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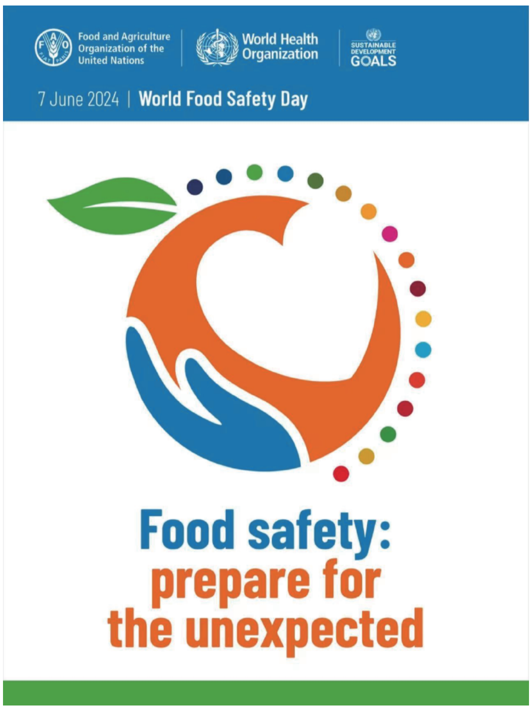

WORLD FOOD SAFETY DAY ISSUE

Preplanned Studies

Outbreak Reports

Perspectives

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Cover Image: adapted from the World Health Organization, https://www.who.int/campaigns/world-food-safety-day/2024.
This week's issue was organized by Guest Editor Yongning Wu.

Preplanned Studies

Exposure to Chloropropanols and Their Fatty Acid Esters and Glycidyl Fatty Acid Esters in the Sixth Total Diet Study — China, 2016–2019

Dan Huang[1,2]; Xiaomin Xu[3,#]; Bing Lyu[2]; Jingguang Li[1,2,#]; Yunfeng Zhao[2]; Yongning Wu[1,2]

Summary

What is already known about this topic?

Chloropropanols, along with their fatty acid esters and glycidyl fatty acid esters (GEs), are prevalent contaminants in a variety of processed foods, posing potential health risks to humans.

What is added by this report?

In the Sixth China Total Diet Study (TDS), 3-monochloropropane-1,2-diol esters (3-MCPD esters) and GEs were identified as the predominant chloropropanols and their esters in composite food samples. Vegetables (47.0%) and cereals (15.4%) were the major contributors to exposure among the 12 food categories evaluated.

What are the implications for public health practice?

The Sixth China TDS highlighted concerns regarding potential health risks associated with dietary exposure to GEs. This study underscores the need for further attention in devising practical strategies to mitigate dietary exposure to GEs.

Chloropropanols and their derivatives, including fatty acid esters and glycidyl fatty acid esters (GEs), are prevalent contaminants arising from food processing. Notably, chloropropanols encompass both mono- and dichloro-substituted variants such as 2-monochloropropane-1,3-diol (2-MCPD) and 3-monochloropropane-1,2-diol (3-MCPD), as well as 1,3-dichloro-2-propanol (1,3-DCP) and 2,3-dichloro-1-propanol (2,3-DCP), each with corresponding fatty acid esters. These compounds are linked to reproductive toxicity, genotoxicity, and carcinogenicity. Evidence suggests that their fatty acid esters can be converted by lipases into free chloropropanols or glycidol, resulting in toxicity within the gastrointestinal tract (*1*). Given that dietary intake is the principal route by which these contaminants are ingested, they present a growing concern for food safety. Consequently, an assessment of dietary exposure to chloropropanols and their esters was performed as part of the Sixth China Total Diet Study (TDS) from 2016 to 2019, as detailed by Lyu et al (*2*). This assessment discovered that 3-MCPD esters and GEs are the most frequently detected contaminants in composite food samples. The escalating concern about the potential health hazards linked to GEs emphasizes the need for robust strategies to mitigate dietary exposure.

3-MCPD has been classified as a "possible human carcinogen" (Group 2B) by the International Agency for Research on Cancer (IARC) (*3*). Despite the recognized risk posed by 3-MCPD, there is limited data on the direct toxicity of other chloropropanols and their esters. Reflecting concerns over the long-term carcinogenic potential of 3-MCPD, the Joint FAO/WHO Expert Committee on Food Additives revised the provisional maximum tolerable daily intake (PMTDI) to 4 μg/kg body weight (BW) per day in 2017 (*1*). In 2018, the European Food Safety Authority (EFSA) established the tolerable daily intake for 3-MCPD and its esters (expressed as 3-MCPD equivalents) at 2 μg/kg BW per day, owing to the comparable toxicity of the chloropropanol esters and the free forms (*4*). This study conservatively applies the PMTDI of 4 μg/kg BW per day as a health-based guidance value (HBGV) for both 2-MCPD and its esters (expressed as 2-MCPD equivalents), assuming their toxicities are identical to those of 3-MCPD and its esters. Currently, food safety authorities have not set HBGVs for GEs. However, the EFSA advocates using a margin of exposure (MOE) approach for assessing the health risks from GE exposure, considering an MOE of 25,000 or higher as indicative of a low health concern (*5*).

The dietary exposure assessment to chloropropanols, their fatty acid esters, and GEs was performed focusing on a typical male adult from China (18–45 years old, 63 kg BW, engaged in light physical activity). This assessment spanned 24 provincial-level administrative divisions (PLADs) across 12 food categories within the scope of the Sixth China TDS. The study incorporated an analysis of seven chloropropanols and several esters, including 2-MCPD, 3-MCPD, 1,3-DCP, 2,3-DCP, 2-MCPD esters, 3-MCPD esters, and GEs. According to prior research, GEs were transformed into 3-bromopropanediol (3-MBPD) esters via bromination, and these, along with 2-MCPD esters and 3-MCPD esters, were hydrolyzed to their corresponding free forms for analysis. These forms were detected and quantified as glycidol equivalents, 2-MCPD, and 3-MCPD respectively (*6*). For detection purposes, derivatization was combined with quantification using internal standards through GC-MS/MS. The limit of detection (LOD) for chloropropanols, their esters, and GEs in dietary samples were established at 2.0, 4.0, and 4.0 μg/kg, respectively. When conducting descriptive statistical analyses of contamination levels and exposure, concentration values for specific food categories were set to 0.0 μg/kg if target contaminants were not detected across all samples within a category. Conversely, if levels were below the LOD, concentrations were calculated as half of the LOD value.

In this study, neither 1,3-DCP nor 2,3-DCP were detected in any of the 288 composite food samples analyzed. 2-MCPD was found only in five samples at concentrations near the LOD, leading to the exclusion of these chloropropanols from dietary intake assessment in this investigation. Table 1 presents summarized data on the contamination levels of detected chloropropanols, chloropropanol esters, and GEs across various food categories. The detection frequency (DF) of 3-MCPD esters (free 3-MCPD form) was notably higher at 87.2%, as was that of GEs (free glycidol form) at 74.3%, compared to 2-MCPD esters (free 2-MCPD form) at 41.3% and 3-MCPD at 30.6% in all samples evaluated. Among the 12 food categories, eggs exhibited the highest contamination levels for all target chloropropanol esters, with a geometric mean [95% confidence interval (95% *CI*)] of 79.7 (78.3, 81.1) μg/kg for 3-MCPD esters and 17.2 (15.5, 18.8) μg/kg for 2-MCPD esters. Vegetables followed, showing levels of 64.8 (63.9, 65.7) μg/kg for 3-MCPD esters and 15.7 (14.6, 16.7) μg/kg for 2-MCPD esters. The highest levels of GEs were found in meat with a geometric mean (95% *CI*) of 61.0 (60.3, 61.7) μg/kg, with vegetables next at 56.5 (55.5, 57.4) μg/kg (Figure 1). However, the peak concentrations for the esters were identified in an egg sample from Zhejiang Province — 4,390.0 μg/kg for 3-MCPD esters, 1,294.0 μg/kg for GEs, and 837.0 μg/kg for 2-MCPD esters. Compared to other food categories, vegetables displayed relatively higher geometric mean (95% *CI*) levels of 3-MCPD at 9.7 (8.4, 11.1) μg/kg, followed by potatoes at 3.5 (2.3, 4.7) μg/kg and meat at 2.3 (1.2, 3.3) μg/kg, with the highest concentration found in a vegetable sample from Guizhou Province (88.9 μg/kg).

Dietary exposure estimates to chloropropanols and their esters during the Sixth China TDS were derived from food consumption and contamination level data. The estimated dietary intakes of chloropropanols, chloropropanol esters, and GEs across the 24 PLADs are detailed in Supplementary Tables S1 and S2 (available at https://weekly.chinacdc.cn/). The average and high (95th percentile) dietary intakes were as follows: 3-MCPD esters (1.07, 2.20 μg/kg BW per day), GEs (0.79, 1.42 μg/kg BW per day), and 2-MCPD esters (0.26, 0.63 μg/kg BW per day) were all higher than those for 3-MCPD (0.14, 0.28 μg/kg BW per day). The highest dietary intake recorded for 3-MCPD esters was 3.51 μg/kg BW per day in Zhejiang Province, with Fujian Province following at 2.27 μg/kg BW per day. Despite eggs exhibiting the highest mean contamination level across the 24 PLADs, vegetables (43.5%) and cereals (15.1%) contributed more to the total intake of 3-MCPD esters than eggs (12.1%) due to their significantly larger consumption. The highest recorded intake of GEs was 2.04 μg/kg BW per day in Shaanxi Province, succeeded by Zhejiang Province (1.45 μg/kg BW per day). Similar to 3-MCPD esters exposure, GEs ingestion predominantly came from vegetables, though meat contributed more to GEs than it did to 3-MCPD or 2-MCPD esters. For 2-MCPD esters, the maximum intake was 0.90 μg/kg BW per day in Fujian Province, with the minimum at 0.06 μg/kg BW per day in Liaoning Province. Although the average intake of 3-MCPD was lower than 2-MCPD esters, the range of 3-MCPD intake (0.05 to 0.64 μg/kg BW per day) paralleled that of 2-MCPD esters. Notably, high intakes of 3-MCPD were observed in Guizhou Province and Hunan Province, at 0.64 and 0.28 μg/kg BW per day, respectively.

DISCUSSION

This study demonstrated that 3-MCPD esters and GEs, prevalent chloropropanols and their esters, are commonly found in various composite food categories, particularly in oil-based processed foods and fatty foods. High concentrations of 3-MCPD esters and

TABLE 1. Concentration levels (μg/kg) and DF (%) of 3-MCPD, 2-MCPD esters, 3-MCPD esters, and GEs in various composite food categories from the Sixth China TDS, 2016–2019.

Food category	Parameter	3-MCPD	2-MCPD esters	3-MCPD esters	GEs
Cereals	GM (95% *CI*)	1.2 (0.6–1.8)	2.2 (1.6–2.7)	8.3 (7.6–9.0)	3.5 (2.7–4.2)
	Median	1.0	2.0	9.0	4.0
	Range	ND to 4.8	ND to 8.0	ND to 24.0	ND to 16.0
	DF	12.5	8.3	95.8	54.2
Legumes	GM (95% *CI*)	2.1 (1.1–3.1)	5.2 (4.2–6.2)	24.6 (23.9–25.3)	20.8 (20.0–21.6)
	Median	1.0	4.5	22.0	19.5
	Range	ND to 14.6	ND to 29.0	9.0 to 75.0	5.00 to 106.0
	DF	45.8	62.5	100.0	100.0
Potatoes	GM (95% *CI*)	3.5 (2.3–4.7)	7.6 (6.2–9.0)	32.8 (31.7–34.0)	19.9 (18.6–21.1)
	Median	3.2	7.0	34.5	17.0
	Range	ND to 28.5	ND to 74.0	6.00 to 237.0	ND to 152.0
	DF	66.7	66.7	100.0	95.8
Meat	GM (95% *CI*)	2.3 (1.2–3.3)	11.2 (10.2–12.3)	59.3 (58.4–60.2)	61.0 (60.3–61.7)
	Median	1.8	11.5	51.0	62.0
	Range	ND to 15.9	ND to 56.0	16.0 to 317.0	22.0 to 196.0
	DF	50.0	87.5	100.0	100.0
Eggs	GM (95% *CI*)	1.8 (0.6–3.0)	17.2 (15.5–18.8)	79.7 (78.3–81.1)	43.4 (42.2–44.6)
	Median	1.0	19.5	68.0	39.0
	Range	ND to 60.7	ND to 837.0	11.0 to 4390.0	5.0 to 1294.0
	DF	29.2	87.5	100.0	100.0
Aquatic foods	GM (95% *CI*)	1.7 (0.8–2.7)	9.1 (7.9–10.3)	35.0 (33.9–36.1)	30.6 (29.8–31.4)
	Median	1.0	10.5	33.0	36.5
	Range	ND to 9.4	ND to 114.0	4.0 to 249.0	7.0 to 114.0
	DF	29.2	79.2	100.0	100.0
Diary products	GM (95% *CI*)	–	–	2.4 (1.9–3.0)	2.7 (2.1–3.3)
	Median	–	–	2.0	2.0
	Range	–	–	ND to 5.0	ND to 6.0
	DF	–	–	25.0	33.3
Vegetables	GM (95% *CI*)	9.7 (8.4–11.1)	15.7 (14.6–16.7)	64.8 (63.9–65.7)	56.5 (55.5–57.4)
	Median	9.9	17.5	61.5	63.5
	Range	ND to 88.9	ND to 102.0	13.0 to 230.0	14.0 to 267.0
	DF	87.5	95.8	100.0	100.0
Fruits	GM (95% *CI*)	–	–	3.9 (3.3–4.6)	–
	Median	–	–	4.0	–
	Range	–	–	ND to 9.0	–
	DF	–	–	75.0	–
Sugar	GM (95% *CI*)	–	2.1 (1.6–2.6)	12.9 (12.3–13.4)	6.7 (5.9–7.5)
	Median	–	2.0	12.5	5.5
	Range	–	ND to 4.0	9.00 to 27.0	ND to 44.0
	DF	–	8.3	100.0	91.7
Water and beverages	GM (95% *CI*)	–	–	3.5 (2.7–4.2)	2.8 (2.1–3.5)
	Median	–	–	3.0	2.0
	Range	–	–	ND to 10.0	ND to 10.0
	DF	–	–	50.0	29.2

Continued

Food category	Parameter	3-MCPD	2-MCPD esters	3-MCPD esters	GEs
Alcohol beverages	GM (95% *CI*)	1.7 (1.0-2.5)	−	9.4 (8.8–10.0)	5.3(4.6–6.1)
	Median	1.0	−	8.5	5.0
	Range	ND to 4.2	−	4.00 to 19.0	ND to 30.0
	DF	8.3	−	100.0	87.5

Note: "−" indicates that the target contaminant was not detected in this food category.
Abbreviation: 3-MCPD=3-monochloropropane-1,2-diol; 2-MCPD=2-monochloropropane-1,3-diol; GEs=glycidyl fatty acid esters; TDS=Total Diet Study; GM=geometric mean; *CI*=confidence interval; ND=non-detected; DF=detection frequency.

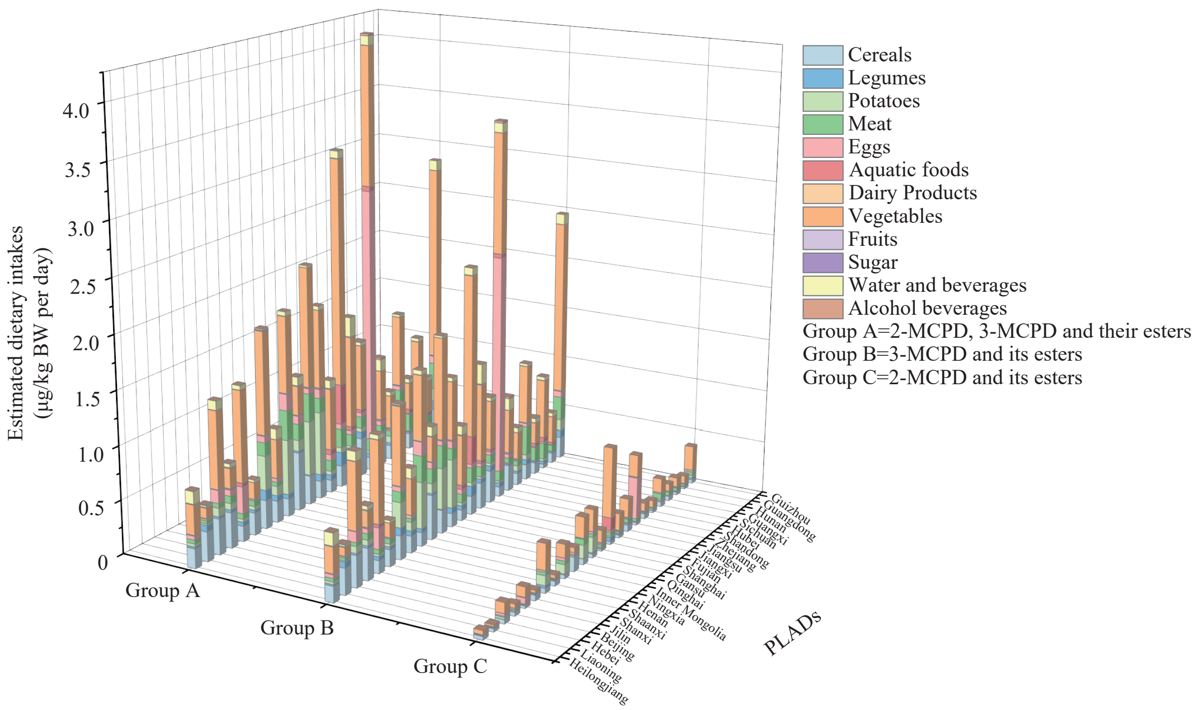

FIGURE 1. Estimated dietary intakes and contributions of various composite food categories of 3-MCPD, 2-MCPD esters, and 3-MCPD esters for adult males in 24 PLADs from the Sixth China TDS, 2016–2019.
Note: Group A=3-MCPD, 2-MCPD and their esters; Group B=3-MCPD and its esters; Group C=2-MCPD and its esters.
Abbreviation: PLADs=provincial-level administrative divisions; 3-MCPD=3-monochloropropane-1,2-diol; 2-MCPD=2-monochloropropane-1,3-diol; TDS=Total Diet Study.

GEs were detected in eggs, vegetables, meat, aquatic foods, and legumes, with DF values reaching 100%. Oil-based processed foods, including eggs and vegetables, are frequently prepared with edible oils and condiments at high temperatures. Previous research has identified high-temperature cooking as a critical factor in the formation of 3-MCPD esters and GEs, with a possible bidirectional transformation process occurring between these contaminants (*7*–*8*). Additionally, it has been noted that in environments containing oils, water, and sodium chloride, 3-MCPD esters can form under relatively low temperatures, facilitated by lipases (*9*).

Variations in dietary and cooking practices, as well as differences in consumption patterns, significantly influenced exposure levels to chloropropanols and their corresponding esters across the 24 PLADs studied. The majority of PLADs showed similar dietary contributions, with vegetables identified as the predominant source of chloropropanol and esters exposure. Cereals, meat, and potatoes were also major contributors to the intake of chloropropanol esters and GEs in most PLADs.

3-MCPD and its esters were aggregated for health risk assessment due to the equivalent toxicity of chloropropanol esters and their free forms. Figure 1 illustrates the estimated dietary intake and its contributions. The average dietary intake of 3-MCPD and its esters across the 24 PLADs was 1.21 μg/kg BW per day, constituting 30.3% of the PMTDI. This suggests that exposure to 3-MCPD and its esters is generally below the HBGV for most residents in China. Nonetheless, significant intake levels were noted in Zhejiang (3.58 μg/kg BW per day), Guizhou (2.46 μg/kg BW per day), and Fujian (2.34 μg/kg BW per day) Provinces, surpassing 55% of PMTDI. Additionally, a conservative health risk assessment calculated estimated intakes of 2-MCPD, 3-MCPD, and their esters, assuming similar toxicity. The mean dietary intake across the 24 PLADs was 1.48 μg/kg BW per day. Zhejiang Province exhibited the most considerable intake at 4.24 μg/kg BW per day, equating to 105.9% of PMTDI. Intakes in Fujian (3.24 μg/kg BW per day), Guizhou (2.80 μg/kg BW per day), and Qinghai (2.28 μg/kg BW per day) provinces approached the HBGV, highlighting potential health risks in these areas. The assessment of GEs utilized the MOE approach. The average MOE value was 12,963, falling below the EFSA's threshold. Only five out of the 24 PLADs had MOE values above 25,000, indicating minimal health concerns in these areas. However, significant health risks from GEs' consumption were identified in Shaanxi Province with an MOE value of 5,002, followed by Zhejiang at 7,044 and Gansu at 8,263.

This study has several limitations. Prior research raised concerns regarding infants and children's exposure to high concentrations of 3-MCPD and its esters, particularly from special diets like infant formula and infants' snacks. However, these foods were not involved in the present study. Additionally, in the present study, the dietary intakes were only estimated for adult males. Further studies on dietary exposure in susceptible populations like children and older populations are needed.

In conclusion, this study indicated that the health risks associated with dietary exposure to chloropropanols and their esters are low in China. However, GEs pose a potential health concern for many residents. Continuous monitoring of dietary exposure to both chloropropanols and their fatty acid esters, as well as GEs, is necessary, with a specific focus on regions where residents are exposed to high levels of these contaminants.

Conflicts of interest: No conflicts of interest.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Estimated dietary intakes (μg/kg BW per day) of 3-MCPD, 2-MCPD esters, 3-MCPD esters, and GEs in 24 PLADs from the Sixth China TDS, 2016–2019.

PLADs	3-MCPD	2-MCPD esters	3-MCPD esters	GEs
Heilongjiang	0.070	0.076	0.559	0.555
Liaoning	0.046	0.056	0.415	0.261
Hebei	0.208	0.184	1.017	1.171
Beijing	0.134	0.101	0.551	0.320
Jilin	0.264	0.184	0.996	0.723
Shanxi	0.066	0.087	0.364	0.274
Shaanxi	0.139	0.445	1.283	2.039
Henan	0.187	0.095	0.603	0.850
Ningxia	0.109	0.312	1.517	1.050
Inner Mongolia	0.052	0.217	1.010	0.611
Qinghai	0.085	0.435	1.761	0.807
Gansu	0.085	0.444	1.328	1.234
Shanghai	0.086	0.187	0.822	0.892
Fujian	0.069	0.898	2.272	0.951
Jiangxi	0.154	0.220	1.238	0.878
Jiangsu	0.084	0.301	0.946	0.746
Zhejiang	0.063	0.659	3.513	1.448
Shandong	0.165	0.136	0.763	0.945
Hubei	0.064	0.109	0.506	0.294
Sichuan	0.253	0.258	0.902	0.637
Guangxi	0.058	0.156	0.505	0.412
Hunan	0.282	0.156	0.644	0.437
Guangdong	0.079	0.123	0.429	0.357
Guizhou	0.640	0.343	1.820	0.993

Abbreviation: 3-MCPD=3-monochloropropane-1,2-diol; 2-MCPD=2-monochloropropane-1,3-diol; PLAD=provincial-level administrative division; GEs=glycidyl fatty acid esters; TDS=Total Diet Study.

SUPPLEMENTARY TABLE S2. Estimated dietary intakes (μg/kg BW per day) of 3-MCPD, 2-MCPD esters, 3-MCPD esters, and GEs by different composite food categories from the Sixth China TDS, 2016–2019.

Food categories	3-MCPD	2-MCPD esters	3-MCPD esters	GEs
Cereals	0.567	0.986	3.894	1.777
Legumes	0.095	0.204	0.793	0.764
Potatoes	0.174	0.578	2.109	1.440
Meat	0.134	0.493	2.408	2.249
Eggs	0.045	0.654	3.113	1.143
Aquatic foods	0.022	0.210	0.583	0.435
Diary products	0	0	0.029	0.034
Vegetables	2.391	3.055	11.201	9.715
Fruits	0	0	0.085	0
Sugar	0	0.002	0.012	0.007
Water and beverages	0	0	1.450	1.266
Alcohol beverages	0.014	0	0.086	0.053

Abbreviation: 3-MCPD=3-monochloropropane-1,2-diol; 2-MCPD=2-monochloropropane-1,3-diol; PLAD=provincial-level administrative division; GEs=glycidyl fatty acid esters; TDS=Total Diet Study.

Preplanned Studies

Pathogenic Surveillance of Foodborne Illness-Related Diarrhea — Beijing Municipality, China, 2013–2023

Chao Wang[1]; Tongyu Wang[1]; Yanlin Niu[1]; Yangbo Wu[1]; Jinru Jiang[1]; Xiaochen Ma[1,#]

Summary

What is already known about this topic?

Foodborne diseases present a significant public health concern, particularly in China, where they represent a significant food safety challenge. Currently, there is a need for a thorough and systematic analysis of the extended epidemiological patterns of foodborne diseases in Beijing Municipality.

What is added by this report?

Monitoring results show that Norovirus and diarrheagenic *Escherichia coli* (DEC) are the most commonly identified foodborne diarrheal pathogens. Individuals aged 19–30 are at a higher risk of foodborne diarrhea in Beijing, with Salmonella infection being associated with fever symptoms.

What are the implications for public health practice?

This study analyzes 11 years of consecutive monitoring data to enhance understanding of the epidemiological and clinical features of foodborne diarrhea in Beijing. It aims to identify high-risk populations, assist in clinical pathogen identification and treatment, and support the development of tailored preventive strategies.

Foodborne illnesses caused by various microorganisms, such as viruses, bacteria, and parasites (*1*), pose a significant global public health threats, leading to widespread illness and mortality. A survey conducted on the burden of acute gastrointestinal infections (AGI) in China between 2014 and 2015 revealed a population prevalence of 2.3% with an annual incidence of 0.3 episodes per person (*2*). Over the decade from 2010 to 2020, there were 18,331 reported outbreaks in Chinese catering facilities, resulting in 206,718 illnesses, 68,561 hospitalizations, and 201 fatalities (*3*). The Beijing CDC initiated a foodborne disease surveillance system in 2013, gradually implementing city-wide population-based surveillance. This study examined data from 36 actively monitored hospitals (25 tertiary-level and 11 secondary-level hospitals) selected through probability proportional to size (PPS) sampling from all hospitals with enteric disease clinics across 16 districts in Beijing Municipality, China.

Patients included in the surveillance were those who visited the sentinel hospital with symptoms of suspected foodborne diarrhea, presenting with over three bowel movements in 24 hours and abnormal stool consistency (e.g., loose, liquid, mucous, or bloody stools), excluding cases linked to antibiotic use or chemical exposure. Surveillance was carried out year-round, with each district aiming to collect a minimum of 330 samples annually.

Fresh stool specimens were collected either in fecal containers or rectal swabs, which were then placed in Cary-Blair transport medium for testing within 24 hours at 4°C (samples for *Vibrio parahaemolyticus* were stored at room temperature). Virus detection samples not immediately sent were stored at −20 °C. Bacterial specimens were enriched, inoculated onto suitable media for culture, and then isolated. Virus detection was conducted through nucleic acid amplification using reverse transcription-polymerase chain reaction (RT-PCR).

The 36 sentinel hospitals were responsible for gathering demographic information, food history, clinical characteristics, and biological samples from individuals under surveillance. A total of 16 district CDC laboratories tested these specimens for major foodborne pathogens: *Salmonella*, *Vibrio parahaemolyticus*, diarrheagenic *Escherichia coli* (DEC), *Shigella*, and Norovirus. The detection results were then sent to higher authorities for confirmation. Surveillance data indicated that Norovirus and DEC were the predominant pathogens, individuals between 19 and 30 years old had the highest infection rates, and patients with *Salmonella* infections were more likely to experience fever symptoms.

Summary statistics, including frequencies and proportions, were computed for categorical variables. The study period was stratified into two time frames, 2013–2017 and 2018–2023, due to changes in testing practices at sentinel hospitals in 2018. The chi-square test was employed to compare demographic characteristics (age, sex, area, and occupation) for four pathogens (*Salmonella*, Norovirus, *Vibrio parahaemolyticus*, and DEC); *Shigella* was excluded due to a limited sample size. Fisher's exact test was used if the conditions for the chi-square test were not met. All tests were two-sided, and a significance level of $P<0.05$ was considered statistically significant.

From January 1, 2013, to December 31, 2023, a total of 60,223 patients were included in the Beijing Foodborne Disease Active Surveillance System. After excluding non-infectious diarrhea cases and those without biological samples, 57,021 specimens were analyzed for *Salmonella*, *Shigella*, *Vibrio parahaemolyticus*, DEC, and Norovirus. The detection rates for *Salmonella*, *Shigella*, *Vibrio parahaemolyticus*, and DEC were 3.96% (2,260/57,021), 0.18% (101/57,021), 3.18% (1,811/57,021), and 7.06% (4,024/57,021), respectively. Among the 23,506 specimens tested for Norovirus, the detection rate was 10.54% (2,478/23,506). The prevalent *Salmonella* serotypes were *Salmonella* Enteritidis (864/2,260) and *Salmonella* Typhimurium (340/2,260). Enteroaggregative *Escherichia coli* (EAEC) and enterotoxigenic *Escherichia coli* (ETEC) were the most common DEC types, constituting 34.57% (1,391/4,026) and 34.09% (1,372/4,026) of the detected DEC, respectively.

The trends in detection rates of various pathogens from 2013 to 2023 were analyzed and shown in Figure 1. From 2013 to 2019, *Salmonella*, DEC, and Norovirus infection rates increased annually, while

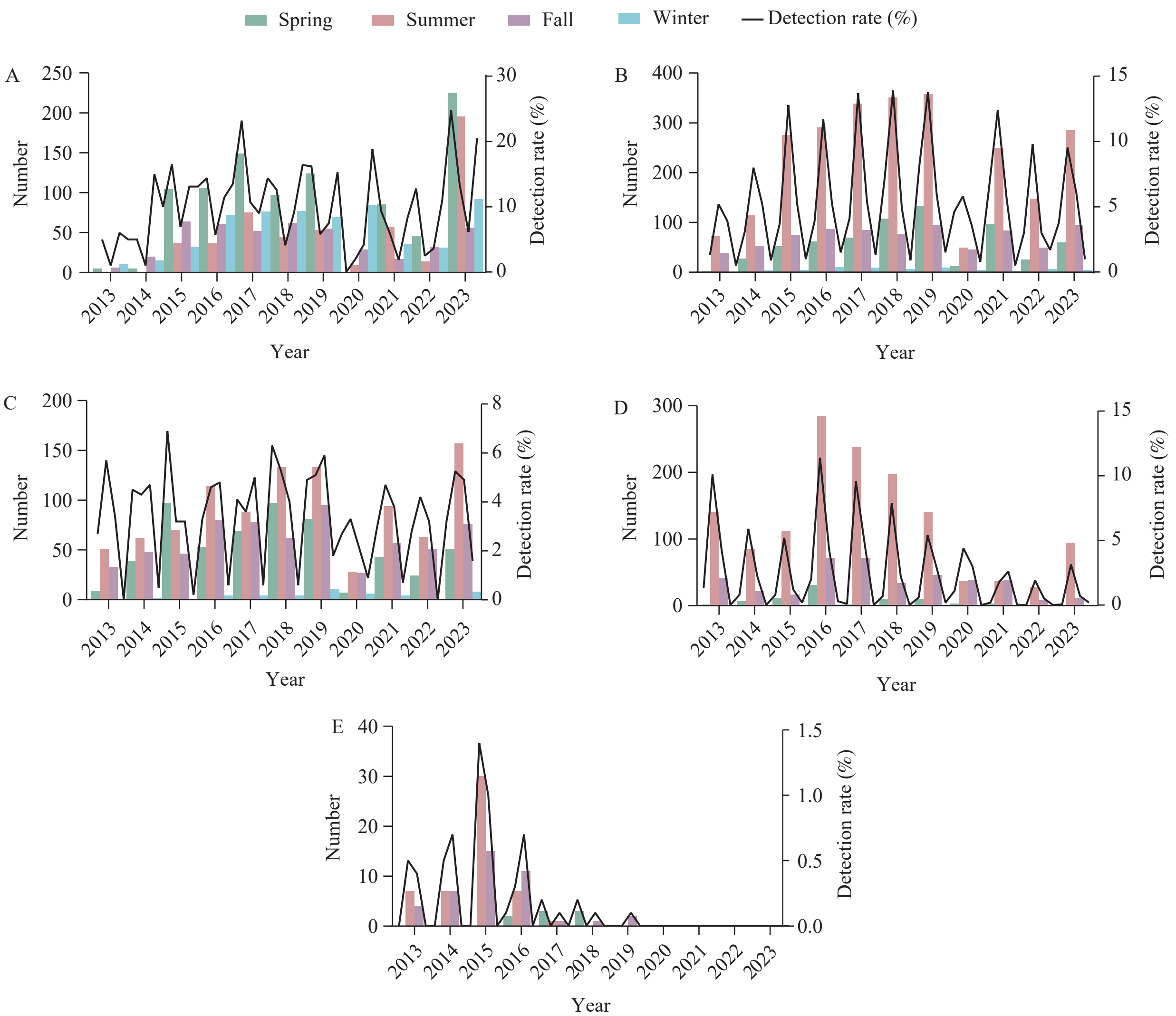

FIGURE 1. Changes in the numbers of positive pathogens and detection rates by pathogen and season in Beijing Municipality, China, from 2013 to 2023. (A) Norovirus; (B) DEC; (C) *Salmonella*; (D) *Vibrio parahaemolyticus*; (E) *Shigella*.
Abbreviation: DEC=diarrhoeagenic *Escherichia coli*.

Shigella infections decreased. *Vibrio parahaemolyticus* peaked in 2016, followed by a yearly decline. During 2020–2022, all pathogen infection rates decreased due to the impact of the COVID-19 pandemic. However, in 2023, detection rates increased for all pathogens except *Shigella*. Notably, pathogenic bacteria were most prevalent in summer, with Norovirus causing winter and spring outbreaks.

The study provides a summary and comparison of the epidemiological characteristics of pathogens over time (Table 1). A high percentage of patients, 28.38% (2,971/10,469), are aged 19–30 years. The incidence of *Vibrio parahaemolyticus* infection is significantly lower in children under 3 years old compared to other age groups (P<0.001). Gender ratios of individuals infected with Norovirus, DEC, *Salmonella*, and *Vibrio parahaemolyticus* show no significant differences between the periods 2013–2017 and 2018–2023 (P>0.05). However, there are notable disparities in the regional distribution of Norovirus (P<0.001) and *Salmonella* (P=0.003) infections between these time frames, with urban infections being more common in

TABLE 1. Variations in demographic characteristics of foodborne diarrhea patients over select time periods in Beijing Municipality, China, 2013–2023, *n* (%).

Variables	Total	Norovirus		*P* value	DEC		*P* value	*Salmonella*		*P* value	*Vibrio parahaemolyticus*		*P* value
	2013–2023	2013–2017	2018–2023		2013–2017	2018–2023		2013–2017	2018–2023		2013–2017	2018–2023	
Total	10,469	888	1,590		1,671	2,353		948	1,312		1,140	671	
Age, years				0.003			<0.001			<0.001			<0.001
≤3	873 (8.34)	98 (11.04)	156 (9.81)		131 (7.84)	214 (9.09)		73 (7.70)	219 (16.70)		4 (0.35)	2 (0.36)	
4–18	674 (6.44)	61 (6.87)	83 (5.22)		77 (4.61)	176 (7.48)		63 (6.65)	131 (9.98)		39 (3.42)	21 (3.13)	
19–30	2,971 (28.38)	292 (32.89)	466 (29.31)		498 (29.80)	571 (24.27)		236 (24.90)	236 (17.99)		467 (40.96)	239 (35.62)	
31–40	2,303 (22.00)	179 (20.16)	405 (25.47)		325 (19.45)	565 (24.01)		179 (18.89)	212 (16.16)		268 (23.51)	223 (33.23)	
41–50	1,100 (10.51)	75 (8.45)	156 (9.81)		165 (9.87)	246 (10.45)		129 (13.61)	132 (10.06)		147 (12.89)	75 (11.18)	
51–60	1,038 (9.91)	98 (11.04)	113 (7.11)		214 (12.81)	213 (9.05)		101 (10.65)	144 (10.98)		97 (8.51)	61 (9.09)	
≥60	1,510 (14.42)	85 (9.57)	211 (13.27)		261 (15.62)	368 (15.64)		167 (17.62)	238 (18.14)		118 (10.35)	50 (7.45)	
Sex				0.934			0.210			0.492			0.535
Male	5,759 (55.00)	492 (55.41)	913 (57.42)		887 (53.08)	1,296 (55.08)		497 (52.43)	707 (55.89)		644 (56.49)	369 (55.00)	
Female	4,710 (45.00)	396 (44.59)	677 (42.58)		784 (46.92)	1,057 (44.92)		451 (47.57)	605 (46.11)		496 (43.51)	302 (45.00)	
Area				<0.001			0.262			0.003			0.005
Urban	4,250 (40.81)	314 (35.36)	706 (45.23)		716 (42.85)	953 (40.69)		355 (37.45)	583 (44.54)		474 (41.58)	257 (38.36)	
Suburbs	4,018 (38.59)	403 (45.38)	637 (40.81)		557 (33.33)	784 (33.48)		400 (42.19)	486 (37.13)		444 (38.95)	310 (46.27)	
Outskirts	2,145 (20.60)	171 (19.26)	218 (13.97)		398 (23.82)	605 (25.83)		193 (20.36)	240 (18.33)		222 (19.47)	103 (15.37)	
Occupation				0.002			<0.001			<0.001			0.022
Official staff	2,438 (23.29)	222 (25.00)	471 (29.62)		367 (21.96)	515 (21.89)		181 (19.09)	159 (15.59)		295 (25.88)	188 (28.02)	
Unemployed	2,262 (21.61)	151 (17.00)	303 (19.06)		388 (23.22)	450 (19.12)		224 (23.63)	219 (21.47)		328 (28.77)	175 (26.08)	
Student	987 (9.43)	97 (10.92)	169 (10.63)		139 (8.32)	259 (11.01)		71 (7.49)	79 (7.75)		80 (7.02)	33 (4.92)	
Children	1,048 (10.01)	102 (11.49)	176 (11.07)		137 (8.20)	255 (10.84)		102 (10.76)	279 (21.27)		14 (1.23)	2 (0.35)	
Worker	663 (6.33)	55 (6.19)	77 (4.84)		102 (6.10)	149 (6.33)		57 (6.01)	69 (5.26)		102 (8.95)	71 (10.58)	
Retirees	1,168 (11.16)	83 (9.35)	169 (10.63)		253 (15.14)	284 (12.07)		113 (11.92)	159 (12.19)		85 (7.46)	38 (5.67)	
Others	1,903 (18.18)	178 (20.05)	225 (14.15)		285 (17.06)	441 (18.74)		200 (21.10)	195 (14.86)		236 (20.70)	164 (24.44)	

Abbreviation: DEC=diarrhoeagenic *Escherichia coli.*

2018–2023 compared to 2013–2017. The majority of Norovirus cases involve official staff (25.00%–29.62%), while cases of DEC, *Salmonella*, and *Vibrio parahaemolyticus* predominantly affect unemployed individuals (17.00%–28.77%). Significant differences exist in the occupational distribution of infection rates for different pathogens in different periods (*P*<0.001).

Figure 2 displays patient self-reports, indicating that meat products were the most commonly reported source of suspected exposure among the four pathogens analyzed, accounting for 22.64%. However, there were differences in the distribution of suspicious food categories across the various pathogens. For *Vibrio parahaemolyticus* infections, aquatic products were the primary food source at 26.06%, followed by meat products at 24.74% and vegetables at 15.74%. Conversely, patients infected with Norovirus, *Salmonella*, and DEC identified meat products and vegetables as the top two food sources.

The clinical characteristics of the pathogens are outlined (Table 2). Nausea was the most common symptom, affecting 51.05% (1,265/2,478) of Norovirus-infected patients. Abdominal cramps were prevalent in DEC, *Salmonella*, and *Vibrio parahaemolyticus* infections, ranging from 41.08% to 73.86%. *Salmonella* infections showed a significantly higher fever prevalence (36.02%) compared to other pathogens during 2013–2023. Across eleven years, the proportion of abdominal cramps from these infections decreased notably from 53.72%–73.86% (2013–2017) to 40.63%–56.93% (2018–2023). The projected trend suggests an increase in patients experiencing loose stools due to pathogens, expected to rise from 16.75%–28.27% (2013–2017) to 35.32%–45.90% (2018–2023).

DISCUSSION

This continuous pathogenic surveillance study examined the incidence of foodborne diseases among outpatients with diarrhea in Beijing. Through comprehensive laboratory testing for four intestinal pathogens and one virus, the study revealed the epidemiological and pathogenic characteristics of foodborne diarrhea in the population, contributing valuable data to the understanding of such diseases in China. Over the past eleven years, 57,021 biological samples were tested for four common intestinal pathogens, while 23,506 samples were specifically tested for a single virus. Norovirus emerged as the most frequently detected pathogen, with a detection rate of 10.54%, aligning with studies conducted in Shanghai Municipality and Zhejiang Province, confirming that norovirus infection is the leading cause of diarrhea in these regions (*4–5*). Noroviruses are the primary etiological agents responsible for sporadic cases and outbreaks of acute gastroenteritis globally, imposing a substantial disease burden in both developed and

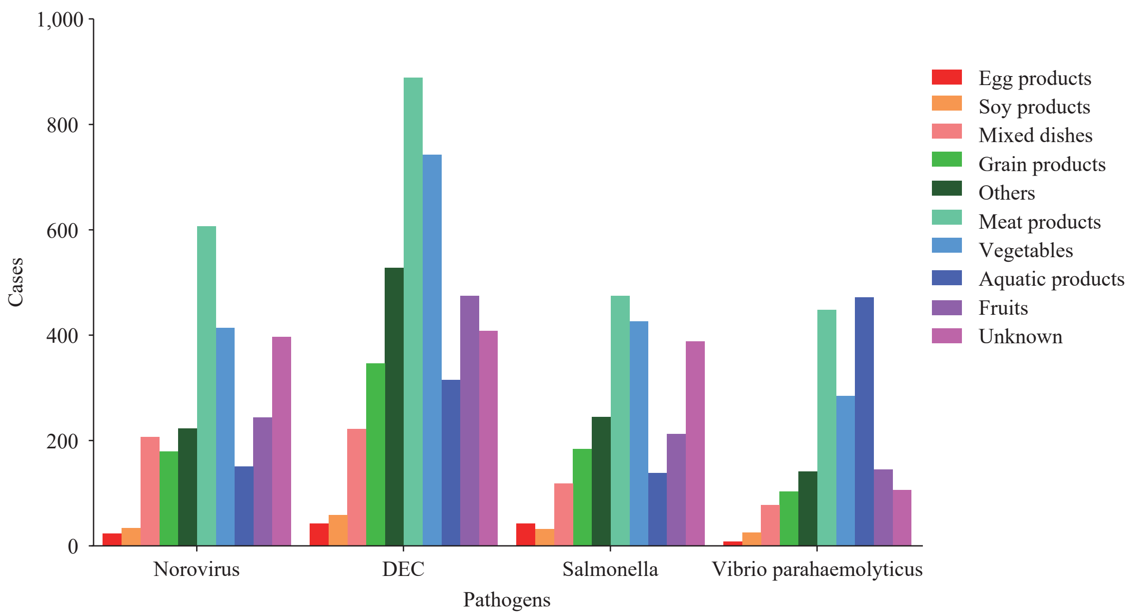

FIGURE 2. Distribution of suspicious food categories by pathogens in Beijing Municipality, China, 2013–2023.
Abbreviation: DEC=diarrhoeagenic *Escherichia coli.*

TABLE 2. Reported signs and symptoms of patients infected with different pathogens in Beijing Municipality, China, 2013–2023, *n* (%).

Variables	Total	Norovirus			DEC			*Salmonella*			*Vibrio parahaemolyticus*			*P* value*
	2013–2023	Total	2013–2017	2018–2023	Total	2013–2017	2018–2023	Total	2013–2017	2018–2023	Total	2013–2017	2018–2023	
Total	10,469	2,478	888	1,590	4,024	1,671	2,353	2,260	948	1,312	1,811	1,140	671	
Clinical symptom														
Nausea	4,778 (45.64)	1,265 (51.05)	487 (54.84)	778 (48.93)	1,654 (41.10)	779 (46.62)	875 (37.19)	856 (37.88)	401 (42.30)	455 (34.68)	1,143 (63.11)	727 (63.77)	416 (62.00)	<0.001
Vomiting	3,023 (28.88)	965 (38.94)	354 (39.86)	611 (38.43)	936 (23.26)	414 (24.78)	522 (22.18)	469 (20.75)	208 (21.94)	261 (19.89)	771 (42.57)	493 (43.25)	278 (41.43)	<0.001
Abdominal cramps	5,542 (52.94)	1,123 (45.32)	477 (53.72)	646 (40.63)	2,123 (53.76)	1,061 (63.49)	1,062 (45.13)	1,142 (50.53)	603 (63.61)	539 (41.08)	1,224 (67.59)	842 (73.86)	382 (56.93)	<0.001
Fever (≥37.5 °C)	2,481 (23.70)	452 (18.24)	201 (22.64)	251 (15.79)	783 (19.46)	424 (25.37)	359 (15.26)	814 (36.02)	357 (37.66)	457 (34.83)	400 (22.09)	281 (24.65)	119 (17.73)	<0.001
Dehydration	785 (7.50)	223 (9.00)	88 (9.91)	135 (8.49)	208 (5.17)	102 (6.10)	106 (4.50)	188 (8.32)	89 (9.39)	99 (7.55)	176 (9.72)	119 (10.44)	57 (8.49)	<0.001
Thirsty	1,365 (13.04)	245 (9.89)	143 (16.10)	102 (6.42)	288 (7.16)	169 (10.11)	119 (5.06)	196 (8.67)	136 (14.35)	60 (4.57)	207 (11.43)	163 (14.30)	44 (6.56)	<0.001
Fatigue	1,253 (13.67)	302 (12.19)	118 (13.29)	184 (11.57)	453 (11.26)	212 (12.69)	241 (10.24)	291 (12.88)	159 (16.77)	132 (10.06)	326 (18.00)	236 (20.70)	90 (13.41)	<0.001
Chills	54 (0.52)	8 (0.32)	5 (0.56)	3 (0.19)	9 (0.22)	2 (0.12)	7 (0.30)	13 (0.58)	4 (0.42)	9 (0.69)	26 (1.44)	17 (1.49)	9 (1.34)	<0.001
Diarrhea frequency ≥ 10/24 h	2,037 (19.46)	433 (17.48)	144 (16.22)	289 (18.18)	683 (16.97)	277 (16.58)	406 (17.25)	583 (25.80)	227 (23.95)	356 (27.13)	341 (18.83)	202 (17.72)	139 (20.72)	<0.001
Diarrhea														
Watery stool	5,936 (56.70)	1,464 (59.08)	510 (57.43)	954 (60.00)	2,082 (51.74)	951 (56.91)	1,131 (48.07)	1,324 (58.58)	584 (61.60)	740 (56.40)	1,159 (64.00)	773 (67.81)	386 (57.53)	<0.001
Loose stool	3,335 (31.86)	824 (33.25)	251 (28.27)	573 (36.04)	1,468 (36.48)	388 (23.22)	1,080 (45.90)	650 (28.76)	175 (18.46)	475 (36.20)	428 (23.63)	191 (16.75)	237 (35.32)	0.690
Mucus stool	518 (4.95)	88 (3.56)	54 (6.08)	34 (2.14)	175 (4.35)	108 (6.46)	67 (2.85)	146 (6.46)	88 (9.28)	58 (4.42)	94 (5.19)	68 (5.96)	26 (3.87)	0.990
Rice-water stool	75 (0.72)	12 (0.48)	9 (1.01)	3 (0.19)	50 (1.24)	47 (2.81)	3 (0.13)	6 (0.27)	5 (0.53)	1 (0.08)	7 (0.39)	5 (0.44)	2 (0.30)	<0.001
Pus and blood stool	66 (0.63)	5 (0.20)	1 (0.11)	4 (0.25)	24 (0.60)	14 (0.84)	10 (0.42)	17 (0.75)	9 (0.95)	8 (0.61)	18 (1.00)	11 (0.96)	7 (1.04)	0.137

Abbreviation: DEC=diarrhoeagenic *Escherichia coli*.

developing nations. Currently, most outbreaks under surveillance in China are large-scale, while smaller clusters also constitute a significant proportion. Therefore, there is a need for further enhancement in their monitoring and analysis (*6*). Regarding temporal distributions, the detection rates of all five pathogens decreased in 2020 due to the coronavirus disease 2019 (COVID-19) pandemic, mirroring similar observations reported in the US (*7*). The detection rate of *Shigella* decreased annually from 2013 to 2023, consistent with a study on *Shigella* infection in China (*8*). This decline is likely due to various factors, including rapid economic growth, improved water supply systems, upgraded sanitation facilities, and heightened awareness of hygiene practices. Regarding seasonality, the detection rates of the four bacterial pathogens peaked in spring and summer, while norovirus was the main cause of winter outbreaks, consistent with previous reports (*9*). Among cases of *Salmonella* infection, meat products and vegetables were the most commonly implicated foods, contrary to a study in the US (*10*) that reported eggs as the most commonly implicated food. The most common clinical symptoms were nausea, vomiting, and abdominal cramps. Patients infected with *Salmonella* were more likely to have a fever. The research on clinical symptoms provides valuable insights for clinical diagnosis. Given the atypical clinical manifestations of various pathogens, differentiating them from non-infectious diarrhea remains challenging. Therefore, there is an urgent need to establish rapid pathogen monitoring methods to enable targeted treatment strategies when patients seek medical care.

The study is subject to some limitations. The surveillance data from 36 medical institutions may not provide an accurate estimate of the overall prevalence of foodborne diseases in Beijing. While efforts were made to adhere to national standards and provide regular training, variations in results among hospitals and laboratories are possible. Moreover, reliance on self-reported food exposure information by patients can introduce recall bias, as there are no valid laboratory methods to confirm these reports.

The advancement of our economy has led to significant lifestyle transformations. The rising popularity of ready-to-eat or pre-cooked meals highlights the need for a comprehensive strategy to safeguard the entire food supply chain, from production to consumption, to safeguard consumers against foodborne diseases. Thus, we advocate for improved food safety education for at-risk groups and the implementation of proactive and efficient control measures tailored to the epidemiological patterns of foodborne diarrhea cases in Beijing.

Conflicts of interest: No conflicts of interest.

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Preplanned Studies

Community Incidence Estimates of Five Pathogens Based on Foodborne Diseases Active Surveillance — China, 2023

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Summary

What is already known about this topic?

Foodborne diseases, representing significant food safety and public health challenges globally, are not well-documented in terms of incidence, particularly for cases characterized by acute gastroenteritis (AGI) in China.

What is added by this report?

This study developed a pyramid model to estimate the incidence of five pathogens, stratified by gender and age. The estimated incidences per 100,000 people with 95% uncertainty intervals (*UI*) are as follows: Norovirus, 3,188.28 (95% *UI*: 2,518.03, 7,296.96); *Salmonella* spp., 1,295.59 (95% *UI*: 1,002.62, 1,573.11); diarrheagenic *E. coli* (DEC), 782.62 (95% *UI*: 651.19, 932.05); *Vibrio parahaemolyticus*, 404.06 (95% *UI*: 342.19, 468.93); and *Shigella* spp., 26.73 (95% *UI*: 21.05, 33.46).

What are the implications for public health practice?

This study elucidates the incidence rates across various gender and age groups, thereby identifying priority populations for targeted preventive interventions aimed at reducing disease burden. These insights are crucial for the development of public health policies and management of food safety risks.

Foodborne diseases represent a significant challenge in food safety and public health worldwide, necessitating increased focus on assessing their burden. In China, the majority of microbial foodborne illnesses are categorized as infectious diarrhea, excluding bacillary dysentery, under statutory category C infectious diseases. The traditional passive surveillance system in place often misses specific pathogens and is plagued by extensive under-reporting and under-diagnosis, complicating the understanding of the actual disease burden. However, the establishment of a laboratory-based foodborne disease surveillance platform in 2011 has enhanced disease tracking. This initiative relies on the ongoing cooperation between local disease prevention and control agencies and clinical laboratories. It involves regular audits to identify new cases and ensure the comprehensive reporting of all infectious diseases. By the end of 2023, over 900 hospitals across 31 provincial-level administrative divisions (PLADs) and Xinjiang Production and Construction Corps (XPCC) had participated in this sentinel surveillance. The pyramid model, commonly applied to estimate the incidence of pathogens causing acute gastroenteritis (AGI), systematically addresses uncertainty at each stage. This model considers steps such as patients seeking care, hospitals collecting stool specimens, laboratories analyzing these samples, and the subsequent identification of pathogens, incorporating parameter distributions to better estimate underreporting rates (*1*).

In this study, we merged data from both sentinel hospital surveillance and previous community surveys in China with data from the population census to estimate the incidence of diarrheal diseases using a pyramid model. The surveillance data encompassed cases defined by three or more daily bowel movements paired with altered stool consistency, attributable to foodborne or suspected foodborne pathogens. These pathogens included *Salmonella* spp., *Vibrio parahaemolyticus*, *Shigella* spp., diarrheagenic *E. coli* (DEC), and norovirus, detected according to the protocols specified in the National Foodborne Disease Surveillance Manual. Prevalences were derived as the proportion of positive results to the total samples tested. Details on administrative regions and population demographics were sourced from publicly accessible records. We determined the incidences of AGI within the community, as well as the likelihood of hospitalization and incidence of diarrhea due to AGI, based on data from prior national community-based surveys (*2*). Rates for stool sample collection, sample submission, and laboratory testing capacity were obtained from the same sentinel hospital data. We used probability distributions of consultation rates and AGI incidences, differentiated by sex and age groups, to enhance the model using average levels across the total population (Supplementary Table S1, available at https://weekly.chinacdc.cn/). We calculated overall incidences by multiplying age-specific incidences with data from the Seventh National Population Census and then dividing this by the broader population total.

Data cleaning and analysis were conducted using R version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria). The 95% confidence intervals (*CIs*) for prevalence were estimated using the binomial test, while differences between groups were assessed using the chi-squared test, with a significance threshold set at α=0.01. Uncertainties were addressed by calculating incidences through 20,000 Monte Carlo simulation iterations, relying on parameter distributions and available data.

The prevalence of infection by five pathogens varied significantly between genders (χ^2=81.09, *P*<0.000), with males showing a higher overall prevalence. Notably, *Salmonella* spp., DEC, and norovirus were more common in males than in females. In contrast, *Vibrio parahaemolyticus* was more prevalent among females, a statistically significant difference (Table 1). Regionally, southern China had the highest prevalence of these pathogens, followed by eastern China, whereas northeastern China had the lowest. Except for the northeastern China, no significant regional differences were observed in the prevalence of norovirus. *Salmonella* spp. was most prevalent in southern China and least prevalent in northeastern China. *Vibrio parahaemolyticus* showed the highest prevalence in coastal regions including the northeastern China, northern China, and southern China. Central China, northwestern China, and southwestern China had lower prevalence rates, with the northwestern China reporting no cases. DEC was most prevalent in northern China and least prevalent in southwestern China. Conversely, *Shigella* was most prevalent in northwestern China, yet was reported as least prevalent in the other region (Table 2).

Norovirus exhibited the highest incidence rate at 3,188.28 [95% uncertainty intervals (*UI*): 2,510.80, 3,872.96] cases per 100,000 population, predominantly affecting the 1–4 years, which showed an incidence of 5,133.68 (95% *UI*: 4,047.24, 6,229.35) cases per 100,000 population. In contrast, *Salmonella* spp. were most prevalent in infants under one year, with an incidence rate of 5,559.18 (95% *UI*: 4,377.10, 6,751.43) cases per 100,000 population, followed by the 1–4 year age group with a rate of 3,927.84 (95% *UI*: 3,096.26, 4,765.52) cases per 100,000 population. The highest incidence of *Vibrio parahaemolyticus* was noted among individuals aged 35–44, with an incidence rate of 716.57 (95% *UI*: 564.79, 869.70) cases per 100,000 population. DEC was most frequent in the 20–24 year age group, presenting a rate of 1,026.32 (95% *UI*: 808.21, 1,246.93) cases per 100,000 population. *Shigella* spp. showed the lowest incidence at 26.73 (95% *UI*: 21.05, 33.46) cases per 100,000 population, with the highest rates found among children aged 5–9 years, at 53.32 cases per 100,000 population (95% *UI*: 41.99, 64.78) (Table 3).

DISCUSSION

The incidence of foodborne diseases, along with other disease burden indicators, is essential for the development of prioritized food safety management and intervention strategies. In this study, norovirus displayed the highest incidence among the five pathogens estimated, aligning with the multi-regional findings reported by World Health Organization in 2015 (*3*). It is important to recognize that only a subset of norovirus cases is attributable to foodborne transmission. Notably, the incidence of norovirus is higher in children aged 1–4, likely due to their lower immunity and greater exposure in environments such as daycare centers and schools (*4*). The estimated overall population incidence of *Salmonella* spp. was higher compared to the rates reported by Li et al. (245 cases per 100,000 populations), Chen et al. (236 cases per 100,000 populations), and those reported in the United States (344 cases per 100,000 populations), Australia (427 cases per 100,000 populations), and Japan (199 cases per 100,000 populations) (*5*–*9*). In China, there are no specific standard restrictions on *Salmonella* spp. for fresh or frozen livestock and poultry products or during slaughtering and processing. This results in a higher positive detection rate of *Salmonella* spp. and an increased likelihood of cross-contamination during food storage, transportation, processing, and cooking. Infants under one year exhibit the highest incidence of *Salmonella* spp., likely due to their vulnerable immune systems and increased exposure to contaminated food or water sources, making them more susceptible to severe outcomes like bacteremia and meningitis. Variations in the study year, data sources, and parameter distributions could explain some differences. Additionally, this study acknowledges potential

TABLE 1. Prevalence of five pathogens across different genders and age groups based on the foodborne diseases surveillance system in China, 2023.

Group	Prevalence (%) (positive cases/total cases) 95% *CI*					
	***Salmonella* spp.**	***Shigella* spp.**	***Vibrio parahaemolyticus***	**Diarrheagenic *E. coli***	**Norovirus**	**All**
Gender						
Male	6.74 (6,172/91,563) (6.58, 6.91)	0.09 (68/79,596) (0.07, 0.11)	0.98 (884/90,096) (0.92, 1.05)	2.68 (2,073/77,430) (2.56, 2.79)	12.71 (6,675/59,463) (12.47, 12.97)	18.77 (17,413/92,774) (18.52, 19.02)
Female	6.15 (4,926/80,145) (5.98, 6.31)	0.09 (85/90,931) (0.08, 0.12)	1.24 (976/78,881) (1.16, 1.32)	2.46 (1,670/67,760) (2.35, 2.58)	11.23 (8,709/68,499) (10.97, 11.48)	17.11 (13,885/81,172) (16.85, 17.37)
χ^2	24.87	0.22	25.11	6.42	66.54	81.09
P	<0.001	0.64	<0.001	0.01	<0.001	<0.001
Age, years						
<1	18.90 (2,204/11,660) (18.20, 19.62)	0.10 (11/11,441) (0.05, 0.17)	0 (0/11,280) (0, 0.03)	1.76 (185/10,524) (1.52, 2.03)	10.21 (926/9,067) (9.60, 10.85)	27.46 (3,248/11,830) (26.65, 28.27)
1–4	13.40 (3,942/29,419) (13.01, 13.79)	0.11 (31/29,043) (0.07, 0.15)	0.02 (5/28,463) (0.01, 0.041)	2.33 (625/26,818) (2.15, 2.52)	17.59 (4,219/23,987) (17.11, 18.08)	28.45 (8,581/30,163) (27.94, 28.96)
5–9	5.55 (531/9,562) (5.10, 6.03)	0.19 (18/9,510) (0.11, 0.30)	0.08 (7/9,306) (0.03, 0.15)	2.08 (178/8,549) (1.79, 2.41)	14.09 (1,104/7,837) (13.32, 14.88)	18.19 (1,792/9,849) (17.44, 18.97)
10–14	3.01 (182/6,040) (2.60, 3.48)	0.15 (9/6,010) (0.07, 0.28)	0.40 (24/5,941) (0.26, 0.60)	2.33 (121/5,192) (1.94, 2.78)	11.39 (535/4,696) (10.50, 12.34)	13.73 (842/6,134) (12.87, 14.61)
15–19	2.54 (282/11,118) (2.25, 2.85)	0.05 (6/11,090) (0.02, 0.12)	0.84 (93/11,071) (0.68, 1.03)	3.01 (267/8,873) (2.66, 3.39)	12.45 (998/8,015) (11.74, 13.19)	14.07 (1,582/11,243) (13.43, 14.73)
20–24	2.11 (221/10,490) (1.84, 2.40)	0.06 (6/10,474) (0.02, 0.12)	1.74 (182/10,439) (1.50, 2.01)	3.50 (299/8,543) (3.12, 3.91)	12.97 (984/7,587) (12.22, 13.75)	15.46 (1,634/10,572) (14.77, 16.16)
25–34	2.74 (679/24,779) (2.54, 2.95)	0.07 (16/24,692) (0.04, 0.11)	2.38 (587/24,688) (2.19, 2.58)	3.37 (665/19,707) (3.13, 3.64)	14.04 (2,483/17,679) (13.54, 14.57)	17.05 (4,266/25,025) (16.58, 17.52)
35–44	2.94 (466/15,825) (2.69, 3.22)	0.05 (8/15,768) (0.02, 0.10)	2.45 (385/15,720) (2.21, 2.70)	3.39 (434/12,801) (3.08, 3.72)	11.78 (1,317/11,184) (11.18, 12.39)	15.76 (2,516/15,963) (15.20, 16.34)
45–54	4.31 (619/14,349) (3.99, 4.66)	0.11 (15/14,257) (0.06, 0.17)	1.62 (230/14,154) (1.42, 1.85)	2.32 (274/11,818) (2.05, 2.61)	9.02 (918/10,181) (8.47, 9.59)	13.84 (2,001/14,453) (13.29, 14.42)
55–64	4.66 (739/15,871) (4.33, 5.00)	0.09 (14/15,779) (0.05, 0.15)	1.4 (219/15,653) (1.22, 1.60)	2.54 (336/13,244) (2.28, 2.82)	8.29 (943/11,369) (7.79, 8.82)	13.74 (2,195/15,979) (13.21, 14.28)
65–74	5.13 (705/13,741) (4.77, 5.51)	0.08 (11/13,672) (0.04, 0.14)	0.76 (103/13,579) (0.62, 0.92)	2.08 (241/11,611) (1.82, 2.35)	6.38 (635/9,953) (5.91, 6.88)	12.00 (1,661/13,837) (11.47, 12.56)
75–84	6.17 (419/6,789) (5.61, 6.77)	0.12 (8/6,738) (0.05, 0.23)	0.32 (21/6,656) (0.20, 0.48)	1.66 (96/5,794) (1.34, 2.02)	5.01 (246/4,912) (4.41, 5.66)	11.34 (774/6,824) (10.60, 12.12)
≥85	5.28 (109/2,065) (4.35, 6.33)	0 (0/2,053) (0, 0.18)	0.20 (4/2,027) (0.05, 0.50)	1.28 (22/1,716) (0.81, 1.93)	5.08 (76/1,495) (4.03, 6.32)	9.93 (206/2,074) (8.68, 11.30)
χ^2	7,204.00	-	1,343.60	209.22	1,673.40	4,257.90
P	<0.001	0.035*	<0.001	<0.001	<0.001	<0.001

Note:"-"not applicable

Abbreviation: *CI*=confidence intervals.

* *P* values were calculated using fisher's exact probability method.

underestimations due to only sending a portion of collected fecal specimens for testing at sentinel hospitals. The The prevalence of *Vibrio parahaemolyticus* was mainly occurs in coastal provinces. The estimated incidence is higher than that reported by Li et al. (806 cases per 100000 people), but lower than that estimated by Chen et al. (206 cases per 100,000 population). However, it was considerably higher than those reported in the United Kingdom (<1 case per 100,000 population), Australia (4 cases per 100,000 population), and the United States (12 cases per 100,000 population) (*5*–*8*,*10*). The 35–44 age group showed the highest incidence of *Vibrio parahaemolyticus*, likely due to a preference for consuming raw or undercooked seafood, including shellfish. Since the COVID-19 pandemic, the newly identified serotype O10:K4 has frequently been detected in sporadic and outbreak cases in China (*11*), gradually supplanting the traditionally dominant serotype O3:K6 (*12*). Ongoing pathogen surveillance and tracing are critical to address this shift. *Shigella* spp. demonstrated an overall low incidence, attributed

TABLE 2. Prevalence of five pathogens in different administrative area groups based on foodborne diseases surveillance symstem in China, 2023.

Area	Prevalence (%) (positive cases/total cases) 95% *CI*					
	***Salmonella* spp.**	***Shigella* spp.**	***Vibrio parahaemolyticus***	**Diarrheagenic *E. coli***	**Norovirus**	**All**
Northeastern China	2.27 (218/9,618) (1.98, 2.58)	0.07 (7/9,601) (0.03, 0.15)	1.12 (107/9,595) (0.91, 1.35)	0.41 (39/9,596) (0.29, 0.56)	4.61 (307/6,664) (4.12, 5.14)	6.91 (668/9,673) (6.41, 7.43)
Eastern China	5.88 (4,347/73,886) (5.71, 6.06)	0.03 (19/73,749) (0.02, 0.04)	1.82 (1,343/73,788) (1.72, 1.92)	4.02 (2,109/52,508) (3.85, 4.19)	13.3 (6,999/52,620) (13.01, 13.59)	19.24 (14,322/74,420) (18.96, 19.53)
Central China	7.48 (1,340/17,926) (7.09, 7.87)	0.06 (11/17,695) (0.03, 0.11)	0.12 (21/17,355) (0.08, 0.18)	1.95 (337/17,276) (1.75, 2.17)	10.12 (1,582/15,632) (9.65, 10.60)	17.50 (3,196/18,263) (16.95, 18.06)
Northern China	4.90 (1,050/21,441) (4.61, 5.19)	0.08 (16/21,451) (0.04, 0.12)	1.05 (223/21,183) (0.92, 1.20)	4.48 (856/19,120) (4.19, 4.78)	11.44 (18,70/16,341) (10.96, 11.94)	17.62 (3,828/21,723) (17.12, 18.14)
Southern China	16.54 (2,518/15,228) (15.95, 17.14)	0.10 (15/14,607) (0.06, 0.17)	0.93 (136/14,576) (0.78, 1.10)	0.54 (79/14,573) (0.43, 0.68)	12.52 (1,124/8,977) (11.84, 13.22)	24.91 (3,816/15,321) (24.22, 25.60)
Northwestern China	3.56 (555/15,572) (3.28, 3.87)	0.36 (55/15,455) (0.27, 0.46)	0 (0/14,959) (0, 0.03)	1.72 (264/15,380) (1.52, 1.93)	12.31 (1,571/12,767) (11.74, 12.89)	14.92 (2,379/15,947) (14.37, 15.48)
Southwestern China	5.93 (1,070/18,037) (5.59, 6.29)	0.17 (30/17,969) (0.11, 0.24)	0.17 (30/17,521) (0.12, 0.24)	0.35 (59/16,737) (0.27, 0.45)	12.91 (1,931/14,961) (12.37, 13.45)	16.61 (3,089/18,599) (16.08, 17.15)
χ^2	3,218.86	170.36	813.53	1530.42	500.59	1,512.61
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total	6.46 (11,098/171,708) (6.35, 6.58)	0.09 (153/170,527) (0.08, 0.11)	1.10 (1,860/168,977) (1.05, 1.15)	2.58 (3,743/145,190) (2.50, 2.66)	12.02 (15,384/127,962) (11.84, 12.20)	17.99 (31,298/173,946) (17.81, 18.17)

Note: Northeastern China includes Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang PLADs and XPCC; eastern China includes Shanghai, Shandong, Jiangsu, Anhui, Jiangxi, Zhejiang, and Fujian PLADs; central China includes Henan, Hubei, and Hunan PLADs; northern China includes Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia PLADs; southern China includes Guangxi, Guangdong, and Hainan PLADs; northwestern China includes Liaoning, Jilin, and Heilongjiang PLADs; southwestern China includes Chongqing, Sichuan, Guizhou, Yunnan, and Xizang PLADs.

Abbreviation: *CI*=confidence intervals; PLAD=provincial-level administrative divisions; XPCC=Xinjiang Production and Construction Corps.

to improvements in healthcare facilities and dietary habits in China. However, in Northwestern China such as Xinjiang Uygur and Xizang Autonomous Regions, where local dietary customs differ, the prevalence of *Shigella* spp. remains relatively high. It is crucial to conduct food safety and health education programs in these areas. This study primarily estimated the incidence of DEC, as only a limited number of sentinel hospitals conducted specific typing and identification. The potential adoption of culture-independent diagnostic testing (CIDT) methods is expected to address this issue gradually. Overall, the incidence of DEC is likely underestimated.

The study is subject to some limitations. First, the estimated incidence may be biased toward PLADs with higher reporting rates, which could affect the calculation of regional incidence rates. Second, the inclusion of data from a previous community AGI survey introduces a temporal discrepancy, potentially rendering the data unreflective of current conditions. Additionally, the lack of detailed information on population distribution concerning AGI and fecal retention cases required that age and gender distributions be inferred solely from the submitted case reports, without accounting for uncertainty. Finally, the reliance on test results from sentinel hospitals to indicate pathogen detection capabilities presupposes uniform sensitivity across all pathogens, an assumption that may not hold true.

This study provides the first estimates of the incidence of five pathogens, classified by age and gender, derived from active surveillance data on foodborne diseases in China. These findings serve as a crucial foundation for informed decision-making and regulation in assessing food safety risks based on disease burden. To maintain current data on disease trends and support effective supervision and management of food safety, continued surveys of the AGI population and the monitoring of sentinel hospitals are recommended.

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TABLE 3. Incidence estimates of five pathogens in different genders and ages groups based on the pyramid model in China, 2023.

Group	Incidence (case/100,000) (95% *UI*)				
	Salmonella spp.	*Shigella* spp.	*Vibrio parahaemolyticus*	Diarrheagenic *E. coli*	Norovirus
Gender					
Male	1,324.47 (1,043.45, 1,607.92)	27.80 (21.90, 33.75)	373.64 (294.46, 453.49)	813.56 (640.69, 987.94)	3,345.81 (2,635.12, 4,063.80)
Female	1,265.34 (996.69, 1,536.63)	25.60 (20.16, 31.10)	435.94 (343.50, 529.20)	750.20 (590.82, 911.17)	3,023.19 (2,380.51, 3,672.95)
Age, years					
<1	5,559.18 (4,377.10, 6,751.43)	27.03 (21.29, 32.82)	0 (-)	507.70 (399.86, 616.68)	2,939.71 (2,313.59, 3,572.02)
1–4	3,927.84 (3,096.26, 4,765.52)	31.62 (24.93, 38.35)	5.13 (4.04, 6.22)	672.67 (530.44, 816.08)	5,133.68 (4,047.24, 6,229.35)
5–9	1,628.83 (1,282.83, 1,978.76)	53.32 (41.99, 64.78)	21.24 (16.73, 25.80)	607.53 (478.28, 738.45)	4,111.88 (3,236.75, 4,997.10)
10–14	877.93 (690.30, 1068.42)	50.57 (39.75, 61.57)	119.44 (93.88, 145.38)	690.05 (542.48, 840.14)	3,315.67 (2,604.74, 4,038.34)
15–19	743.20 (585.17, 902.74)	16.18 (12.74, 19.65)	243.84 (192.00, 296.12)	867.61 (683.00, 1,054.17)	3,584.01 (2,821.13, 4,356.19)
20–24	614.06 (483.66, 745.71)	17.25 (13.59, 20.96)	510.95 (402.41, 620.53)	1,026.32 (808.21, 1,246.93)	3,808.68 (2,998.18, 4,629.28)
25–34	798.92 (629.93, 969.42)	18.83 (14.84, 22.86)	695.65 (548.52, 843.96)	9,89.51 (779.44, 1,200.81)	4,116.38 (3,243.89, 4,996.47)
35–44	861.31 (678.73, 1,045.43)	14.84 (11.69, 18.01)	716.57 (564.79, 869.70)	990.76 (780.37, 1,202.92)	3,440.00 (2,710.14, 4,177.66)
45–54	1,269.18 (999.93, 1,540.39)	31.56 (24.87, 38.30)	466.21 (367.31, 565.90)	679.32 (535.09, 824.79)	2,642.93 (2,081.75, 3,209.47)
55–64	1,370.00 (1,079.77, 1,662.86)	26.74 (21.06, 32.45)	403.92 (318.27, 490.30)	743.67 (585.94, 902.83)	2,410.79 (1,899.08, 2,927.11)
65–74	1,502.83 (1,183.62, 1,824.64)	23.23 (18.30, 28.20)	220.93 (173.98, 268.26)	605.61 (476.94, 735.36)	1,864.06 (1,467.48, 2,264.44)
75–84	1,799.33 (1,415.88, 2,187.36)	34.66 (27.27, 42.15)	91.80 (72.23, 111.61)	483.44 (380.21, 588.18)	1,462.72 (1,150.12, 1,779.98)
≥85	1,583.40 (1,239.52, 1,937.40)	0 (0, 0)	63.98 (50.07, 78.31)	367.21 (286.90, 450.27)	1,472.45 (1,149.39, 1,808.13)
Total	1,295.59 (1,020.62, 1,573.11)	26.73 (21.05, 33.46)	404.06 (318.41, 491.45)	782.62 (616.34, 950.46)	3,188.28 (2,510.80, 3,872.96)

Note:"-"not applicable

Abbreviation: *UI*=uncertainty intervals.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Variables for reconstructing the pyramid model for a specific pathogen in different age and gender.

Variables	Description	Distribution/Formula
a*	Probability of seek medical care	beta (a_1+1,a_2-a_1+1)
b*	Probability of submitting a stool specimen	beta (b_1+1,b_2-b_1+1)
c*	Probability of analysing a pathogen in specimens	beta (c_1+1,b_1-c_1+1)
d*	Sensitivity of laboratory analysis	beta (d_1+1,d_2-d_1+1)
e	Probability of diarrhea caused by five pathogens	beta (e_1+1,e_2-e_1+1)
f*	AGI incidence per person-year	norm (0.28,0.03)
b_1	Number of seek medical care of in SH	Data;
b_2	Number of seek submitting a stool specimen	Data;
c_1	Number of analysing a pathogen	Data;
m	Number of positive specific pathogen detected in SH	Data;
n	The actual number of cases of a specific pathogen in the population covered by SH	$m/(a \cdot b \cdot c \cdot d)$
N	The actual population of the community covered by SH	$b_1/(e \cdot f \cdot a)$
p	Incidence of specific pathogen	n/N

Abbreviation: SH=sentinel hospitals; AGI=acute gastroenteritis.

* The results are derived from previous national community-based AGI survey. a_1=346, number of seek medical care from AGI in community survey. a_2=948, number of total AGI in community survey. d_1=434, number of sentinel hospitals passing check. d_2=471, number of all sentinel hospitals participating check. e_1=28838, number of AGI with diarrhea in community survey. e_2=30048, number of AGI in community survey.

Outbreak Reports

Two Photosensitive Dermatitis Outbreaks Caused by *Cordierites frondosus* — Chuxiong Yi Autonomous Prefecture, Yunnan Province, China, 2023

Jiaju Zhong[1,2]; Hongshun Zhang[1]; Chengmin Yu[2]; Jipin Li[2]; Yizhe Zhang[1]; Jiaqi Liang[1]; Chengye Sun[1,#]; Qunmei Yao[2,#]

Summary

What is already known about this topic?

Cordierites frondosus (*C. frondosus*) is a species of toxic mushroom known to induce symptoms of photosensitive dermatitis.

What is added by this report?

In the months of May and June 2023, a total of four patients in Chuxiong Yi Autonomous Prefecture, Yunnan Province, were affected by *C. frondosus* poisoning, occurring over two distinct incidents. The condition of two patients deteriorated after they were re-exposed to sunlight on the seventh day following the initial poisoning. Separately, an additional two patients reported experiencing a mild, needle-like sensation on areas of their skin exposed to the sun, recorded on the twelfth day subsequent to the poisoning.

What are the implications for public health practice?

Given that symptoms of photosensitive dermatitis, a potential severe consequence of *C. frondosus* poisoning, can manifest up to a week post-sun exposure, it is advisable to avoid sunlight for a minimum of two weeks following poisoning.

Between May 17 and June 9, 2023, four cases of suspected mushroom poisoning were treated at the People's Hospital of Chuxiong Yi Autonomous Prefecture. The patients presented with photosensitive dermatitis 21 to 45 hours after ingesting wild "wood ear" mushrooms. The China CDC partnered with the local hospital to investigate the incidents. A comprehensive examination — involving epidemiological investigations, assessing clinical symptoms, and performing morphological and molecular identifications of the toxic mushrooms — suggested that the poisonings were triggered by the inadvertent consumption of *Cordierites frondosus* (Kobayasi) Korf (*C. frondosus*). This is a wild mushroom species that bears a striking resemblance to the traditionally edible *Auricularia* fungi. For two of the patients, the symptoms intensified upon re-exposure to sunlight a week following the ingestion, while the other two exhibited cutaneous photosensitivity up to 12 days post-poisoning. This underscores the alarmingly prolonged duration and the severity of *C. frondosus* poisoning. Following these incidents, extensive public education and outreach initiatives were disseminated through official platforms to mitigate risks of *C. frondosus* ingestion and to aid in distinguishing it from safe-to-eat wood ears. Pleasingly, these measures resulted in no further cases being reported until October in Chuxiong.

INVESTIGATION AND RESULTS

On May 17, 2023, two patients suspected of mushroom poisoning were treated at the People's Hospital of Chuxiong Yi Autonomous Prefecture. Both patients exhibited definitive symptoms of photosensitive dermatitis, such as redness, swelling, itching, blister formation, and sharp pain in the facial region and the dorsal surface of their hands. These symptoms were amplified upon exposure to sunlight. On June 9, the hospital admitted two more patients, revealing similar symptoms (Figure 1A). All patients had consumed "wood ears" prior to the manifestation of these symptoms, prompting the hypothesis of photosensitive dermatitis induced by mushroom poisoning. In response to these cases, the China CDC and the hospital initiated case-finding and epidemiological investigations. The criteria for the definition of these cases were: patients with a history of "wood ears" consumption and manifested symptoms of photosensitive dermatitis during the period of May to June.

Four cases, comprised of three males and one female aged 45 to 57, were identified in Cangling District,

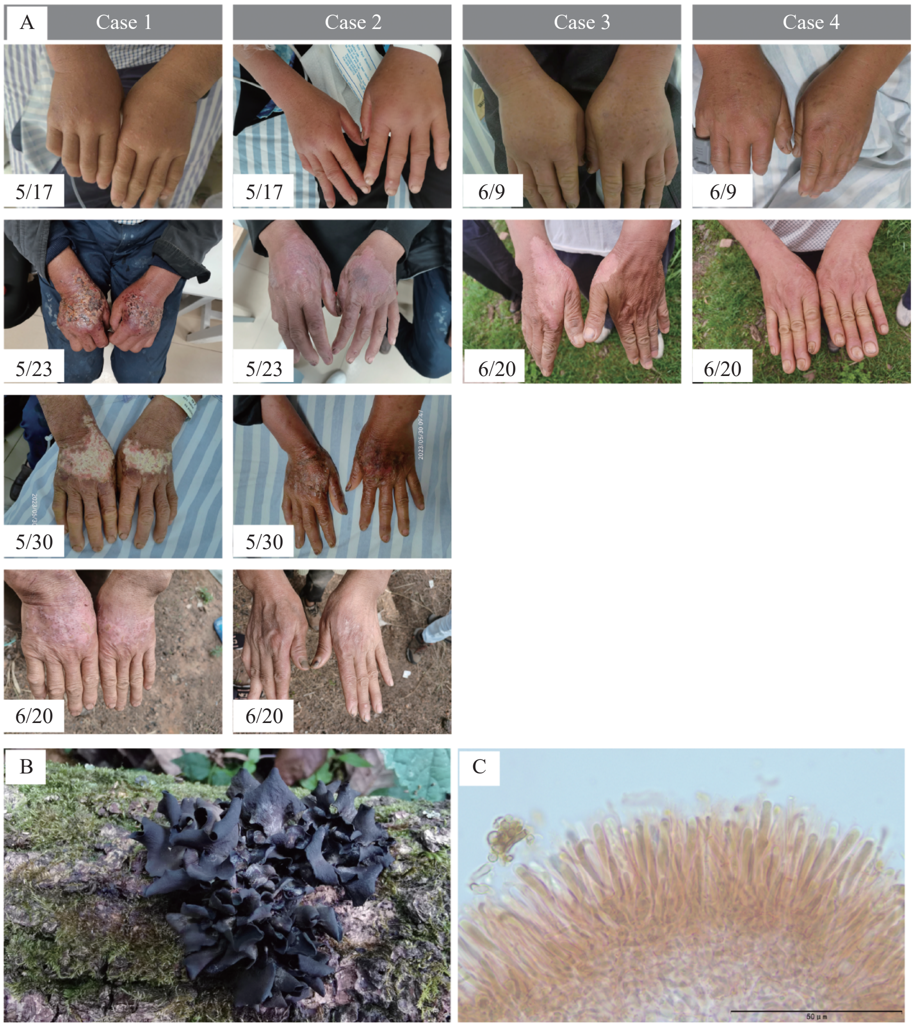

FIGURE 1. Photographs from the patients and morphological characteristics of *Cordierites frondosus*. (A) Images of photosensitive dermatitis on the dorsal surfaces of the hands from four patients in Chuxiong, Yunnan Province, captured in May and June 2023. (B) Ascoma; (C) Asci of *Cordierites frondosus*.

Note: Upon admission to the hospital on May 17 and June 9, all patients presented with mild erythema, edema, and vesicles on the dorsum of their hands. Case 1 showed symptom progression with the formation of ulcers and erosions following re-exposure to sunlight on May 23. These ulcers and erosions persisted in Case 1 and Case 2 as of May 30. By June 20, desquamation and scarring were evident on the dorsal surface of the hands in all patients.

Chuxiong Yi Autonomous Prefecture, Yunnan Province. The subjects, all rural dwellers who lived approximately 30 kilometers apart, met the case criteria. Two patients manifested gastrointestinal symptoms three hours after mushroom consumption. Subsequent development of photosensitive dermatitis in all patients occurred 21 to 45 hours after consuming 30–50 g of mushrooms. Laboratory results demonstrated minor myocardial damage, lymphocyte irregularities, and a significant increase in the inflammatory cytokine, interleukin 6 (Table 1). Case severity was correlated with high poisonous mushroom intake and exposure to sunlight. Preventive measures included isolating patients from sunlight while therapeutic approach encompassed administration of dexamethasone, vitamin C, chlorpheniramine maleate, and calcium gluconate for anti-inflammatory, antioxidant, and anti-allergic effects. Sufentanil was supplied via infusion pumps for pain relief.

The epidemiological investigation shed light on the unfolding of the poisoning event. On the morning of May 15, 2023 — a day varying between rainy and cloudy weather — a farmer foraged around 80 g of “wood ear” mushrooms from deciduous trees near his home. These mushrooms were subsequently used in a rice noodle lunch dish at 11:00, that he and his wife consumed. By 14:00, both began to exhibit symptoms indicative of food poisoning, such as nausea, vomiting,

TABLE 1. Demographic and clinical data for four patients with *Cordierites frondosus* poisoning.

Patients	References	Case 1	Case 2	Case 3	Case 4
Sex		Female	Male	Male	Male
Age (years)		57	57	49	45
Medical history		–	–	–	Diabetes
Mushrooms ingested (g)		50	30	30	20
Ingestion to gastrointestinal symptoms onset (h)		3	3	–	–
Ingestion to photosensitive dermatitis onset (h)		39	45	21	21
Ingestion to hospital admission (h)		51	51	36	36
Hospitalization duration (days)		13	11	5	5
Outcome		Recovered	Recovered	Recovered	Recovered
Alanine aminotransferase (U/L)	7–40	28	28	26	44
Aspartate amino transferase (U/L)	13–35	32	48	104	64
Total bilirubin (μmol/L)	3–22	19.4	16.1	21.9	32.7
Blood urea nitrogen (mmol/L)	3.2–7.1	3.42	4.23	6.18	4.31
Serum creatinine (μmol/L)	58–110	42.1	79.2	58.9	47.8
Creatine kinase (U/L)	30–153	56	474	1284	341
Creatine kinase isoenzyme (U/L)	0–24	50.6	44.3	64.7	114.6
Interleukin 6 (pg/mL)	0–7	50.98	36.85	10.02	23.65
White blood cell count (10^9/L)	3.5–9.5	10.16	15.94	6.37	13.18
Neutrophil count (10^9/L)	1.8–6.3	8.93	15.5	5.3	12.77
Lymphocyte count (10^9/L)	1.1–3.2	0.32	0.39	0.67	0.33
Monocyte count (10^9/L)	0.1–0.6	0.03	0.04	0.4	0.05
Eosinophil count (10^9/L)	0.02–0.52	0	0	0	0
Basophil count (10^9/L)	0–0.06	0.01	0.01	0	0.03

Note: "−" indicates no past medical history.

and diarrhea. For the rest of that day and the next day, which was cloudy transitioning to sunny weather, the couple consumed standard meals excluding mushrooms and partook in outdoor activities. However, by the early morning hours of May 17, a sunny day, they developed photosensitive dermatitis. The distressing symptoms led them to seek medical intervention at 14:00 that day. Their symptoms improved considerably by May 22, another sunny day, upon which they requested discharge. Nevertheless, they had to be readmitted the following day due to deterioration of their symptoms after exposure to sunlight. The condition of their skin, particularly on the back of their hands, worsened, developing into ulcers and erosions. They underwent topical treatments involving fusidic acid cream, halometasone cream, and silver sulfadiazine cream. Discharged on May 28 and May 31, their health showed noticeable improvement. A follow-up examination on June 20 reported significant recovery, however, the backs of their hands displayed extensive scarring (Figure 1A).

On a rainy morning of June 8, 2023, a farmer collected approximately 50 g of "wood ear" mushrooms from deciduous trees near his dwelling to include in his lunch. His younger brother and wife also partook in the noontime meal, which consisted of pan-fried pork, vegetable soup, and rice. The wife, however, refrained from eating the gathered mushrooms. Moreover, both brothers drank alcohol with their meals. That afternoon, they abstained from outdoor activity, consuming a mushroom-free dinner later. By 9:00 the next day, which transitioned from rain to overcast weather, both siblings started showing signs of photosensitive dermatitis (Figure 1A) while laboring outside and sought medical aid at 21:50 that night. It is noteworthy to mention that the farmer's wife didn't exhibit any symptoms indicative of poisoning. Both patients witnessed improvement and were discharged from the hospital on June 14, another rainy day. However, during a subsequent check-up conducted on a sunny day on June 20, it was revealed that while their recovery was significant, they continued to feel a mild needle-like sensation on their faces and the backs of their hands when exposed to sunlight.

The mushroom samples were re-gathered from the exact location where the patients had previously collected their specimens. Initial identification was based on the observation of macroscopic features such as color, size, and shape, in addition to microstructural elements like asci and ascospores. For molecular identification, we sequenced the internal transcribed spacer (ITS) sequences, and conducted a phylogenetic analysis using the maximum parsimony (MP) method (ITS GenBank accession numbers OR884094, OR885350). We confirmed that both samples were *C. frondosus* specimens (Figure 1B&C). By associating the results of species identification with the patients' clinical manifestations, it was inferred that both episodes were caused by *C. frondosus*, resulting in photosensitive dermatitis.

PUBLIC HEALTH RESPONSE

Local officials in Chuxiong have installed informational signs in every village about the poisonous mushrooms indigenous to Yunnan. These signs aim to educate the residents on identifying toxic mushrooms and comprehending the risks associated with mushroom poisoning. Since the implementation of this measure, no additional instances of similar poisoning have been reported in the region.

DISCUSSION

Mushroom toxicity presents a pressing food safety issue in China, particularly in Yunnan Province (*1–4*). Statistically, 31.8% of foodborne disease outbreaks and 47.4% of corresponding mortalities nationwide are associated with mushroom poisoning (*3*). Disconcertingly, Yunnan Province bears the brunt of this epidemic, responsible for 40% of outbreaks, 43.6% of illnesses, and 41% of fatalities attributed to mushroom poisoning (*4*). A particular concern is the incidence of photosensitive dermatitis caused by *C. frondosus* in Chuxiong Yi Autonomous Prefecture, Yunnan Province, with 43 documented poisoning episodes from 2015 to 2020 (*5*). Additionally, *Bulgaria inquinans*, another mushroom species, similarly evokes photosensitive dermatitis (*6*). Given their distribution throughout various regions of China (*6–7*), the collection and consumption of these photosensitive mushrooms imply a widespread risk across the country.

In concurrence with earlier research, the patient in the present study showed signs of photosensitive dermatitis, marked by erythema, swelling, a burning sensation, pruritus, blisters, and skin peeling, in tandem with elevated levels of the inflammation indicator, interleukin 6, and irregularities in inflammatory cells (*8–10*). Therefore, the initial treatment strategies comprise avoiding light exposure and administering therapies with antioxidant, anti-inflammatory, and antihistaminic properties (*8*). A recent finding suggests that patients' conditions worsened when re-exposed to sunlight a week after ingesting *C. frondosus* mushrooms. The prolonged presence of photosensitivity symptoms for as long as 12 days post-ingestion underscores the extended elimination period for photosensitizing agents in cases of *C. frondosus* poisoning. Notably, there have been fatal incidents of laryngeal edema in children and reports of patients needing up to 15 days of hospitalization due to severe poisoning (*9–10*). Based on these observations, it is advisable to avoid sun exposure for a minimum of two weeks following intoxication with this mushroom species.

Addressing the issue of mushroom poisoning requires multidisciplinary collaboration. It is critical that government and health authorities enforce restrictions against the collection and consumption of *C. frondosus*. Agencies responsible for disease prevention and control need to raise awareness of the characteristics and risks associated with this mushroom, in order to avert unintentional consumption by the public. Biologists have a crucial role in accurately identifying toxic mushrooms essential for clinical diagnosis. In situations of inadvertent consumption, it is paramount to seek immediate medical help and counsel patients to avoid sun exposure. Any leftover mushroom samples should be brought in for examination. Medical facilities must promptly report any cases and administer effective treatment methods to mitigate patient conditions and prevent fatalities.

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Perspectives

Potential Provoking Effects of Environmental Pollutants on Food Allergy: An Issue That Is Gaining Increasing Attention

Yiyun Zhang[1,2,3]; Lei Zhang[2,3,#]; Di Wu[4]; Yongning Wu[1,2,3,#]

Allergic diseases are widespread globally, affecting over 40% of the population. Food allergy (FA), characterized by an abnormal immune response to harmless proteins in foods, is one of these prevalent conditions. Current estimates suggest that approximately 220 million people worldwide suffer from FA (*1*). In children, over one-third of parents report their children experiencing hypersensitive reactions to food, with FA affecting around 8% of this demographic. In China, 11.5% of individuals report having a physician-diagnosed FA [95% Confidence Interval(*CI*): 9.8%, 13.5%]. Notably, the prevalence of FA has increased significantly within a single generation, as evidenced by studies showing a rise in prevalence from 3.5% to 11.1% between 1999 and 2019 (*2–3*). This sharp increase coincides with rapid industrialization and urbanization, elevating FA to a major public health issue. While genetic factors contribute to around 50% of the susceptibility to allergic diseases (*4*), the dramatic rise in FA prevalence cannot solely be attributed to genetic changes alone. Environmental factors, particularly pollutants, are increasingly recognized as significant contributors to the development of FA (*5*). For instance, higher serum levels of perfluoroalkyl and polyfluoroalkyl substances have been associated with increased self-reported FA in adolescents (*6–7*). The widespread dispersion of pollutants such as persistent endocrine-disrupting compounds, persistent organic pollutants (POPs), fine particulates (FPs), and emerging contaminants like pharmaceutical and personal care products (PPCPs) follows industrial and urban expansion. These pollutants pose considerable health risks (*8*) and have been linked to the onset of allergic diseases (*9–10*). They can modify immune responses, leading to immunotoxic effects. The dual allergen exposure hypothesis suggests that disruptions to epithelial barrier integrity, along with microbial dysbiosis and immune dysregulation, are plausible mechanisms for the development of FA (*6,11*). At the molecular level, processes such as the acute inflammatory response, reactive oxygen species (ROS) generation, neutrophil activation, inflammatory cytokine expression, immune cell signaling disruptions, and apoptosis are implicated in the interaction between environmental pollutants and the immune system (*10*). However, the long-term effects of these pollutants on FA prevalence remain poorly understood.

This narrative review offers a comprehensive examination of risk factors for FA, particularly emphasizing the role of environmental pollutants.

THE GENETICS OF FA

The development of FA is influenced by intricate genetic mechanisms. Research into familial heritability has established a genetic foundation for FA (*1*). Both genome-wide association studies and candidate gene studies confirm that FA are inheritable, associating this condition with variances in the Human Leukocyte Antigen DR/DQ region and genes such as Filaggrin, Human Leukocyte Antigen, and Forkhead Box P3. Studies involving twin pairs reveal significantly higher concordance rates for sensitization in monozygotic twins compared to dizygotic twins. Moreover, children with two or more allergic family members face an increased likelihood of developing FA. Specifically, genetic studies on shellfish and peanut allergies suggest that genetic factors contribute to approximately 50% of the heritability of these allergies (*4*).

ASSOCIATIONS BETWEEN ENVIRONMENTAL POLLUTANTS AND FA

Although genetic factors are significant in the development of FA, environmental factors also play a vital role. Recent decades have seen an increase in the prevalence of FA, which has raised concerns regarding environmental pollutants. Numerous pollutants are known to disrupt immune responses and result in immunotoxicity (*6*). The potential causal link between FA and exposure to environmental pollutants remains under-investigated. Research utilizing data from the 2005–2006 National Health and Nutrition Examination Survey in the US indicated that increased urinary levels of triclosan, a common EDC, were associated with specific FA in males (*12*). Additionally, exposure to bisphenol A diglycidyl ether may enhance food sensitization in early childhood (*13*). In a weaning mouse model for food sensitization, di(2-ethylhexyl) phthalate acted as an immunoadjuvant, augmenting ovalbumin-specific IgE and IgG1 production, and induced an imbalanced humoral immune response. The development of FA involves a complex two-step process of sensitization and the manifestation of clinical symptoms, with sensitization serving as the foundation for allergies and a focus of many studies (*14*). Collectively, these findings suggest that exposure to environmental pollutants may contribute to the development or exacerbation of FA, underscoring the need for further research into the underlying mechanisms.

UNDERLYING MECHANISM OF ENVIRONMENTAL POLLUTANTS TO FA

Immunotoxicity plays a significant role in the onset of allergic diseases, including FA and asthma, via intricate mechanisms (*5*). Increasing evidence is elucidating the pathophysiological pathways and immunotoxicological impacts of human exposure to environmental pollutants (*15*). At present, direct studies examining the connection between environmental pollutants and FA are scarce; however, several potential mechanisms have been proposed.

The mechanisms by which pollutants contribute to the onset of allergic diseases are complex and multifaceted. Current research is deepening our understanding of the interaction between the epithelial barrier and inflammatory responses (*15*). The dual allergen exposure hypothesis posits that disruptions to the epithelial barrier by various factors are associated with numerous immune-related conditions, including allergies. Pollutants compromise epithelial barrier function, initiate inflammatory immune reactions beneath the epithelium, and enhance exposure to allergens and irritants. Moreover, prolonged exposure to environmental toxins can alter the microbial landscapes of the tissues involved. Such disturbances may facilitate the growth of opportunistic pathogens, increasing the risk of inflammation, tissue damage, and chronic conditions. Impairments in the epithelial barrier, along with microbial dysbiosis, induce a Th2-biased immune response that is central to allergic sensitization and disease manifestation (*11*). These interactions indicate that environmental agents can undermine the protective barriers of the skin, airways, and gastrointestinal mucosa, rendering them susceptible to bacterial translocation and dysbiosis, which further contributes to the development of chronic immune-mediated and metabolic disorders.

Chronic exposure to environmental pollutants is known to induce immunotoxicity (*10*). Exposure to air pollution, for example, leads to the generation of ROS and other oxidative stresses in the airways, resulting in cellular damage that compromises epithelial integrity and increases permeability. In epithelial cells, polycyclic aromatic hydrocarbons (PAHs) activate the aryl hydrocarbon receptor and nuclear factor erythroid 2-related factor 2 , which enhances the production of cytokines such as IL-25, IL-33, and thymic stromal lymphopoietin, thereby promoting inflammatory responses (*9*,*11*). Furthermore, PAHs and other compounds stimulate AhR in keratinocytes, increasing the production of IL-33 and other factors that contribute to pruritus and atopic dermatitis (*10*). Exposure to bisphenol A and phthalates has been shown to suppress regulatory T cell (Treg) activities, elevate the expression of interferon-gamma (IFN-γ) and IL-10, and decrease the expression of transforming growth factor-beta (TGF-β), further promoting inflammatory responses. While molecular mechanisms associated with these effects are becoming clearer, significant knowledge gaps persist regarding the immunotoxic effects of environmental pollutants and their relationship with FA. Addressing these gaps requires a more detailed understanding of how specific pollutants contribute to the development of FA. Continued research is critical to fully elucidate these mechanisms.

DISCUSSION AND PERSPECTIVE

FA results from a complex interaction between genetic factors and environmental influences (*3*). Current epidemiological studies focusing on environmental exposure cohorts that comprehensively assess ‘environment-gene’ interactions are scarce (*12*). Moreover, the rise in allergy diseases has been associated with the adoption of a westernized lifestyle, marked by rapid urbanization and widespread use of cleaning products. Numerous theories have been suggested to elucidate the growing prevalence of allergic diseases linked to these lifestyle changes (*9*). The widely accepted dual allergen exposure hypothesis integrates the hygiene and biodiversity hypotheses (also known as the Old Friends Hypothesis). This theory links epithelial barrier defects and microbial dysbiosis with varying allergen exposure pathways, explaining how these can guide the immune response towards either tolerance or allergy in current models.

While the associations between environmental factors and allergic diseases has been explored, the complexities of these relationships remain incompletely understood (*9*). There remain substantial knowledge gaps in defining specific pollutants, exposure levels, and the mechanisms by which they trigger and exacerbate allergic reactions. Challenges persist in the accurate identification, detection, and risk assessment of environmental exposures, influenced by various factors including detection methodologies, modeling techniques, and limited data availability, which add uncertainty to these assessments (*8*). Furthermore, uncertainties also exist in the manifestations of FA reactions. For instance, a study found that over 50% of siblings of children with FA exhibited sensitization (as shown by positive skin prick tests or elevated IgE levels) without displaying clinical symptoms (*4*). Given the complex nature of FA symptoms and variable individual sensitivity influenced by factors such as stress, physical activity, and other health conditions, thresholds for FA may vary. Additionally, cross-reactivity among different foods and changes in an individual's allergic status over time — from sensitization to full-blown allergy — are possible. This highlights that the actual prevalence of FA could be underestimated, and suggests that the interplay between environmental factors and genetics could be more intricate than previously considered. Research into the links between sensitized populations and environmental pollutants could be valuable for the early detection and management of health risks associated with environmental pollution. In recent decades, the prevalence of FA in China has surged, aligning now with rates seen in developed western countries (*9*), primarily due to lifestyle shifts and environmental pollution from urbanization (*5*). In light of China's fast-paced economic development, there is a pressing need for enhanced preventive measures, better policy interventions, and improved treatment strategies to curb the rising prevalence and ensure food safety.

The significance of environmental pollutants in the onset of FA diseases is well-recognized, but the identification of specific culpable pollutants and the mechanisms by which they contribute remain poorly delineated. The current focus centers on pollutants known to pose health hazards and environmental risks even at low concentrations, including POPs, FPs, PPCPs, and pesticides. Strategies to mitigate these pollutants primarily involve reinforcing regulatory frameworks, implementing stringent standards, regular monitoring, and enhancing public awareness of environmental and health implications. Although the proactive elimination or control of these pollutants is critically discussed, efficient strategies are still insufficient. It is vital to further investigate the potential mechanisms through which environmental pollutants influence FA. Enhancing our understanding of these mechanisms is crucial for advancing public health and ensuring food safety, in line with the World Health Organization's food safety mandates for the 21st century.

Conflicts of interest No conflicts of interest.

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