Chapter I: Chemical hazards

Introduction

Chemical contamination refers to the presence of chemical substances in food that may cause adverse health effects when ingested. These substances may occur naturally in food or be introduced during agricultural production, animal breeding, food processing, preparation, storage or handling. Several chemical substances may coexist within the same food matrix. Their combined effects may be additive, synergistic or antagonistic, potentially modifying their overall toxicological impact.

1. Products added to or generated in foods

1.1. Potentially carcinogenic compounds formed during cooking

Some chemical contaminants may be generated during food preparation, particularly during high-temperature cooking, prolonged heating, direct exposure to flames or contact with smoke.
Their formation depends on the composition of the food, cooking temperature, cooking time and processing conditions. The main examples include:

1.1.1. Acrylamide

Acrylamide is a chemical compound that may form in starch-rich foods during high-temperature cooking, generally above 120 °C, particularly under relatively dry conditions. It is mainly produced through the Maillard reaction involving the amino acid asparagine and reducing sugars.
It may be found in fried potatoes, potato crisps, bread, biscuits and other bakery products.

1.1.2. Polycyclic aromatic hydrocarbons (PAHs)

PAHs are a large group of chemical compounds formed during the incomplete combustion of organic materials. In food, they may be generated during charcoal or wood grilling, smoking and smoke-drying. They may also contaminate food when fat drips onto hot coals or flames, producing smoke that deposits on the food surface.
Grilled and smoked meat and fish are common sources of dietary exposure.

1.1.3. Heterocyclic aromatic amines (HAAs)

They are chemical compounds formed mainly when meat, poultry or fish are cooked at high temperatures, particularly during prolonged grilling, frying or roasting.
Their formation results from chemical reactions involving amino acids, sugars and creatine or creatinine naturally present in muscle foods.

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1.2. Food additives

Food additives are substances intentionally added to food in small quantities to perform specific technological functions, such as preservation, colouring, flavour enhancement, sweetening or texture improvement. Their use is regulated, and only authorized additives may be used in specified food categories and within established maximum levels.

However, food additives may represent a chemical hazard when they are used in excessive quantities, in unauthorized foods or in violation of regulatory requirements.

2. Veterinary drug residues

Veterinary drug residues are substances or their metabolites that may remain in food-producing animals or in products of animal origin following the administration of veterinary medicines.

These residues may be present in meat, milk, eggs, fish and other products of animal origin when medicines are incorrectly used, administered at inappropriate doses or when withdrawal periods are not respected.

2.1. Anabolic agents (hormones)

Anabolic agents are substances that promote tissue growth. Their use in food-producing animals is strictly regulated and, in some jurisdictions, prohibited for growth promotion.

Potential health concerns associated with exposure to unauthorized or excessive residues include endocrine disturbances, reproductive effects and developmental disorders. Some hormonal substances may also have carcinogenic potential.

2.2. Antibiotic residues

When administered to food-producing animals, residues of antibiotics or its metabolites may remain in edible tissues, milk and eggs. Residues may occur when antibiotics are used without respecting the prescribed dose, duration of treatment or withdrawal period.

Potential health effects include allergic reactions, toxicity and microbiota disturption. Another major concern is antimicrobial resistance.

2.3. Antiparasitic residues

Antiparasitic drugs are used in veterinary medicine to prevent or treat parasitic infections caused by internal or external parasites.

Residues may persist in animal tissues, milk or eggs following treatment. Their presence may result from incorrect administration, excessive doses or failure to respect the withdrawal period.

Depending on the molecule and level of exposure, residues may cause toxic effects, including neurological, hepatic or gastrointestinal disturbances.

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2.4. Tranquilizer residues

Tranquilizers and sedative drugs are substances used in veterinary medicine to reduce anxiety, agitation or excessive activity in animals. Their use in food-producing animals is subject to strict regulatory requirements.

Residues may remain in edible tissues or other animal products if these substances are misused or if the required withdrawal period is not respected.

Depending on the substance, exposure may produce effects on the central nervous system, including sedation, drowsiness, impaired coordination and other neurological disturbances.

3. Industrial or agricultural pollutants

Industrial and agricultural pollutants are chemical contaminants introduced into the food chain through environmental pollution, agricultural activities, industrial processes or inadequate cleaning and sanitation practices.

They may contaminate food directly or indirectly through soil, water, air, raw materials, food-contact surfaces and production equipment.

3.1. Detergents and disinfectants (biocides)

Detergents and disinfectants are chemical products used in food industries to maintain cleanliness and control microbial contamination.

- Detergents are used to remove organic and inorganic residues, grease and other impurities from surfaces and equipment.
- Disinfectants are used to reduce or eliminate microorganisms on previously cleaned surfaces.

Food contamination may occur when these products are incorrectly stored, improperly diluted, accidentally mixed with food or insufficiently rinsed from food-contact surfaces when rinsing is required.

Exposure to detergent or disinfectant residues may cause irritation of the digestive tract, chemical burns or systemic toxic effects, depending on the product and the quantity ingested.

3.2. Nitrates, nitrites and nitrosamines

Nitrates and nitrites are nitrogen-containing compounds that may occur naturally in the environment and in foods. Nitrates are particularly present in vegetables because plants absorb them from the soil.

They may also enter the food chain through agricultural fertilizers, contaminated water and certain food-processing practices.

Nitrates can be converted into nitrites through microbial activity. Nitrites may then react with secondary amines under favourable conditions to form N-nitroso compounds, including nitrosamines. Nitrate → Nitrite → Nitrosamines

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Some nitrosamines have carcinogenic properties and may be formed during food processing, storage or digestion under specific conditions.

Nitrites are also used in cured meat products because they inhibit *Clostridium botulinum* and contribute to colour and flavour stability.

However, excessive nitrite exposure may cause methemoglobinemia, particularly in infants, by oxidizing haemoglobin into methemoglobin and reducing its oxygen-carrying capacity.

3.3. Heavy metals and metalloids

Heavy metals are metallic chemical elements that have a relatively high density. They are environmental contaminants that may enter the food chain through industrial activities, mining, atmospheric deposition, contaminated soil and water, and agricultural practices.

They are of particular concern because they are persistent, non-biodegradable and may accumulate in biological tissues.

3.3.1. Lead (Pb)

Food contamination may occur through polluted soil and water, industrial emissions and the use of contaminated equipment or food-contact materials.

The main target organs are the nervous system and the haematopoietic system. Lead exposure is particularly dangerous during pregnancy and childhood. Lead may cross the placental barrier and reach the developing fetus.

3.3.2. Mercury (Hg)

Mercury is an environmental contaminant that may be present in different chemical forms. Methylmercury is particularly important in food safety because it is highly toxic and can accumulate along aquatic food chains (bioaccumulation and biomagnification).

Methylmercury primarily affects the nervous system and is particularly harmful to fetal neurological development.

3.3.3. Cadmium (Cd)

Cadmium is released into the environment through industrial activities, mining, atmospheric emissions and the use of certain fertilizers.

It may accumulate in agricultural products, particularly cereals and leafy vegetables, and may also be found in shellfish and organ meats.

Chronic exposure to cadmium can damage the kidneys and bones. It is also classified as carcinogenic to humans.

3.3.4. Arsenic (As)

Arsenic is a metalloid that occurs naturally in the environment and may contaminate groundwater, particularly in certain geological regions. It may also be present in rice, fish and seafood. Its toxicity

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depends strongly on its chemical form, with inorganic arsenic generally being more toxic than most organic forms found in seafood.

Chronic exposure to inorganic arsenic may cause skin lesions and increase the risk of cancers, particularly of the skin, lungs and bladder.

3.4. Pesticides

Pesticides are chemical substances used in agriculture to prevent, destroy, repel or control organisms that are harmful to crops and stored agricultural products.

Their main objective is to protect crops, reduce agricultural losses and improve productivity.

3.4.1. Classificaton of pesticides

According to the target organism, pesticides are classified into:

- Insecticides: Used to control harmful insects.
- Acaricides: Used to control mites and ticks affecting crops.
- Nematicides: Used to control soil nematodes.
- Herbicides: Used to eliminate weeds.
- Fungicides: Used to control fungal diseases in plants.
- Rodenticides: Used to control rodents.

3.4.2. Pesticide residues in food

Following agricultural application, pesticides or their degradation products may remain on or inside food commodities. Food consumption is an important route of human exposure.

The level of residues depends on several factors, including the chemical nature of the pesticide, the applied dose, the application method, the number of treatments and compliance with the pre-harvest interval.

The pre-harvest interval is the minimum period that must elapse between the last pesticide application and the harvest. Respecting this interval helps ensure that residues remain within established Maximum Residue Limits (MRLs).

3.4.3. Health hazards associated with pesticides

Acute exposure to pesticides may cause nausea, vomiting, headaches, dizziness, abdominal pain and neurological disturbances. The severity depends on the pesticide involved and the quantity absorbed.

Chronic exposure may be associated with endocrine disruption, reproductive toxicity, neurotoxicity and an increased risk of certain cancers, depending on the substance and level of exposure.

3.5. Others polluants

Dioxins and polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs) that may contaminate the environment and enter the food chain.

Dr. S. NOUICHI

3.5.1. Dioxins

Dioxins are a group of toxic compounds that may be formed unintentionally during certain industrial and combustion processes, particularly when chlorine-containing materials are involved.

They are highly persistent in the environment and can accumulate in the fatty tissues of animals. Their presence in food is therefore particularly important in products of animal origin.

The main dietary sources include meat, fish, eggs, milk and dairy products, as well as animal fats.

Exposure to dioxins may affect the immune, reproductive and endocrine systems. Some dioxins are also classified as carcinogenic to humans.

3.5.2. Polychlorinated biphenyls (PCBs)

PCBs are synthetic industrial chemicals formerly used in electrical equipment, hydraulic systems and other industrial applications. Their production has been banned or severely restricted in many countries because of their persistence and toxicity.

They may remain in the environment for long periods and accumulate in the fatty tissues of animals. Foods of animal origin, particularly fatty fish, meat, eggs and dairy products, may be sources of human exposure.

PCBs may cause endocrine disruption, immune system effects, reproductive and developmental toxicity. Certain PCBs are classified as carcinogenic to humans.

Risk Factors

Several factors can influence the severity of foodborne chemical hazards. The main risk factors include:

- Characteristics of the chemical substance involved
- Dose
- Duration of exposure
- Age
- Health status and individual behavior
- Interactions with other substances
- Genetic factors

Toxicity assessment

Toxicity assessment addresses two fundamental questions:

- ✓ Identification of exposure sources, including food commodities acting as vectors, contamination levels, and the distribution of dietary intake within the general population.
- ✓ Establishment of a daily intake level that prevents the occurrence of adverse health effects.

These toxicological reference values are increasingly derived from dose–response modeling, which allows a more accurate characterization of the relationship between exposure and biological effects.

Dr. S. NOUICHI

- **No Observed Adverse Effect Level (NOAEL)**

It is defined as the highest dose of a substance at which no significant toxicological (adverse) effects are observed in the most sensitive tested species

- **ADI (Acceptable Daily Intake)**

The ADI is the estimated amount of a substance in food or drinking water that can be ingested daily over a lifetime without appreciable health risk.

The ADI is calculated from the NOAEL using uncertainty (safety) factors:

$$\text{ADI} = \frac{\text{NOAEL}}{100} \quad (\text{mg/kg body weight})$$

This factor of 100 includes:

- A factor of 10 for interspecies variability, assuming that humans may be up to ten times more sensitive than the most sensitive animal species tested.
- A factor of 10 for interspecies variability, accounting for differences in sensitivity among humans (e.g. children, pregnant women, elderly individuals).

The ADI is generally expressed in milligrams of substance per kilogram of body weight per day and applies to chemical substances such as food additives, pesticide residues, and veterinary drug residues.

The ADI concept does not apply to carcinogenic substances or compounds capable of inducing hypersensitivity reactions.

- **Withdrawal Period**

The withdrawal period is the minimum time required for residue levels to fall below the established Maximum Residue Limit (MRL). It is expressed as:

- Days or weeks (for pesticides),
- Days before slaughter (for food-producing animals),
- Number of milkings to be discarded (for dairy animals).

- **MRL (Maximum Residue Limit)**

The MRL is the maximum concentration of a residue resulting from the use of a pesticide in accordance with Good Agricultural Practices (GAP), as established by the Codex Alimentarius Commission.

It is expressed in milligrams of residue per kilogram of food commodity.

Dr. S. NOUICHI