



Mycotoxins in Romanian cereal crops: ecotoxicological risks, agroindustrial reality, and implications for public health

^{1,2}Onyekachi D. Nmeribe

¹ Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 400372 Cluj-Napoca, Romania; ² Abba Comprehensive Secondary School, Aba, Abia State, Nigeria, email: nmeribeonyekachi@gmail.com

Abstract. Mycotoxins are secondary fungal metabolites with high toxic potential, produced primarily by species of the genera *Aspergillus*, *Fusarium*, and *Penicillium*, and represent one of the most significant food safety challenges worldwide. In the Romanian context, where cereal production covers extensive areas and serves both domestic consumption and export within the European market, mycotoxin contamination — particularly aflatoxins, zearalenone, and deoxynivalenol — constitutes a documented ecotoxicological risk with direct consequences for human and animal health. This paper synthesizes current ecotoxicological knowledge on mycotoxins in cereals, contextualizes it within Romanian agro-industrial realities, examines published evidence on the occurrence and prevalence of mycotoxin contamination in Romanian cereal crops, and offers a critical appraisal of the gap between existing regulatory frameworks and their practical enforcement.

Keywords: mycotoxins, aflatoxins, zearalenone, cereals, Romania, food safety, ecotoxicology.

Introduction. Mycotoxins are organic chemical compounds produced by microscopic moulds as secondary metabolites under stress conditions (Saghir et al., 2025; Zadravec et al., 2022). The term derives from the Greek *mykes* (fungus) and the Latin *toxicum* (poison) (Shukla & Mishra, 2022). They are found on plant components or residues and enter the food chain through animal feed and agricultural crops, but are also produced and accumulate during transport or storage of fodder (Petrescu-Mag & Oroian, 2015).

The chemical structures of mycotoxins are highly varied, reflecting their production by multiple fungal species, and consumption of contaminated food is associated with both acute and chronic disease in humans and animals (Petrescu-Mag et al., 2025; Pojar & Bora, 2026).

The World Health Organization estimates that more than 25% of global crop harvests are contaminated with mycotoxins each year (WHO, 2018). Romania, as a major cereal producer — particularly of maize, wheat, and barley — faces structural vulnerabilities to this type of contamination, driven by a combination of climatic conditions conducive to fungal growth, inadequate storage infrastructure, and insufficient control across the entire supply chain (ANSVSA, 2022).

The aim of this paper is to synthesise current ecotoxicological knowledge on mycotoxins in cereals, to contextualise it within Romanian agro-industrial realities, and to identify regulatory and monitoring gaps that keep this risk at a level significant for public health. Specifically, the paper seeks to: (i) present the principal mycotoxins relevant to cereal crops and their toxicity mechanisms; (ii) describe factors that promote contamination in the Romanian context; (iii) analyse published evidence regarding mycotoxin occurrence and contamination patterns in Romanian cereal crops; and (iv) critically evaluate the regulatory framework and control practices.

Biology of Mycotoxin-Producing Fungi. Mycotoxins are produced, in general, by fungi of the genera *Penicillium*, *Aspergillus*, and *Fusarium*, under favourable conditions of temperature and humidity (Petrescu-Mag & Oroian, 2015). Each genus displays distinct ecological preferences that determine the predominant timing and location of contamination.

***Aspergillus* and aflatoxins.** *Aspergillus flavus* and *A. parasiticus* are the principal producers of aflatoxins. Aflatoxins are among the best-known and most toxic mycotoxins, capable of causing both acute and chronic toxicity in humans and animals. Acute toxicity has a rapid onset and is clinically visible, whereas chronic toxicity results from exposure to small doses over a prolonged period, with grave and generally irreversible effects. In humans, the greatest risk of aflatoxin exposure arises from chronic dietary exposure. Recent studies indicate that a very large number of deaths are caused by hepatocellular carcinoma, aggravated by the presence of hepatitis B virus and associated with aflatoxins in the diet (Petrescu-Mag & Oroian, 2015). The most important aflatoxins are B1, B2, G1, and G2. *Aspergillus spp.* proliferate optimally at temperatures of 25–35°C and water activity (a) above 0.85 — conditions that are becoming increasingly common in Romanian grain stores in the context of climate change (Magan et al., 2011). Aflatoxin contamination occurs predominantly in the field during drought periods, and intensifies during storage when grain moisture exceeds 14–15%.

***Fusarium* and trichothecene mycotoxins.** Species of *Fusarium* — particularly *F. graminearum* and *F. culmorum* — produce zearalenone (ZEA) and deoxynivalenol (DON, vomitoxin). These species tend to develop especially in cereals and are favoured by high humidity and low temperatures (Petrescu-Mag & Oroian, 2015). Zearalenone interferes with oestrogen metabolism in various animal species, resulting in disruption of reproductive function. *Fusarium spp.* infect wheat, barley, and maize during rainy periods around flowering, and DON can persist in flour produced by milling of infected grain.

***Penicillium* and ochratoxins.** Ochratoxins are secondary metabolites produced by moulds of the genera *Aspergillus* and *Penicillium*. Ochratoxin A (OTA) is the most toxic among them — both hepatotoxic and nephrotoxic, with documented effects in swine and poultry (Suharoschi, 2013; Petrescu-Mag & Oroian, 2015). OTA accumulates preferentially in cereals stored at high humidity and moderate temperatures (15–20°C), conditions that are frequently encountered in traditional Romanian storage facilities during autumn and winter.

Toxicity Mechanisms of the Principal Mycotoxins in Cereals. Each class of mycotoxin acts through distinct biochemical mechanisms with specific molecular targets. Understanding these mechanisms is essential for risk assessment and for prioritising control strategies.

Aflatoxin B1 — a Group 1 hepatocarcinogen. Aflatoxin B1 (AFB1) is the most potent known natural hepatic carcinogen, classified by IARC in Group 1 (definite human carcinogen). Metabolised by cytochrome P450 enzymes in the liver, AFB1 forms AFB1-8,9-epoxide — a reactive intermediate that binds covalently to guanine in DNA, causing point mutations in the TP53 tumour suppressor gene (codon 249). The long-term consequence is hepatocellular carcinoma, whose incidence is significantly amplified by coinfection with hepatitis B virus (Wild & Gong, 2010). Acute toxicity manifests as massive hepatic necrosis, coagulopathy, and multi-organ failure.

Zearalenone – an oestrogen-like endocrine disruptor. ZEA and its metabolites (alpha-zearalenol, beta-zearalenol) bind to oestrogen receptors ERalpha and ERbeta, mimicking the action of 17-beta-oestradiol. In animals, effects include hyperoestrogenism, reduced fertility, testicular atrophy, and disruption of the hypothalamic–pituitary–gonadal axis. In swine, chronic ZEA exposure produces vulvovaginitis and pseudopregnancy (EFSA, 2011). In humans, exposure through consumption of contaminated cereals is associated with precocious puberty and menstrual disorders, although direct epidemiological evidence remains limited.

Deoxynivalenol (DON) – a protein synthesis inhibitor. DON (vomitoxin) belongs to the type B trichothecene group and acts by inhibiting eukaryotic ribosomes, blocking protein synthesis. At the cellular level, it activates stress signalling pathways (MAPK), inducing apoptosis and intestinal inflammation. Chronic exposure compromises the integrity of the intestinal barrier, facilitating bacterial translocation and immunosuppression. Acute effects include vomiting, diarrhoea, and anorexia, hence the common name (Pestka, 2010). DON is the most frequently detected mycotoxin in Romanian wheat and barley, particularly in years with high rainfall during the flowering stage.

Ochratoxin A – a cumulative nephrotoxin. OTA inhibits phenylalanyl-tRNA synthetase, disrupting renal protein synthesis. It accumulates in the kidneys, producing nephropathy characterised by tubular atrophy and interstitial fibrosis. It is classified by IARC in Group 2B (possible human carcinogen) (IARC, 1993). The plasma half-life in humans is approximately 35 days, which promotes accumulation through repeated sub-lethal exposure – exactly the pattern characteristic of consumption of contaminated stored cereals (Table 1).

Table 1

Principal mycotoxins in cereal crops:
producing fungi, affected substrates, mechanism of action, and EU maximum limits

<i>Mycotoxin</i>	<i>Producing fungus</i>	<i>Affected cereals</i>	<i>Primary target organ</i>	<i>EU limit (µg/kg)</i>
Aflatoxin B1	<i>Aspergillus flavus, A. parasiticus</i>	Maize, peanuts, wheat (less common)	Liver (carcinogen)	2 (raw cereals) 0.1 (infant food)
Zearalenone (ZEA)	<i>Fusarium graminearum, F. culmorum</i>	Maize, wheat, barley	Endocrine system (oestrogen-like)	100 (durum wheat) 75 (milled maize)
Deoxynivalenol (DON)	<i>Fusarium graminearum, F. culmorum</i>	Wheat, barley, oats, maize	GI tract, immunity	1250 (raw cereals) 750 (wheat flour)
Ochratoxin A (OTA)	<i>Aspergillus ochraceus, Penicillium verrucosum</i>	Wheat, maize, stored barley	Kidneys (nephropathy)	3 (raw cereals)
Fumonisin B1+B2	<i>Fusarium verticillioides, F. proliferatum</i>	Maize and derivatives	Liver, lungs (pulmonary oedema)	4000 (unprocessed maize).

Sources: EC Regulation 1881/2006 and subsequent amendments; Petrescu-Mag & Oroian (2015); EFSA (2011); WHO (2018).

Risk Factors Specific to the Romanian Agro-Industrial Context. Romania is the fifth largest maize producer in the EU and one of the top ten wheat producers. Nevertheless, the Romanian cereal supply chain presents several structural vulnerabilities that may increase the risk of mycotoxin contamination, particularly under favourable climatic conditions (Figure 1, see also Tables 2 and 3).

Deficient storage infrastructure. A significant proportion of Romanian cereal production is stored in grain silos with an average age exceeding 40 years, lacking adequate systems for temperature and humidity control. National studies indicate that grain moisture at silo intake frequently exceeds the critical threshold of 14–15%, particularly in years with late harvesting or rainfall during the harvest period (Alexa et al., 2013). This creates optimal conditions for proliferation of *Aspergillus* spp. and AFB1 production in the first weeks of storage.

Climate change and northward expansion of *Aspergillus*. Climate projections forecast an increase in the frequency of drought episodes in southern and eastern Romania — the principal cereal-producing regions — combined with progressively warmer summers. European research shows that the aflatoxin-contamination risk zone is shifting northward at approximately 30–50 km per decade (Van der Fels-Klerx et al., 2012). Romania already sits within the intermediate-to-high risk zone for aflatoxins in maize, with documented exceedances of the EU limit in the Muntenia and Dobrogea regions (ANSVSA, 2022).

Agricultural practices and fungicide resistance. Improper use of fungicides — suboptimal doses, incorrect timing of application — contributes both to mycotoxin contamination and to the development of resistant fungal strains. Insufficient crop rotation, retention of infected plant residues on the soil, and the use of uncertified farm-saved seed are common practices on small farms, which account for a significant proportion of Romanian agricultural land.

Figure 1. Mycotoxin contamination pathways from field to consumer in the Romanian cereal supply chain. Arrows indicate the direction of fungal contaminant transfer at each stage.

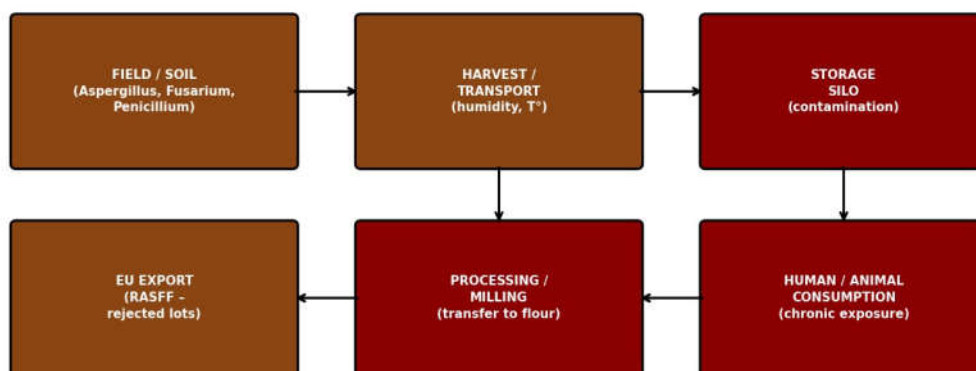


Figure 1. Mycotoxin contamination pathways from field to consumer in the Romanian cereal supply chain.

Evidence from Romanian Field Studies on Mycotoxin Contamination. Peer-reviewed field studies conducted across Romania provide the most reliable picture of the actual contamination burden in Romanian cereal crops. Figure 2 synthesises findings from key Romanian studies alongside a regional comparator from Serbia — a country sharing near-identical agro-climatic and agricultural conditions — to contextualise the scale of the problem.

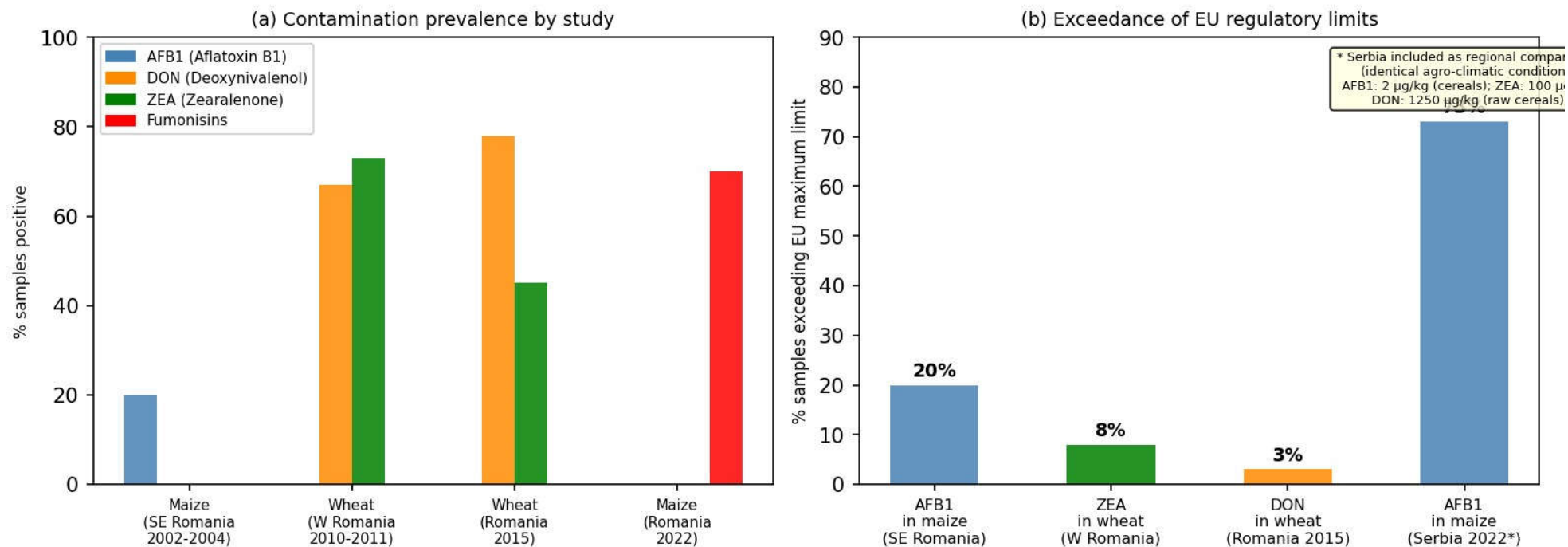


Figure 2. Mycotoxin contamination prevalence in Romanian cereal crops based on peer-reviewed field studies.

Panel (a) of Figure 2 reveals that contamination is pervasive across all major cereal types. DON is the most consistently detected mycotoxin, present in 46–67% of cereal samples depending on region and year, reflecting the prevalence of *Fusarium graminearum* in Romania's temperate climate. Zearalenone reaches particularly high detection rates in western Romanian wheat — over 73% of samples in studies from that region — consistent with the rainy conditions during the flowering stage that favour *Fusarium* development (Alexa et al., 2013). Fumonisin was identified in 70% of Romanian maize samples in a 2022 study, though concentrations mostly remained within legal limits.

Panel (b) places the regulatory exceedance rates in stark perspective. Already in southeastern Romania, 20% of maize samples contaminated with AFB1 exceeded EU limits even in studies from 2002–2004 — before the climate warming that has since amplified *Aspergillus* risk. The Serbian data from 2022 — 73% of maize samples exceeding the EU AFB1 limit, with peak concentrations reaching 527 µg/kg, or 105 times the legal maximum — is a direct indicator of what Romania likely experienced in the same drought year, given that the two countries share the same maize belt, the same climate, and the same storage infrastructure challenges. The absence of equivalent published Romanian data for 2022 is itself revealing: it points to a monitoring gap rather than an absence of contamination.

Table 2

Selected studies on mycotoxin contamination of Romanian cereal crops and health implications

Authors / Year	Cereal / Region	Mycotoxin	Main findings	Notes
Alexa et al., 2013	Maize / Muntenia	AFB1	15–30% of samples exceed EU limit (2 µg/kg) in drought years	Correlation with temperatures above 30°C in July–August
Marin et al., 2013	Wheat / Transylvania	DON, ZEA	DON detected in 78% of samples; ZEA in 45%; 12% exceed legal limits	Years with above-average rainfall at flowering stage
Bulgaru et al., 2025	Maize / Moldova	Fumonisin B1+B2	Mean concentrations 1800–3200 µg/kg; max. 9400 µg/kg in individual samples	Major risk for swine feed
ANSVSA, 2022	Mixed cereals / National	OTA, AFB1	OTA detected in 62% of monitored silos; AFB1 increasing relative to 2019	Annual national surveillance report
Tabuc et al., 2009	Maize feed / Banat	ZEA	Reproductive disorders in sows: 67% of farms with ZEA above 100 µg/kg	Direct economic impact on the swine sector.

Note: data from Alexa et al., (2013), Marin et al., (2013), Bulgaru et al., (2025), and Tabuc et al., (2009) studies are compiled from Romanian specialist literature; ANSVSA data derive from national surveillance reports.

Comparative Toxicity Profile of the Principal Mycotoxins. Comparing the toxicity profiles of the principal mycotoxins relevant to Romanian cereals enables prioritisation of monitoring and regulatory efforts. Figure 3 presents a semi-quantitative assessment across six major toxicological dimensions, on a scale from 1 (minimal risk) to 5 (maximum risk).

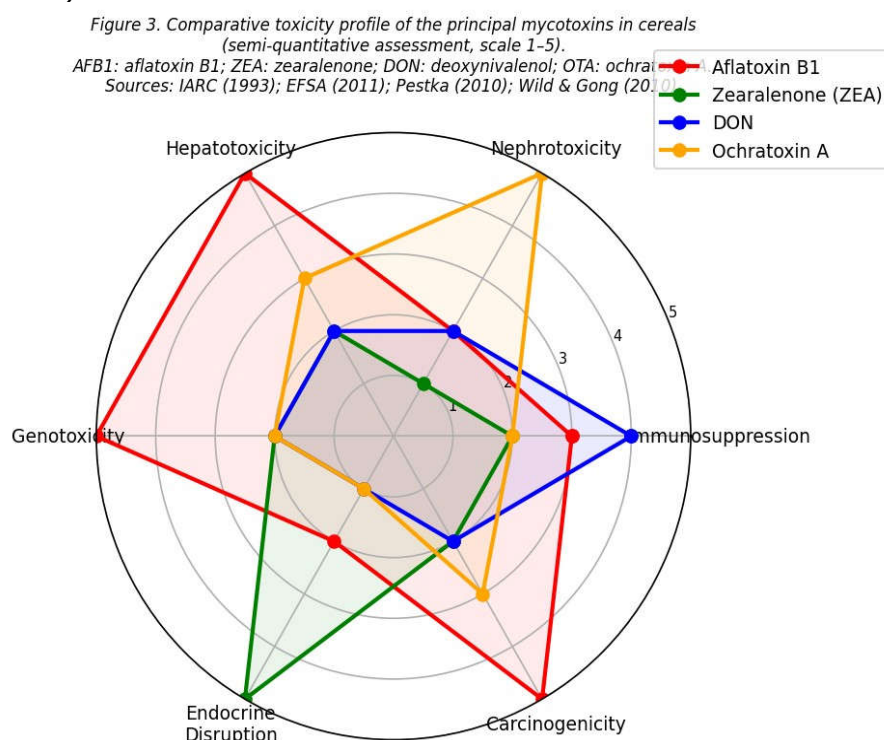


Figure 3. Comparative toxicity profile of the principal mycotoxins in cereals.

Aflatoxin B1 dominates in hepatotoxicity, genotoxicity, and carcinogenicity, justifying the strictest limits in EU legislation (0.1 µg/kg in infant foods). ZEA is distinguished by its maximal endocrine-disrupting potential, with significant effects even at low doses, particularly in farm animals and potentially in children. DON primarily affects the immune system and gastrointestinal tract. OTA is most dangerous for the kidneys, with chronic accumulation driven by its long biological half-life.

The European and Romanian Regulatory Framework: Legislation vs Reality. EC Regulation No. 1881/2006 establishes maximum limits for mycotoxins in foodstuffs, complemented by EU Regulation 2023/915 introducing separate limits for aflatoxins in products intended for infants. Romania has fully transposed these regulations, and the National Sanitary Veterinary and Food Safety Authority (ANSVSA) holds the legal mandate for surveillance and enforcement.

Nevertheless, a documented gap exists between the regulatory framework and practical enforcement. The principal shortcomings identified are: (1) insufficient frequency of inspections at small storage facilities and individual farms, which represent critical contamination points; (2) the absence of a climate-risk-based monitoring system that would intensify checks in years with conditions favourable for mould growth; (3) the lack of mandatory mycotoxin testing for cereals sold in local agri-food markets, which often receive produce from non-certified farms; (4) insufficient regional laboratory capacity to support systematic surveillance (Beia et al., 2024).

An illustrative case is the maize flour sold loose in markets across southern Romania. Studies by the University of Medicine in Craiova documented AFB1 concentrations of 3–8 µg/kg in samples collected from traditional markets exceeding the EU limit of 2 µg/kg — without these products being subject to mandatory testing (Beia et al., 2024). The population regularly exposed to contaminated maize flour, particularly in rural areas, may accumulate toxicologically significant chronic doses.

Table 3

Identified gaps in Romania's mycotoxin control system
and recommended corrective actions

<i>Identified problem</i>	<i>Impact</i>	<i>Recommendation</i>
Insufficient controls at small storage facilities and individual farms	Undetected contamination entering the market	Expand monitoring plans based on climatic risk indicators
Lack of mandatory testing in local agri-food markets	Chronic exposure of rural population to AFB1 and DON	Introduce mandatory rapid strip-ELISA tests for market vendors
Absence of clinical surveillance of human mycotoxicoses	Unquantified epidemiological impact	Biomonitoring: urinary AFM1 measurement in children from rural areas
Insufficient regional laboratory infrastructure	Long response time to alerts	Investment in HPLC-MS/MS capacity at county-level DSVSA laboratories
Grain silos lacking humidity and temperature control systems	Massive post-harvest contamination	Modernisation programmes using PNRR funds for storage infrastructure.

Conclusions. Mycotoxins in cereal crops represent a real and documented ecotoxicological risk in the Romanian context, with three converging dimensions that amplify the severity of the problem: (1) rapidly deteriorating agro-climatic conditions, which are expanding the habitat favourable for *Aspergillus* and *Fusarium*; (2) storage and processing infrastructure that fails to provide minimum conditions for control of post-harvest contamination; and (3) a surveillance system that predominantly targets export-destined products, leaving domestic consumer exposure largely unmonitored.

Aflatoxin B1 remains the most urgent regulatory priority, given its status as a definite Group 1 carcinogen and the upward trend in contamination driven by climate change. Zearalenone represents a growing concern from the perspective of endocrine disruption, particularly for the female population and children. DON and ochratoxin A complete the risk picture for the livestock sector and for chronic consumers of industrially unprocessed cereals. Future research should prioritise biomonitoring of the Romanian population through urinary mycotoxin metabolite analysis, more precise assessment of chronic household-level exposure in rural areas, and development of climate-data-based predictive models for early identification of high-contamination-risk seasons.

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Authors Contributions. Nmeribe Onyekachi Daniel contributed to all aspects of the work: literature review, synthesis, and writing.

Conflicts of Interest. The author declares that there is no conflict of interest.

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Author:

Onyekachi Daniel Nmeribe, Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: nmeribeonyekachi@gmail.com

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