the crop's growth rate, changes in its metabolism, and the crop's response to external environmental stimuli. These implications can affect both the genetically modified crop and the natural habitat in which they can survive. Additionally, there is concern about the transfer of antibiotic-resistant genes to gut flora and the potential for new allergens to be introduced in genetically modified crops, both of which are considered significant health risks to humans (Craig et al., 2008).

The presence of chemical contaminants in food poses a serious and ongoing threat to public health. People of all ages, races, genders, and income levels are vulnerable to the effects of chemical contamination, regardless of their location in the world. This issue has been well-documented by various authors who have studied the health implications of consuming chemical contaminants in food, including mycotoxins, pesticides, antimicrobials, polychlorinated biphenyls and dioxins, polycyclic aromatic hydrocarbons, and metals.

Table 3 provides an overview of various chemical contaminants found in food, the corresponding foods in which they are commonly present, and the potential health issues associated with their consumption. It serves as a reference for understanding the relationship between chemical contaminants, food sources, and their impact on human health.

3.4. *Storage and packaging contaminants*

Food packaging offers several advantages, from physical protection, barrier protection, and enhanced food preservation, which prolongs the shelf life of food products. Various additives (including stabilizers, antioxidants, slip agents or plasticizers) are often introduced to polymers during the manufacturing of food packaging to improve material qualities (Nerin et al., 2016, pp. 81–93), which can migrate from direct or indirect contact with the packaging material to the food, and potentially endanger consumers' health (Diamantidou et al., 2022). For this reason, there is a need for appropriate and reliable frequent analytical control for the detection and quantitative analysis of all these targeted analytes (Alberto & Tsochatzis, 2023; Tsochatzis & Begou, 2022).

Metallic cans used in food packaging may allow metallic ions such as iron or tin to migrate into the food due to corrosion on the can's metallic surface (Buculei et al., 2012). A review (Udovicki et al., 2022) of the occurrence of microplastics and its effects on the health of human after exposure found that there is widespread occurrence and a large amount appears to be consumed yearly. Another review of global trends and concentrations of microplastics in foods and beverages (Sewwandi et al.,) found that even To overcome the challenges, Kwon et al. (2020) suggested that more research on human microplastic consumption should be carried out. The detection of plastic oligomers in food contact materials requires analytical strategies which may be demanding (Alberto Lopes & Tsochatzis, 2023), hence, a worldwide collaborative research will be beneficial especially to developing countries. The consensus in the literature is the inability of plastics to degrade, hence it is believed

Table 3
Chemical contaminants, foods present, and possible health issues.

Category	Chemical Contaminant	Foods Present	Possible Health Issues	Reference
Mycotoxins	Aflatoxin	Ground nut oil	Immunodeficiency, Liver damage, Acute toxicity, Carcinogenicity, Impaired growth effect	(Darwish et al., 2014; Gong et al., 2016)
	Deoxynivalenol	Wheat, barley	Impaired intestinal integrity, Impaired gut-associated immune system	Robert et al. (2017)
	Ochratoxin	Wheat flour	Nephropathy	Khlifa et al. (2012)
	Fumonisins	Maize	Esophageal cancer and birth defects	Park et al. (2017)
	Zearalenone	Wheat and barley	Hyperestrogenism and reproductive dysfunction	Chang et al. (2017)
Antimicrobials	Sulfonamides	–	Kidney damage and nephropathy	Darwish, Atia, Khedr, and Eldin (2018)
	Macrolides	–	Hypersensitivity and anaphylactic shock	Bayomi et al. (2016)
Pesticides	DDTs	Edible offal, milk, chicken	Neurological symptoms	Thompson et al. (2017)
Polychlorinated biphenyls and Dioxins	–	Baby food	Language delay	Caspersen et al. (2016)
Metals	Lead	Grains and vegetables	Death among children, Complications in the red blood cells and nervous system	(Darwish, Atia, Reda, et al., 2018; Yabe et al., 2015)
	Mercury	Grains and vegetables	Associated with reproductive, neurotoxicity and cardiovascular, developmental toxicity, immunotoxicity, carcinogenicity, and nephrotoxicity	Genchi et al. (2017)
Polycyclic aromatic hydrocarbons (PAHs)	Benzo [*a*]pyrene	Barbecued food	Cognitive dysfunction among children, Impaired male fertility, DNA damage and oxidative stress, Mutagenicity and carcinogenicity	(Dai et al., 2015; Darwish et al., 2015, 2018a; Jedrychowski et al., 2015)

that biodegradable polymers may be a way out in the future (Samir et al., 2022).

Glass jars are commonly used for packing marmalades, jams, beans, sauces, and vegetables and copper lids used to seal them cause migration in this case. To ensure a good seal, these lids normally feature a polyvinyl chloride gasket (PVC) (Nerin et al., 2016, pp. 81–93). Epoxidized soybean oil is one of the plasticizers used in PVC, and it has been found in food by a number of authors (Choi et al., 2018). Polyethylene, polyethylene terephthalate, high-density polyethylene, PVC, polycarbonate and polystyrene (PS), are some of the most commonly used polymers in food packaging. All these ingredients can migrate.

Dry foods like sugar and flour and items like frozen food and cereals are typically packaged with paper and board (Nerin et al., 2016, pp. 81–93). Contaminants can migrate from printing inks or paperboard additives to the food. It is worth noting that paper is by far the most recyclable packaging material, and therefore, using recyclable materials could expose food to contaminants such as plasticizers or mineral oils contained in adhesives or printing inks. Set-off transference has been documented more recently because of migrations from components produced from printing inks (Aznar et al., 2015).

Recyclying material such as polyethylene terephthalate for food packaging to avoid the use of virgin resources may be difficult to be proven safe (Tsochatzis et al., 2022).

3.5. *Food contaminants during processing and transportation*

The prevention of contamination during food processing and transportation is critical for ensuring the safety and quality of food products. Proper cleaning and disinfection procedures can help eliminate harmful microorganisms and reduce the risk of contamination. However, the use of disinfectants during the processing of minimally processed fruits and vegetables can result in residual concentrations of these chemicals on the processed food products, which can cause potential health risks (Villanueva et al., 2018). The use of non-ionic surfactants such as stearyl alcohol ethoxylate and quaternary ammonium compounds in cleaning food products can also result in the transfer of these chemicals to food, due to remnants of these surfactants left on food handling equipment (Rather et al., 2017; Tuladhar et al., 2012).

Sustainability goals, particularly the recycling of food contact materials (FCMs), are essential for preventing chemical contaminants in food and promoting safe and sustainable food production (De Tandt et al., 2021). Recycling FCMs reduces the environmental impact of their disposal by decreasing the need for raw materials extraction and reducing energy consumption and greenhouse gas emissions. It also contributes to resource conservation by extending the lifespan of materials, aligning with the principles of sustainable food production. Focusing on FCM recycling fosters a circular economy, ensuring materials are reused and recycled rather than being wasted in landfills. Moreover, by properly managing and recycling FCMs, the risk of chemical contaminants entering the food supply chain is minimized, enhancing food safety and supporting sustainable practices in the food industry (Briassoulis, 2023).

New (bio)plastic polymers (polyhydroxyalkanoates, polylactic acid, polybutylene succinate, polyhydroxyurethane, and polyethylene furanoate) are being introduced, and this is important for reducing chemical contamination of food and ensuring safe, sustainable food production (Omerović et al., 2021; Zhao et al., 2023). These materials provide substitute packaging choices with lowered contamination hazards. They are designed to reduce dangerous ingredient migration, ensuring food safety. Many (bio)plastic polymers are also compostable or biodegradable, minimising their negative effects on the environment and the danger of microplastic contamination. Regulations and standards, however, are required to guarantee their safety and fitness for interaction with food.

Contamination of food can also occur during transportation, through gasoline and diesel vehicle emissions or cross-contamination within vehicles. Cross-contamination poses a significant threat to food safety and has been responsible for foodborne outbreaks in the past, such as a pandemic in the European Economic Community in 1999 that was attributed to pallets contaminated with fungicide used to transport food packaging materials (Kamboj et al., 2020).

The production process itself can also result in the formation of chemical contaminants in food. High cooking temperatures, commonly used in both home and industrial food processing, can produce toxic compounds such as chloropropanols, nitrosamines, furanes, PAHs, and acrylamide, which can negatively impact food quality and safety (Nerin et al., 2016, pp. 81–93). Frying is a major contributor to the formation of hazardous chemicals during the food manufacturing process (Roccato et al., 2015).

The heating treatment employed in the production process is another source of chemical contaminants. High cooking temperatures are typical food processing activities in both homes and industries. Cooking at a high temperature, combined with environmental factors, can produce toxic compounds that jeopardize food quality and safety. Toxic compounds such as chloropropanols, nitrosamines, furanes, PAHs or acrylamide are produced during food processing operations such as roasting, heating, grilling, canning, baking, fermentation, or hydrolysis (Nerin et al., 2016, pp. 81–93). In the food manufacturing process, frying is a major producer of a variety of hazardous chemicals (Roccato et al., 2015). Fig. 2 gives a comprehensive view of how chemical contamination enters the food production process through various sources and pathways.

3.6. Monitoring and surveillance

Monitoring and surveillance are essential for safeguarding consumers from chemical contaminants and preserving the security of the food supply chain. To find, evaluate, and manage chemical hazards in food, numerous governmental and non-governmental organisations worldwide are engaged in monitoring and surveillance programmes (Connolly et al., 2016). These initiatives seek to determine and quantify the contaminants present, evaluate the hazards they may provide, and put in place the safety measures required.

Different nations and areas have different levels of monitoring and surveillance for chemical contaminants in food. Developed nations typically have more well-established systems with thorough monitoring programmes and strict laws (Wahidin & Purnhagen, 2018). To assess the safety of the food supply, these systems frequently include routine sampling of food products, laboratory testing, and risk assessment techniques.

Despite current monitoring and surveillance efforts, a number of possible gaps and challenges need to be resolved.

1. Analytical Methods: There is ongoing challenge in the development of precise, sensitive, and quick analytical techniques to identify and measure chemical contaminants in various food matrices (Hird et al., 2014). Advancements in analytical technique can improve detection abilities and lower the possibility of false-positive or false-negative results.
2. Emerging Contaminants: Due to the constantly changing nature of developing chemical pollutants, such as new pesticide residues or innovative food additives, identification and monitoring can be difficult (Umapathi et al., 2022). To stay up with new threats, ongoing research and observation are required.
3. Global Harmonization: It is crucial to achieve global harmonization in the methodology, regulatory standards, and practises for chemical contamination monitoring and surveillance. Different laws and standards in different nations can complicate international trade and jeopardize consumer protection.
4. Resource Limitations: Strong monitoring and surveillance programmes require adequate finance, infrastructure, and personnel with the necessary skills. The effectiveness and reach of monitoring operations might be hampered by a lack of resources, particularly in developing nations.
5. Data Sharing and Collaboration: The efficiency of monitoring and surveillance operations can be increased by increased collaboration and data sharing across nations, regulatory agencies, and scientific groups (WHO, 2020). Sharing data on emerging risks, analytical techniques, and best practises can help close gaps and advance food safety.
6. Rapid Alert Systems: Rapid alert systems must be established and improved to enable prompt communication and response to food safety situations involving chemical pollutants (Savelli et al., 2019). Effective channels of communication can speed up the recall of contaminated products and minimize any potential health hazards.

4. Knowledge gaps and prospects

The monitoring of chemical contaminants in food products is a critical aspect of ensuring food safety and quality. However, in many developing countries, there are significant gaps in the process of chemical contaminant monitoring and control. For example, there is lack of clear guidance and legislation outlining the relevant limits for different types of food contaminants. Furthermore, even where legislation exists, there is often a lack of a robust monitoring program to verify the presence and quantity of chemical contaminants in different food products. This makes it difficult to ensure that the food we consume is free from harmful chemicals.

Moreover, there is need for more research into the toxicological consequences of food contamination, particularly in developing countries. This involve investigating how chemicals toxicants are transmitted from farms to plates and understanding the impact of environmental factors on food contamination. Threshold limits for toxicants at low

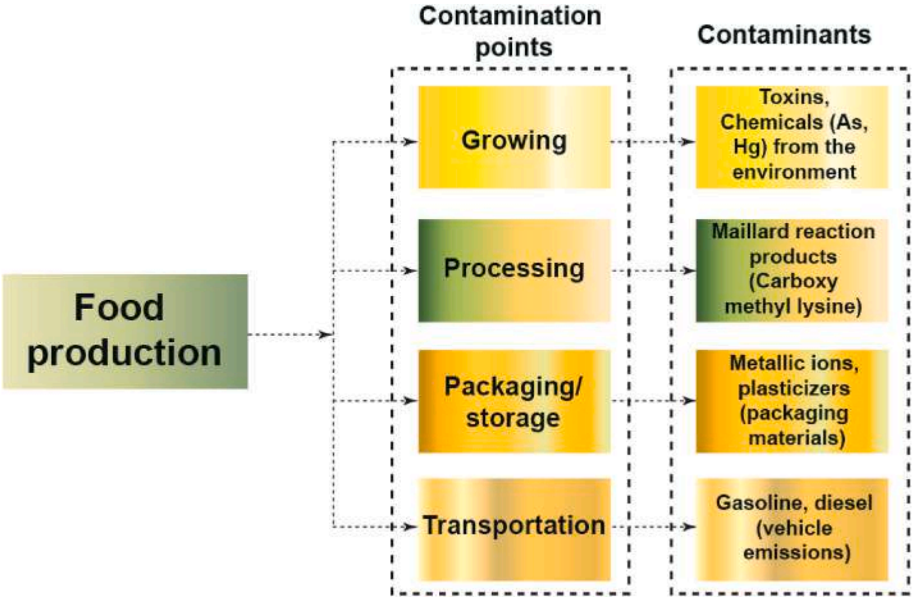

Fig. 2. Sources and pathways of chemical contamination in food production.

concentrations must be established, and national food safety management systems evaluated. There is a particular need for increased oversight and promotion of compliance with chemical control in agriculture-intensive countries.

There are also significant gaps in the process of risk assessment in most developing countries. Due to scarce resources, a lack of infrastructure and experience, poor data availability and quality, obsolete regulatory frameworks, and competing agendas, risk assessment procedures for chemical contaminants in food differ greatly between nations, especially in developing countries (Morse et al., 2018). Effective risk evaluations are further hindered by insufficient data and inconsistent legislation (Alfei et al., 2020). Risk assessment will play a crucial role in ensuring food safety by evaluating the potential hazards associated with chemical contaminants in food products (Ng et al., 2022). By conducting risk assessments, policymakers and regulatory bodies can make informed decisions about food safety standards and develop appropriate control measures to protect public health.

In the context of chemical contaminant monitoring in food, harmonization plays a vital role in setting uniform limits and guidelines for contaminants across borders (King et al., 2017). It helps prevent discrepancies in safety standards and facilitates a smoother exchange of food products between nations. Globally, there are significant challenges to harmonising enforcement and surveillance operations for chemical contamination in food. It is important to understand how consistency is hampered by various regulatory frameworks, limited capacity, different priorities, complicated global trade, and inadequate information exchange. It is also key to understand how to address these issues through global cooperation, which includes enhancing partnerships, creating global standards, boosting capacity building, promoting cutting-edge technology, and strengthening regulatory frameworks to improve global food safety and public health.

The gaps in current legislation regarding chemical contaminant monitoring in food, particularly in developing countries include the absence of clear guidance and legislation regarding limits for different contaminants. Such inconsistencies create challenges in ensuring food safety and can lead to variations in safety standards among different countries.

Government action is needed to reduce chemical contamination in food, methods must be developed to capture the economic impact of these illnesses, and this information must be linked to global sustainable best practices and goals. Understanding the concerns of food producers about systems for producing food with minimal contamination is also crucial for food safety and quality.

5. Conclusion

Over the years, there has been a growing concern on the presence of chemical contaminants in food due to the potential harm to human health that these chemical contaminants can cause. Chemical contaminants get into along the food supply chain which when consumed with food could harm the consumers. Residual chemicals from disinfectants and surfactants such as stearyl alcohol ethoxylate and quaternary ammonium compounds in cleaning food products can pose health risks. Rather than using chemicals to eliminate food borne pathogens that can leave harmful residues in food, safer methods, such as natural cleaning solutions and thorough equipment cleaning, like the use of natural or organic cleaning solutions, such as vinegar or baking soda, can effectively eliminate harmful microorganisms without leaving harmful residues in the food. The use of lower cooking temperatures and alternative cooking methods such as steaming or boiling are encouraged instead of using high cooking temperatures that can produce toxic compounds such as chloropropanols, nitrosamines, furanes, PAHs, and acrylamide which are harmful to human health. There is need for Governments to increase oversight and promote compliance in industries like agriculture to prevent chemical contamination and ensure food products are safe for consumption.

Authors' contributions

Helen Onyeaka: Conceptualization, Writing- Reviewing and Editing, Supervision, Validation. Soumya Ghosh, KeChrist Obileke, Taghi Miri, Olumide A. Odeyemi, Ogueri Nwaiwu, Phemelo Tamasiga Writing, Reviewing and Editing.

Financial interest

All authors declare that they have no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

Consent for publication

All the authors read and agreed to publish this article.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Declaration of competing interest

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

Data availability

Data will be made available on request.

References

Adamse, P., Schoss, S., Theelen, R. M., & Hoogenboom, R. L. (2017). Levels of dioxins and dioxin-like PCBs in food of animal origin in The Netherlands during the period 2001–2011. *Food Additives & Contaminants: Part A, 34*(1), 78–92.

Alberto Lopes, J., & Tsochatzis, E. D. (2023). Poly (ethylene terephthalate), poly (butylene terephthalate), and polystyrene oligomers: Occurrence and analysis in food contact materials and food. *Journal of Agricultural and Food Chemistry, 71*(5), 2244–2258.

Alfei, S., Marengo, B., & Zuccari, G. (2020). Nanotechnology application in food packaging: A plethora of opportunities versus pending risks assessment and public concerns. *Food Research International, 137*, 109664.

Andersen, W. C., Turnipseed, S. B., Karbiwnyk, C. M., Clark, S. B., Madson, M. R., Gieseker, C. M., Miller, R. A., Rummel, N. G., & Reimschuessel, R. (2008). Determination and confirmation of melamine residues in catfish, trout, tilapia, salmon, and shrimp by liquid chromatography with tandem mass spectrometry. *Journal of Agricultural and Food Chemistry, 56*(12), 4340–4347.

Aoshima, K. (2022). *Itai-itai disease: Health issues caused by environmental exposure to cadmium and residents' fight to rebuild the environment in the jinzu river basin in toyama, overcoming environmental risks to achieve sustainable development GoalsSpringer* (pp. 21–29).

da Araújo, C. F. S., Lopes, M. V., Vasquez, M. R., Porcino, T. S., Ribeiro, A. S. V., Rodrigues, J. L. G., Oliveira, S., d, P. S., & Menezes-Filho, J. A. (2016). Cadmium and lead in seafood from the Aratu Bay, Brazil and the human health risk assessment. *Environmental Monitoring and Assessment, 188*(4), 1–12.

Axelrad, D. A., Goodman, S., & Woodruff, T. J. (2009). PCB body burdens in US women of childbearing age 2001–2002: An evaluation of alternate summary metrics of NHANES data. *Environmental Research, 109*(4), 368–378.

Aznar, M., Domeño, C., Nerín, C., & Bosetti, O. (2015). Set-off of non volatile compounds from printing inks in food packaging materials and the role of lacquers to avoid migration. *Dyes and Pigments, 114*, 85–92.

Bayomi, R. M. E., Darwish, W. S., El-Moaty, A. M. A., & Gad, T. M. (2016). Prevalence, antibiogram, molecular characterization and reduction trial of *Salmonella typhimurium* isolated from different fish species. *Japanese Journal of Veterinary Research, 64*(2), S181–S186.

Bortey-Sam, N., Nakayama, S. M., Ikenaka, Y., Akoto, O., Baidoo, E., Yohannes, Y. B., Mizukawa, H., & Ishizuka, M. (2015). Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). *Ecotoxicology and Environmental Safety, 111*, 160–167.

Boucher, O., Muckle, G., & Bastien, C. H. (2009). Prenatal exposure to polychlorinated biphenyls: A neuropsychologic analysis. *Environmental Health Perspectives, 117*(1), 7–16.

Briassoulis, D. (2023). Agricultural plastics as a potential threat to food security, health, and environment through soil pollution by microplastics: Problem definition. *Science of the Total Environment, 164533*.

Bruemmer, B. (2003). Food biosecurity. *Journal of the Academy of Nutrition and Dietetics, 103*(6), 687.

Buculei, A., Gutt, G., Sonia, A., Adriana, D., & Constantinescu, G. (2012). Study regarding the tin and iron migration from metallic cans into foodstuff during storage. *Journal of Agroalimentary Processes and Technologies, 18*(4), 299–303.

Byrne, P. (2014). *Genetically modified (GM) crops: Techniques and applications. Fact sheet*. Crop series: Colorado State University. Extension. no. 0.710.

Callejón, R. M., Rodríguez-Naranjo, M. I., Ubeda, C., Hornedo-Ortega, R., Garcia-Parrilla, M. C., & Troncoso, A. M. (2015). Reported foodborne outbreaks due to fresh produce in the United States and European union: Trends and causes. *Foodborne pathogens and disease, 12*(1), 32–38.

Carter, C. J., & Blizard, R. (2016). Autism genes are selectively targeted by environmental pollutants including pesticides, heavy metals, bisphenol A, phthalates and many others in food, cosmetics or household products. *Neurochemistry International, 101*, 83–109.

Caspersen, I., Haugen, M., Schjølberg, S., Vejrup, K., Knutsen, H., Brantsaeter, A., Meltzer, H., Alexander, J., Magnus, P., & Kvalem, H. (2016). Maternal dietary exposure to dioxins and polychlorinated biphenyls (PCBs) is associated with language delay in 3 year old Norwegian children. *Environment International, 91*, 180–187.

Chang, H., Kim, W., Park, J.-H., Kim, D., Kim, C.-R., Chung, S., & Lee, C. (2017). The occurrence of zearalenone in South Korean feedstuffs between 2009 and 2016. *Toxins, 9*(7), 223.

Chan, E., Griffiths, S., & Chan, C. (2008). Public-health risks of melamine in milk products. *The Lancet, 372*(9648), 1444–1445.

Chmil, V. D., Golokhova, O. V., Vydrin, Yu, D., & Kruk, V. I. (2020). Relevance of the problem of dioxins and polychlorinated biphenyls (PCBs) determination in baby food products. *One Health and Nutrition Problems of Ukraine, 52*, 32–39, 10.33273/2663-9726-2020-52-1-32-39.

Choi, M. S., Rehman, S. U., Kim, H., Han, S. B., Lee, J., Hong, J., & Yoo, H. H. (2018). Migration of epoxidized soybean oil from polyvinyl chloride/polyvinylidene chloride food packaging wraps into food simulants. *Environmental Science and Pollution Research, 25*(5), 5033–5039.

Connolly, A. J., Luo, L. S., Woolsey, M., Lyons, M., & Phillips-Connolly, K. (2016). A blueprint for food safety in China. *China Agricultural Economic Review, 8*(1), 129–147.

Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). An overview of general features of risk assessments of genetically modified crops. *Euphytica, 164*(3), 853–880.

Dai, J.-B., Wang, Z.-X., & Qiao, Z.-D. (2015). The hazardous effects of tobacco smoking on male fertility. *Asian Journal of Andrology, 17*(6), 954.

Darwish, W. S., Atia, A. S., Khedr, M. H., & Eldin, W. F. S. (2018a). Metal contamination in quail meat: Residues, sources, molecular biomarkers, and human health risk assessment. *Environmental Science and Pollution Research, 25*(20), 20106–20115.

Darwish, W. S., Atia, A. S., Reda, L. M., Elhelaly, A. E., Thompson, L. A., & Saad Eldin, W. F. (2018). Chicken giblets and wastewater samples as possible sources of methicillin-resistant Staphylococcus aureus: Prevalence, enterotoxin production, and antibiotic susceptibility. *Journal of Food Safety, 38*(4), Article e12478.

Darwish, W. S., Ikenaka, Y., Nakayama, S. M., & Ishizuka, M. (2014). An overview on mycotoxin contamination of foods in Africa. *Journal of Veterinary Medical Science, 76*(6), 789–797.

Darwish, W. S., Ikenaka, Y., Nakayama, S., Mizukawa, H., & Ishizuka, M. (2015). Mutagenicity of modelled-heat-treated meat extracts: Mutagenicity assay, analysis and mechanism of mutagenesis. *Japanese Journal of Veterinary Research, 63*(4), 173–182.

Dasgupta, P. K., Kirk, A. B., Dyke, J. V., & Ohira, S.-I. (2008). Intake of iodine and perchlorate and excretion in human milk. *Environmental Science & Technology, 42*(21), 8115–8121.

De Tandt, E., Demuytere, C., Van Asbroeck, E., Moerman, H., Mys, N., Vyncke, G., & Ragaert, K. (2021). A recycler's perspective on the implications of REACH and food contact material (FCM) regulations for the mechanical recycling of FCM plastics. *Waste Management, 119*, 315–329.

Diamanti-Kandarakis, E., Bourguignon, J.-P., Giudice, L. C., Hauser, R., Prins, G. S., Soto, A. M., Zoeller, R. T., & Gore, A. C. (2009). Endocrine-disrupting chemicals: An endocrine society scientific statement. *Endocrine Reviews, 30*(4), 293–342.

Diamantidou, D., Mastrogianni, O., Tsochatzis, E., Theodoridis, G., Raikos, N., Gika, H., & Kalogiannis, S. (2022). Liquid chromatography-mass spectrometry method for the determination of polyethylene terephthalate and polybutylene terephthalate cyclic oligomers in blood samples. *Analytical and Bioanalytical Chemistry, 414*(4), 1503–1512.

Durban, R., Groetch, M., Meyer, R., Collins, S. C., Elverson, W., Friebert, A., Kabourek, J., Marchand, S. M., McWilliam, V., & Netting, M. (2021). Dietary management of food allergy. *Immunology and Allergy Clinics, 41*(2), 233–270.

EFSA, P. (2013). Panel (EFSA Panel on Plant Protection Products and their Residues), 2013. Guidance on tiered risk assessment for plant protection products for aquatic organisms in edge-of-field surface waters. *EFSA Journal, 11*(7), 3290.

EFSA. (2021). Bisphenol A: Draft opinion proposes lowering the tolerable daily intake | EFSA. Available online. https://www.efsa.europa.eu/en/news/bisphenol-efsa-draft-opinion-proposes-lowering-tolerable-daily-intake. (Accessed 4 March 2023).

Enault, J., Robert, S., Schlosser, O., de Thé, C., & Loret, J.-F. (2015). Drinking water, diet, indoor air: Comparison of the contribution to environmental micropollutants exposure. *International Journal of Hygiene and Environmental Health, 218*(8), 723–730.

Esmaillzadeh, A., Kimiagar, M., Mehrabi, Y., Azadbakht, L., Hu, F. B., & Willett, W. C. (2007). Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *American Journal of Clinical Nutrition, 85*(3), 910–918.

Gallo, M., Ferrara, L., Calogero, A., Montesano, D., & Naviglio, D. (2020). Relationships between food and diseases: What to know to ensure food safety. *Food Research International, 137*, 109414.

Genchi, G., Sinicropi, M. S., Carocci, A., Lauria, G., & Catalano, A. (2017). Mercury exposure and heart diseases. *International Journal of Environmental Research and Public Health, 14*(1), 74.

Gong, Y. Y., Watson, S., & Routledge, M. N. (2016). Aflatoxin exposure and associated human health effects, a review of epidemiological studies. *Food safety, 4*(1), 14–27.

Guimarães, J. R., Ikingura, J., & Akagi, H. (2000). Methyl mercury production and distribution in river water-sediment systems investigated through radiochemical techniques. *Water, Air, and Soil Pollution, 124*(1), 113–124.

Hassan, A., Fauziah, S. H., Pariatamby, A., Nurul Shamsinah, M. S., Noor Maiza binti, M. R., Kimberly, N. H. L., & Mohan, P. (2023). Bioaugmentation-assisted bioremediation and biodegradation mechanisms for PCB in contaminated environments: A review on sustainable clean-up technologies. *Journal of Environmental Chemical Engineering, 11*, 3, 10.1016/j.jece.2023.110055.

Herbstman, J. B., Sjödin, A., Kurzon, M., Lederman, S. A., Jones, R. S., Rauh, V., Needham, L. L., Tang, D., Niedzwiecki, M., & Wang, R. Y. (2010). Prenatal exposure to PBDEs and neurodevelopment. *Environmental Health Perspectives, 118*(5), 712–719.

Hiramoto, S., Itoh, K., Shizuuchi, S., Kawachi, Y., Morishita, Y., Nagase, M., & Kimura, N. (2004). Melanoidin, a food protein-derived advanced Maillard reaction product, suppresses Helicobacter pylori in vitro and in vivo. *Helicobacter, 9*(5), 429–435. https://doi.org/10.1111/j.1083-4389.2004.00263.x

Hird, S. J., Lau, B. P. Y., Schuhmacher, R., & Krska, R. (2014). Liquid chromatography-mass spectrometry for the determination of chemical contaminants in food. *TrAC, Trends in Analytical Chemistry, 59*, 59–72.

Hodge, J. E. (1953). Dehydrated foods, chemistry of browning reactions in model systems. *Journal of Agricultural and Food Chemistry, 1*(15), 928–943.

Ingelfinger, J. R. (2008). Melamine and the global implications of food contamination. *New England Journal of Medicine, 359*(26), 2745–2748.

Jedrychowski, W. A., Perera, F. P., Camann, D., Spengler, J., Butscher, M., Mroz, E., Majewska, R., Flak, E., Jacek, R., & Sowa, A. (2015). Prenatal exposure to polycyclic aromatic hydrocarbons and cognitive dysfunction in children. *Environmental Science and Pollution Research, 22*(5), 3631–3639.

Kaiser, M. L., Williams, M. L., Basta, N., Hand, M., & Huber, S. (2015). When vacant lots become urban gardens: Characterizing the perceived and actual food safety concerns of urban agriculture in Ohio. *Journal of Food Protection, 78*(11), 2070–2080.

Kamboj, S., Gupta, N., Bandral, J. D., Gandotra, G., & Anjum, N. (2020). Food safety and hygiene: A review. *International journal of chemical studies, 8*(2), 358–368.

Karagas, M. R., Choi, A. L., Oken, E., Horvat, M., Schoeny, R., Kamai, E., Cowell, W., Grandjean, P., & Korrick, S. (2012). Evidence on the human health effects of low-level methylmercury exposure. *Environmental Health Perspectives, 120*(6), 799–806.

Katare, Y., Singh, P., Sankhla, M. S., Singhal, M., Jadhav, E. B., Parihar, K., & Bhardwaj, L. (2021). Microplastics in aquatic environments: Sources, ecotoxicity, detection & remediation. *Biointerface Res. Appl. Chem, 12*, 3407–3428.

Kennedy, S. P. (2021). *History of food fraud and development of mitigation requirements and standards*. Food Fraud Elsevier.

Khan, A. S., Swerdlow, D. L., & Juranek, D. D. (2001). Precautions against biological and chemical terrorism directed at food and water supplies. *Public Health Reports, 116*(1), 3.

Khlifa, K. H., Ghali, R., Mazigh, C., Aouni, Z., Machgoul, S., & Hedhili, A. (2012). Ochratoxin A levels in human serum and foods from nephropathy patients in Tunisia: Where are you now? *Experimental & Toxicologic Pathology, 64*(5), 509–512.

Kim, B., Perkins, L. B., Bushway, R. J., Nesbit, S., Fan, T., Sheridan, R., & Greene, V. (2008). Determination of melamine in pet food by enzyme immunoassay, high-performance liquid chromatography with diode array detection, and ultra-performance liquid chromatography with tandem mass spectrometry. *Journal of AOAC International, 91*(2), 408–413.

King, T., Cole, M., Farber, J. M., Eisenbrand, G., Zabaras, D., Fox, E. M., & Hill, J. P. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. *Trends in Food Science & Technology, 68*, 160–175.

Kirk, A. B., Dyke, J. V., Martin, C. F., & Dasgupta, P. K. (2007). Temporal patterns in perchlorate, thiocyanate, and iodide excretion in human milk. *Environmental Health Perspectives, 115*(2), 182–186.

Klimczak, M., Liu, G., Awyn, R., Fernandes, Kilanowicz, A., & Falandysz, J. (2023). An updated global overview of the manufacture and unintentional formation of polychlorinated naphthalenes (PCNs). *Journal of Hazardous Materials, 457*. https://doi.org/10.1016/j.jhazmat.2023.131786

Knecht, K. J., Dunn, J. A., McFarland, K. F., McCance, D. R., Lyons, T. J., Thorpe, S. R., & Baynes, J. W. (1991). Effect of diabetes and aging on carboxymethyllysine levels in human urine. *Diabetes, 40*(2), 190–196.

Knox, P., & Mayer, H. (2013). *Small town sustainability, small town SustainabilityBirkhäuser*.

Kowalska, A., & Manning, L. (2022). Food safety governance and guardianship: The role of the private sector in addressing the EU ethylene oxide incident. *Foods, 11*(2), 204.

Kwon, J. H., Kim, J. W., Pham, T. D., Tarafdar, A., Hong, S., Chun, S. H., Lee, S. H., Kang, D. Y., Kim, J. Y., Kim, S. B., & Jung, J. (2020). Microplastics in food: A review on analytical methods and challenges. *International Journal of Environmental Research and Public Health, 17*(18), 6710. https://doi.org/10.3390/ijerph17186710

Lebelo, K., Malebo, N., Mochane, M. J., & Masinde, M. (2021). Chemical contamination pathways and the food safety implications along the various stages of food production: A review. *International Journal of Environmental Research and Public Health, 18*(11), 5795.

Leung, A. M., Pearce, E. N., & Braverman, L. E. (2014). Environmental perchlorate exposure: Potential adverse thyroid effects. *Current Opinion in Endocrinology Diabetes and Obesity, 21*(5), 372–376.

Li, L., He, Z., Shi, Y., Sun, H., Yuan, B., Cai, J., Chen, J., & Long, M. (2023). *Role of epigenetics in mycotoxin toxicity: A review, environmental Toxicology and pharmacology* (Vol. 100). https://doi.org/10.1016/j.etap.2023.104154

Lipp, M., & Chase, C. G. (2015). Chemical contaminants in foods: Health risks and public perception. *Food Technology, 69*(11), 43–48.

Lowe, K., & McLaughlin, E. (2015). 'Caution! The bread is poisoned': The Hong Kong mass poisoning of january 1857. *Journal of Imperial and Commonwealth History, 43*(2), 189–209.

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A. J., Jenkins, A., Ferrier, R. C., Li, H., & Luo, W. (2015). Impacts of soil and water pollution on food safety and health risks in China. *Environment International, 77*, 5–15.

Lynch, M. L., Huang, L.-S., Cox, C., Strain, J., Myers, G. J., Bonham, M. P., Shamlaye, C. F., Stokes-Riner, A., Wallace, J. M., & Duffy, E. M. (2011). Varying coefficient function models to explore interactions between maternal nutritional status and prenatal methylmercury toxicity in the Seychelles Child Development Nutrition Study. *Environmental Research, 111*(1), 75–80.

Main, K. M., Mortensen, G. K., Kaleva, M. M., Boisen, K. A., Damgaard, I. N., Chellakooty, M., Schmidt, I. M., Suomi, A.-M., Virtanen, H. E., & Petersen, J. H. (2006). Human breast milk contamination with phthalates and alterations of endogenous reproductive hormones in infants three months of age. *Environmental Health Perspectives, 114*(2), 270–276.

Markus, L. (2015). *Chemical contaminants in foods: Health risks and public perception*.

Martin, A., & Beutin, L. (2011). Characteristics of Shiga toxin-producing Escherichia coli from meat and milk products of different origins and association with food producing animals as main contamination sources. *International Journal of Food Microbiology, 146*(1), 99–104.

Mastrorilli, C., Cardinale, F., Giannetti, A., & Caffarelli, C. (2019). Pollen-food allergy syndrome: A not so rare disease in childhood. *Medicina, 55*(10), 641.

Meadows, M. (2004). The FDA and the fight against terrorism. *FDA Consum Mag [serial online], 38*(4).

Meng, J., Sakata, N., Takebayashi, S., Asano, T., Futata, T., Nagai, R., & Taniguchi, N. (1998). Glycoxidation in aortic collagen from STZ-induced diabetic rats and its relevance to vascular damage. *Atherosclerosis, 136*(2), 355–365.

Mickelbart, M. V., Hasegawa, P. M., & Bailey-Serres, J. (2015). Genetic mechanisms of abiotic stress tolerance that translate to crop yield stability. *Nature Reviews Genetics, 16*(4), 237–251.

Mihai, F.-C., Gündoğdu, S., Markley, L. A., Olivelli, A., Khan, F. R., Gwinnett, C., Gutberlet, J., Reyna-Bensusan, N., Llanquileo-Melgarejo, P., & Meidiana, C. (2021). Plastic pollution, waste management issues, and circular economy opportunities in rural communities. *Sustainability, 14*(1), 20.

Montet, D., & Dey, G. (2018). History of food traceability. *Food Traceability and Authenticity*, 1–30.

EFSA Scientific Committee, More, S. J., Bampidis, V., Benford, D., Bennekou, S. H., Bragard, C., Halldorsson, T. I., Hernández-Jerez, A. F., Koutsoumanis, K., Naegeli, H., Schlatter, J. R., Silano, V., Nielsen, S. S., Schrenk, D., Turck, D., Younes, M., Benfenati, E., Castle, L., Cedergreen, N., Hardy, A., Laskowski, R., Leblanc, J. C., Kortenkamp, A., Ragas, A., Posthuma, L., Svendsen, C., Solecki, R., Testai, E., Dujardin, B., Kass, G. E. N., Manini, P., Jeddi, M. Z., Dorne, J.-L. C. M., & Hogstrand, C. (2019). Guidance on harmonised methodologies for human health, animal health and ecological risk assessment of combined exposure to multiple chemicals. *EFSA Journal, 17*(3), 77. https://doi.org/10.2903/j.efsa.2019.5634, 2019. 5634.

Morse, T. D., Masuku, H., Rippon, S., & Kubwalo, H. (2018). Achieving an integrated approach to food safety and hygiene—meeting the sustainable development goals in sub-saharan Africa. *Sustainability, 10*(7), 2394.

Nandwani, D., & Nwosisi, S. (2016). *Global trends in organic agriculture, Organic farming for sustainable agricultureSpringer*.

Nassar, N., Abeywardana, P., Barker, A., & Bower, C. (2010). Parental occupational exposure to potential endocrine disrupting chemicals and risk of hypospadias in infants. *Occupational and Environmental Medicine, 67*(9), 585–589.

Natella, F., Nardini, M., Giannetti, I., Dattilo, C., & Scaccini, C. (2002). Coffee drinking influences plasma antioxidant capacity in humans. *Journal of Agricultural and Food Chemistry, 50*(21), 6211–6216.

Nayak, R., Manning, L., & Waterson, P. (2022). Exploration of the fipronil in egg contamination incident in The Netherlands using the Functional Resonance Analysis Method. *Food Control, 133*, 108605.

Nelms, S. E., Galloway, T. S., Godley, B. J., Jarvis, D. S., & Lindeque, P. K. (2018). Investigating microplastic trophic transfer in marine top predators. *Environmental Pollution, 238*, 999–1007.

Nerín, C., Aznar, M., & Carrizo, D. (2016). Food contamination during food process. *Trends in Food Science & Technology, 48*, 63–68.

Nerin, C., Silva, F., Manso, S., & Becerril, R. (2016). *The downside of antimicrobial packaging: Migration of packaging elements into food*. Antimicrobial food packagingElsevier.

Ng, S., Shao, S., & Ling, N. (2022). Food safety risk-assessment systems utilized by China, Australia/New Zealand, Canada, and the United States. *Journal of Food Science, 87*(11), 4780–4795.

Omerović, N., Djisalov, M., Živojević, K., Mladenović, M., Vunduk, J., Milenković, I., & Vidić, J. (2021). Antimicrobial nanoparticles and biodegradable polymer composites for active food packaging applications. *Comprehensive Reviews in Food Science and Food Safety, 20*(3), 2428–2454.

Onyimba, F., Crowe, S. E., Johnson, S., & Leung, J. (2021). Food allergies and intolerances: A clinical approach to the diagnosis and management of adverse reactions to food. *Clinical Gastroenterology and Hepatology, 19*(11), 2230–2240. e1.

Park, J., Chang, H., Hong, S., Kim, D., Chung, S., & Lee, C. (2017). A decrease of incidence cases of fumonisins in south Korean feedstuff between 2011 and 2016. *Toxins, 9*(9), 286.

Patterson, J., Donald, G., Wong, L.-Y., Turner, W. E., Caudill, S. P., DiPietro, E. S., McClure, P. C., Cash, T. P., Osterloh, J. D., Pirkle, J. L., & Sampson, E. J. (2009). Levels in the US population of those persistent organic pollutants (2003− 2004) included in the Stockholm Convention or in other long-range transboundary air pollution agreements. *Environmental Science & Technology, 43*(4), 1211–1218.

Perez-Torrado, R., Querol, A., & Guillamón, J. M. (2015). Genetic improvement of non-GMO wine yeasts: Strategies, advantages and safety. *Trends in Food Science & Technology, 45*(1), 1–11.

Perkins, A. (2021). *Life and death rays*. Radioactive Poisoning and Radiation ExposureCRC Press.

Peteva, Z., Krock, B., Georgieva, S., & Stancheva, M. (2018). Occurrence and variability of marine biotoxins in mussel (mytillus galloprovincialis) and in plankton samples from Bulgarian coast in spring 2017. *International Journal of Agriculture & Environmental Science, 5*(4), 1–11.

Phillips, T. (2008). Genetically modified organisms (GMOs): Transgenic crops and recombinant DNA technology. *Nature Education, 1*(1), 213.

Rather, I. A., Koh, W. Y., Paek, W. K., & Lim, J. (2017). The sources of chemical contaminants in food and their health implications. *Frontiers in Pharmacology, 8*, 830.

Robert, H., Payros, D., Pinton, P., Theodorou, V., Mercier-Bonin, M., & Oswald, I. P. (2017). Impact of mycotoxins on the intestine: Are mucus and microbiota new targets? *Journal of Toxicology and Environmental Health, Part A B, 20*(5), 249–275.

Roccato, A., Uyttendaele, M., Cibin, V., Barrucci, F., Cappa, V., Zavagnin, P., Longo, A., & Ricci, A. (2015). Survival of Salmonella Typhimurium in poultry-based meat preparations during grilling, frying and baking. *International Journal of Food Microbiology, 197*, 1–8.

Rose, M., Bennett, D. H., Bergman, Å., Fangstrom, B., Pessah, I. N., & Hertz-Picciotto, I. (2010). PBDEs in 2− 5 year-old children from California and associations with diet and indoor environment. *Environmental Science & Technology, 44*(7), 2648–2653.

Salter, S. J. (2014). The food-borne identity. *Nature Reviews Microbiology, 12*(8), 533, 533.

Samir, A., Ashour, F. H., Hakim, A. A. A., et al. (2022). Recent advances in biodegradable polymers for sustainable applications. *Npj Mater Degrad, 6*, 68. https://doi.org/10.1038/s41529-022-00277-7

Savelli, C. J., Bradshaw, A., Ben Embarek, P., & Mateus, C. (2019). The FAO/WHO international food safety authorities network in review, 2004–2018: Learning from the past and looking to the future. *Foodborne pathogens and disease, 16*(7), 480–488.

Schantz, S. L., Widholm, J. J., & Rice, D. C. (2003). Effects of PCB exposure on neuropsychological function in children. *Environmental Health Perspectives, 111*(3), 357–576.

Schecter, A., Colacino, J., Patel, K., Kannan, K., Yun, S. H., Haffner, D., Harris, T. R., & Birnbaum, L. (2010). Polybrominated diphenyl ether levels in foodstuffs collected from three locations from the United States. *Toxicology and Applied Pharmacology, 243*(2), 217–224.

Schreier, V. N., Çörek, E., Appenzeller-Herzog, C., Brüschweiler, B. J., Geueke, B., Wilks, M. F., & Odermatt, A. (2023). Evaluating the food safety and risk assessment evidence-base of polyethylene terephthalate oligomers: A systematic evidence map. *Environment International, 176*, 107978.

Schussler, E., Sobel, J., Hsu, J., Yu, P., Meaney-Delman, D., Grammer, L. C., III, & Nowak-Węgrzyn, A. (2018). Workgroup report by the joint task force involving American academy of allergy, asthma & immunology (AAAAI); food allergy, anaphylaxis, dermatology and drug allergy (FADDA)(Adverse reactions to foods committee and adverse reactions to drugs, biologicals, and latex committee); and the Centers for disease control and prevention botulism clinical treatment guidelines workgroup—allergic reactions to botulinum antitoxin: A systematic review. *Clinical Infectious Diseases, 66*(suppl_1), S65–S72.

Segalla, S. (2020). *Empire and catastrophe: Decolonization and environmental disaster in north africa and mediterranean France since 1954*.

Shabani, E., Zareei, A., & Muhammadi, R. (2022). Biological weapons and their functions in the middle ages of Iran. *The International Journal of Humanities, 29*(1), 1–23.

Shirafkan, H., Abolghasemi, M., Esmaeilzadeh, S., Golsorkhtabaramiri, M., & Mirabi, P. (2023). Polychlorinated biphenyls and the risk of endometriosis: Systematic review and meta-analysis. *Journal of Gynecology Obstetrics and Human Reproduction, 52*(5). https://doi.org/10.1016/j.jogoh.2023.102574

Sitaraman, R., & Rao, G. (2019). A pediatric case of accidental eucalyptus oil poisoning from New Delhi, India: Emergency measures, historical context, and implications for practice. *Cureus, 11*(9).

Smedley, P. L., & Kinniburgh, D. G. (2002). A review of the source, behaviour and distribution of arsenic in natural waters. *Applied Geochemistry, 17*(5), 517–568.

Sobel, J., Khan, A. S., & Swerdlow, D. L. (2002). Threat of a biological terrorist attack on the US food supply: The CDC perspective. *The Lancet, 359*(9309), 874–880.

Song, Q., Zheng, Y.-J., Xue, Y., Sheng, W.-G., & Zhao, M.-R. (2017). An evolutionary deep neural network for predicting morbidity of gastrointestinal infections by food contamination. *Neurocomputing, 226*, 16–22.

Spink, J., & Moyer, D. C. (2011). Defining the public health threat of food fraud. *Journal of Food Science, 76*(9), R157–R163.

Swan, S. H. (2008). Environmental phthalate exposure in relation to reproductive outcomes and other health endpoints in humans. *Environmental Research, 108*(2), 177–184.

Tamanna, N., & Mahmood, N. (2015). Food processing and maillard reaction products: Effect on human health and nutrition. *International journal of food science, 2015*.

Tareke, E., Rydberg, P., Karlsson, P., Eriksson, S., & Törnqvist, M. (2000). Acrylamide: A cooking carcinogen? *Chemical Research in Toxicology, 13*(6), 517–522. https://doi.org/10.1021/tx9901938

The Royal Society. (2016). What GM crops are currently being grown and where?, 2016. Available online. https://royalsociety.org/topics-policy/projects/gm-plants/what-gm-crops-are-currently-being-grown-and-where/#:~:text=The%20USA%2C%20Brazil%20and%20Argentina,are%20carrying%20out%20controlled%20trials.

Thompson, L. A., & Darwish, W. S. (2019). *Environmental chemical contaminants in food: Review of a global problem. Journal of toxicology, 2019*.

Thompson, L. A., Darwish, W. S., Ikenaka, Y., Nakayama, S. M., Mizukawa, H., & Ishizuka, M. (2017). Organochlorine pesticide contamination of foods in africa: Incidence and public health significance. *Journal of Veterinary Medical Science*, 16–214.

Tirima, S., Bartrem, C., von Lindern, I., von Braun, M., Lind, D., Anka, S. M., & Abdullahi, A. (2018). Food contamination as a pathway for lead exposure in children during the 2010–2013 lead poisoning epidemic in Zamfara, Nigeria. *Journal of Environmental Sciences, 67*, 260–272.

Tsochatzis, E. D., & Begou, O. (2022). Analysis of contaminants and residues in food. *Applied Sciences, 12*(19), 10076.

Tsochatzis, E. D., Lopes, J. A., & Corredig, M. (2022). Chemical testing of mechanically recycled polyethylene terephthalate for food packaging in the European Union. *Resources, Conservation and Recycling, 179*, 106096.

Tsochatzis, E. D., Lopes, J. A., Gika, H., Dalsgaard, T. K., & Theodoridis, G. (2021). Development and validation of an UHPLC-qTOF-MS method for the quantification of cyclic polyesters oligomers in pasta by applying a modified QuEChERS clean-up. *Food Chemistry, 347*, 129040.

Tuladhar, E., Hazeleger, W. C., Koopmans, M., Zwietering, M. H., Beumer, R. R., & Duizer, E. (2012). Residual viral and bacterial contamination of surfaces after cleaning and disinfection. *Applied and Environmental Microbiology, 78*(21), 7769–7775.

Turnbull, J., Adams, H., & Gorard, D. (2015). The diagnosis and management of food allergy and food intolerances. *Alimentary Pharmacology and Therapeutics, 41*(1), 3–25.

Udovicki, B., Andjelkovic, M., Cirkovic-Velickovic, T., & Andreja, R. (2022). Microplastics in food: Scoping review on health effects, occurrence, and human exposure. *Food Contamination, 9*, 7. https://doi.org/10.1186/s40550-022-00093-6

Umapathi, R., Park, B., Sonwal, S., Rani, G. M., Cho, Y., & Huh, Y. S. (2022). Advances in optical-sensing strategies for the on-site detection of pesticides in agricultural foods. *Trends in Food Science & Technology, 119*, 69–89.

United Nations. (2023). Chemicals and waste available. https://sdgs.un.org/topics/chemicals-and-waste. (Accessed 4 March 2023).

U.S Department for Agriculture. (2021). *Butterball, LLC recalls ground Turkey products due to possible foreign matter contamination*.

US Food and Drug Administration (FDA). (2021). Bisphenol A (BPA): Use in food contact application. Retrieved from https://www.fda.gov/food/food-additives-petitions/bisphenol-bpa-use-food-contact-application.

U.S. Fda. (2020). GMO crops, animal food, and beyond., 2020. Available online. https://www.fda.gov/food/agricultural-biotechnology/gmo-crops-animal-food-and-beyond.

Vail, T. M., Jones, P. R., & Sparkman, O. D. (2007). Rapid and unambiguous identification of melamine in contaminated pet food based on mass spectrometry with four degrees of confirmation. *Journal of Analytical Toxicology, 31*(6), 304–312.

Vanga, S. K., Jain, M., & Raghavan, V. (2018). Significance of fruit and vegetable allergens: Possibilities of its reduction through processing. *Food Reviews International, 34*(2), 103–125.

Villanueva, C. M., Gracia-Lavedan, E., Julvez, J., Santa-Marina, L., Lertxundi, N., Ibarluzea, J., Llop, S., Ballester, F., Fernández-Somoano, A., & Tardón, A. (2018). Drinking water disinfection by-products during pregnancy and child neuropsychological development in the INMA Spanish cohort study. *Environment International, 110*, 113–122.

Wahidin, D., & Purnhagen, K. (2018). Improving the level of food safety and market access in developing countries. *Heliyon, 4*(7), Article e00683.

Wang, X., Wang, C., Zhu, T., Gong, P., Fu, J., & Cong, Z. (2019). Persistent organic pollutants in the polar regions and the Tibetan plateau: A review of current knowledge and future prospects. *Environmental Pollution, 248*, 191–208.

Wang, L., & Zhang, L. (2011). *Study on pork crisis from the perspective of crisis management, 2011 third international conference on multimedia information networking and security*. IEEE.

Wiedenfeld, H. (2011). Toxicity of pyrrolizidine alkaloids-a serious health problem. *Clinical and Experimental Health Sciences, 1*(2), 79.

Wigle, D. T., Arbuckle, T. E., Turner, M. C., Bérubé, A., Yang, Q., Liu, S., & Krewski, D. (2008). Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. *Journal of Toxicology and Environmental Health, Part A B, 11*(5–6), 373–517.

World Health Organization. (2020). *Meeting report: The second global meeting of the FAO/WHO international food safety authorities network (INFOSAN)* (pp. 9–11). Abu Dhabi: United Arab Emirates. December 2019.

Yabe, J., Nakayama, S. M., Ikenaka, Y., Yohannes, Y. B., Bortey-Sam, N., Oroszlany, B., Muzandu, K., Choongo, K., Kabalo, A. N., & Ntapisha, J. (2015). Lead poisoning in children from townships in the vicinity of a lead–zinc mine in Kabwe, Zambia. *Chemosphere, 119*, 941–947.

Yuan, Y., Gao, R., Liang, Q., Song, L., Huang, J., Lang, N., & Zhou, J. (2020). A foodborne bongkrekic acid poisoning incident—heilongjiang province, 2020. *China CDC Weekly, 2*(51), 975.

Zeidan, R., Ul-Hassan, Z., Al-Thani, R., Balmas, V., & Jaoua, S. (2018). Application of low-fermenting yeast Lachancea thermotolerans for the control of toxigenic fungi Aspergillus parasiticus, Penicillium verrucosum and Fusarium graminearum and their mycotoxins. *Toxins, 10*(6), 242.

Zhao, Q., Wang, Y., Cao, Y., Chen, A., Ren, M., Ge, Y., Yu, Z., Wan, S., Hu, A., & Bo, Q. (2014). Potential health risks of heavy metals in cultivated topsoil and grain, including correlations with human primary liver, lung and gastric cancer, in Anhui province, Eastern China. *Science of the Total Environment, 470*, 340–347.

Zhao, X., Wang, Y., Chen, X., Yu, X., Li, W., Zhang, S., & Zhu, H. (2023). Sustainable bioplastics derived from renewable natural resources for food packaging. *Matter, 6*(1), 97–127.