

## Systematic Review

# Workplace exposure to aflatoxins & its health effects: A systematic review

Geethu Mathew<sup>1</sup>, Lavannya Mary Thayil<sup>4</sup>, Preetham Shenoy M.<sup>4</sup>, Meera Sasidharan<sup>4</sup>, Pawan Kumar B.<sup>4</sup>, Priya Selvam<sup>1</sup>, Shubhangi Pingle<sup>2</sup>, Raghavan Sampathraj<sup>3</sup>, Nanjesh Kumar S.<sup>4</sup>, Ravichandran Beerappa<sup>3</sup>, & Bhavani Shankara Bagepally<sup>5</sup>

*Departments of <sup>1</sup>Occupational Medicine, <sup>2</sup>Biochemistry, & <sup>3</sup>Industrial Hygiene and Toxicology, ICMR - Regional Occupational Health Centre (Southern), National Institute of Occupational Health, Bengaluru, <sup>4</sup>Department of Community Medicine, KS Hegde Medical Academy, Nitte, Mangaluru, Karnataka, & <sup>5</sup>Department of Health Systems Research, ICMR-National Institute of Epidemiology (NIE), Chennai, Tamil Nadu, India*

Received June 9, 2025; Accepted October 3, 2025; Published January 31, 2026

**Background & objectives:** Aflatoxins pose serious health risks to humans and livestock, with ingestion being the most common route of exposure. In occupational settings, workers can also be exposed through inhalation of organic dust and dermal contact. The review aimed to provide an overview of aflatoxin exposure and health effects among workers.

**Methods:** Observational studies investigating occupational exposure to aflatoxins and their health effects were systematically screened in PubMed, Embase, and Scopus till June 2024. Studies meeting inclusion criteria, were assessed for their methodological quality using the Newcastle-Ottawa Scale.

**Results:** Overall, 12,610 studies were screened of which 17 studies were included in the final review. Food-grain workers, farmers, millers, bakers, grain handlers, oil pressors, and feed mixers, are at a higher risk of occupational exposure to aflatoxins. Assessment of exposure was done by analysing biological fluids (Blood, Urine, and Bronchoalveolar lavage) and samples from the working environment (settled dust, airborne dust, and personal sampling) using enzyme-Linked Immunoassay and High-Performance Liquid Chromatography. Studies have shown an elevation of hepatic and renal enzymes, an increased risk for hepatobiliary cancer, and an increased risk for tumour markers, oxidative markers, and reduced antioxidant levels. One recent study has also found an association between aflatoxin exposure and weight for age and height among children of workers.

**Interpretation & conclusions:** Occupational exposure to aflatoxins is associated with hepatic and renal toxicity and increased carcinogenic risk. These findings highlight the need of large scale dose- response studies, workplace monitoring and regular health surveillance among workers.

**Key words** Aflatoxins - biological assessment - cancer - environmental assessment - food-grain workers - health effects

Aflatoxins, patulin, fumonisins, ochratoxins, zearalenone, and nivalenol/deoxynivalenol are the most frequently found mycotoxins that can cause potential harm to humans and animals<sup>1-4</sup>. Aflatoxins are

considered the most dangerous and potent carcinogens among all mycotoxins, attracting significant attention due to their harmful effects even at low concentrations<sup>4,5</sup>. Aflatoxins are a family of related Bis-furanocoumarin compounds produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*<sup>6,7</sup>. Aflatoxin-producing fungi proliferate rapidly on grains, seeds, nuts, and other foodstuffs, resulting in the contamination of approximately one-quarter of global agricultural commodities<sup>2</sup>. The prevalence of aflatoxin-producing fungi on cereal grains poses a significant health risk in Asian countries, where these staples constitute a substantial portion of the diet<sup>8</sup>. Although ingestion is the primary entry route for aflatoxin exposure<sup>9</sup>, workers can also be at risk through skin contact and inhalation of organic dust<sup>10,11</sup>. This puts them in additional risk compared to the general population, owing to the possibility of cumulative exposure through different routes<sup>12</sup>. Chronic exposure to aflatoxins, which primarily results from contaminated food, is known to have a number of long-term consequences, most notably growth impairment and liver cancer<sup>1</sup>.

Aflatoxin exposure has been linked to damage in various organs, including the kidney, liver, immune system, and central nervous system. It can lead to carcinogenicity, mutagenicity, and teratogenicity<sup>13-15</sup>. With no safe level of exposure defined among humans and a lack of a monitoring system in place, exposed workers are at a higher risk of adverse health effects<sup>16,17</sup>.

Most of the existing reviews on this topic are not recent and narrative in nature<sup>6,9</sup> and some of them dealt with all mycotoxins in general and their health effects<sup>1</sup>. This review aims to identify studies that assessed aflatoxin exposure in the workplace and its health impact on workers<sup>9,13</sup>.

## Materials & Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines<sup>18</sup>, ensuring a rigorous and standardized methodology. The protocol for the review was registered in Prospero (Prospero 2023- CRD42023451307).

*Search strategy:* A thorough search was conducted in electronic databases including PubMed, Scopus, and Embase to select articles from inception (an earliest study found was in the year 1984) to June 2024. A comprehensive search was conducted, including a manual review (perusing reference lists and hand searching in the library), to ensure no relevant articles

were inadvertently omitted. The search was conducted employing categories such as “occupational exposure”, “aflatoxins” and “health outcomes”. The complete search strategies based on the PICO format along with PRISMA checklist are reported in supplementary file:1 (11,907 in primary search till November 2023 and +703 articles in additional search in June 2024).

*Inclusion criteria:* We have included observational studies from inception to June 2024 investigating occupational exposure to aflatoxins among workers from different occupational settings and their associated health outcomes/effects.

*Exclusion criteria:* We have excluded studies on animals, languages other than English, review articles, opinions/case reports, study protocols, and those articles that dealt with aflatoxin exposure without health effects or/and without any occupational route of exposure. When necessary, corresponding authors of publications were contacted to seek the full text or any missing data needed for the review.

*Quality assessment:* The Newcastle-Ottawa Scale (NOS) was utilized to evaluate the methodological quality and potential for bias in the chosen observational studies. For cross-sectional, cohort, and case-control studies, there are specific NOS instruments with sections on exposure, outcome, comparability, and selection. Studies with a total score of six or higher, three to five, or less than three are categorized as high, medium, or low quality, respectively<sup>4,19</sup>.

## Results

*Data extraction:* The final included studies reference list was screened to get similar studies for the review. All identified studies, *i.e.* 12,610 in the initial search 11,907 (PubMed- 4,806, Scopus-5,631, Embase-1470) and additional search 703 (PubMed-66, Scopus-564, Embase-73) were compiled and uploaded into Rayyan Software to remove duplicates and a total of 2,661 duplicates were removed. Post deduplication, the titles, and abstracts were independently screened by two reviewers (PS, LM), and any disagreement was resolved by 3<sup>rd</sup> reviewer (GM), who reviewed and conducted an open discussion with other reviewers till a consensus was reached. This was followed by obtaining the articles with full text to screen for final review. To choose the articles for final review, all articles were independently screened by two reviewers to reduce the selection bias. Reviewer 3 reviewed the articles that had a conflict in opinion and decided whether to include the article for

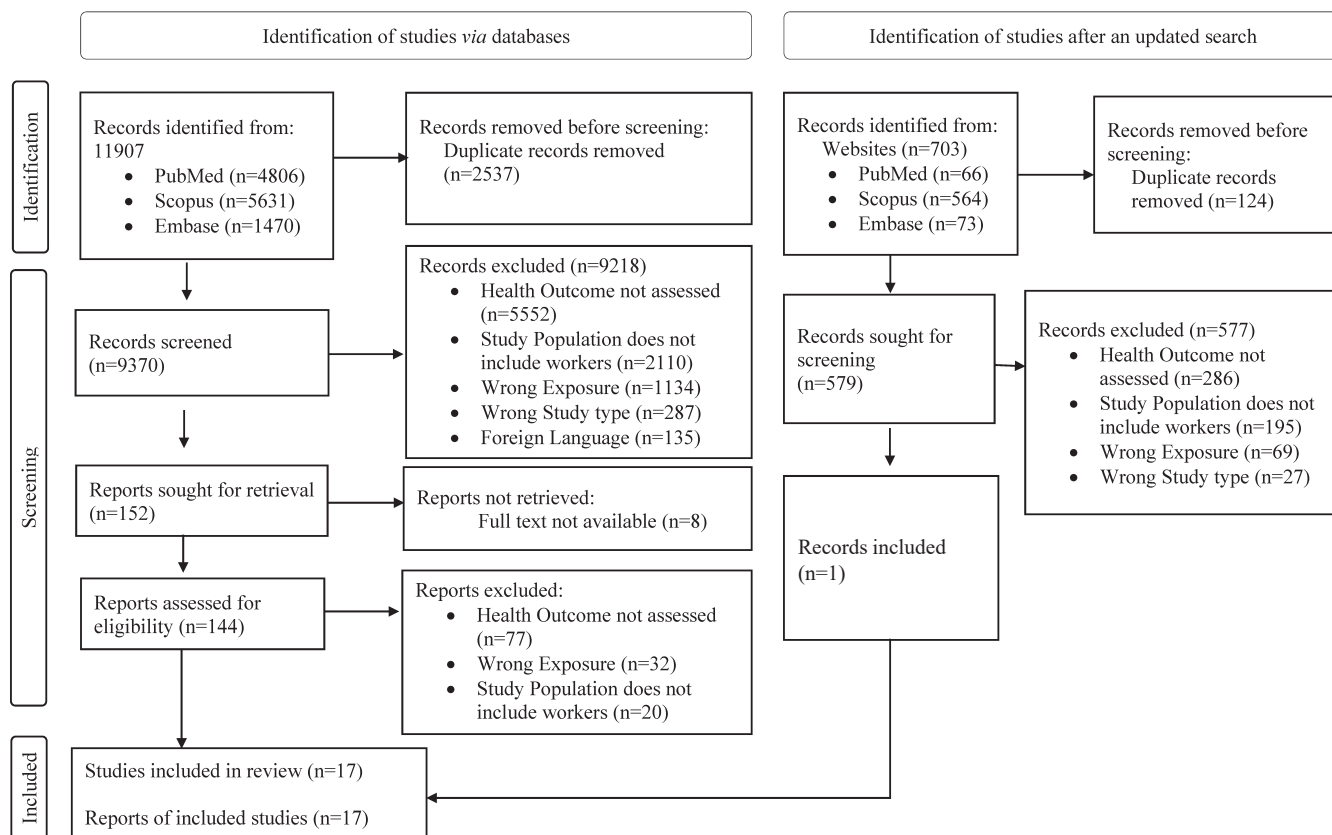


Fig. 1. PRISMA flow diagram.

review after discussing with the reviewers till consensus. After resolving the conflicts, a final list of articles was made, which was used for data extraction. Additional search yielded 703 articles from all 3 sources, and 1 study qualified for final data extraction. Extraction of data was attempted using a data extraction form in Microsoft Excel software by two reviewers together through open discussion and cross-checked by 3<sup>rd</sup> reviewer to extract relevant information about general details such as authors, year of publication, place of study, study design, study setting, sample characteristics (age, gender, and occupation), exposure (exposure duration, type of industry, aflatoxin levels/presence in workplace and biological samples), sample size and outcome (Health effects) was extracted for further narrative synthesis presented in text and table. Steps of the screening process, along with reasons for exclusion, were provided in the PRISMA flow diagram in figure 1.

The review included 17 papers that examined the relationship between occupational aflatoxin exposure and health outcomes. Details of the included studies with quality assessment score are shown in table 1<sup>8,11,12,20-33</sup>. Of the 17 chosen studies, cross-sectional studies were the most frequently used study design

(n=12) followed by retrospective record-based cohort (n=3) and case-control studies (n=2). Geographically, these studies were spread throughout China (n=1), India (n=1), Malaysia (n=1), Sweden (n=1), Thailand (n=1), the Netherlands (n=1), Denmark (n=1), Iran (n=2), Tanzania (n=1), Bangladesh (n=1), and Egypt (n=6).

*Worker profile:* The majority of the studied groups were employed in food-handling occupations, including farmers, flour millers, oil pressers, and livestock feed company workers. Sugar and paper factories, textile mills, waste management companies that handle both dry and wet household waste, and sawmills were among the others studied. With a mean age of between 30 and 40 yr, most workers were in the 20–60 age range. Except for five studies in which only male workers constituted the study participants, the majority of studies have included participants from both genders. The minimum duration of work varied from six months to 10 years across studies. Few studies have not specified a minimum duration of work among the study population. Most of the workers in the control groups were employed at the same factory and handled workplace administrative tasks.

**Table I.** Basic details of the included studies with quality assessment score

Sl. No.	Study ID (Author & yr)	Country	Study design	Sample size	Occupational group	Quality assessment score
1	Ali <i>et al</i> <sup>23</sup> , 2024	Bangladesh	Cross Sectional	76 (E-51, NE-25)	Grain & spice mill workers	****
2	Gichohi-Wainaina <i>et al</i> <sup>28</sup> , 2023	Tanzania	Cross Sectional	250	Farming mothers	****
3	Karamkhani <i>et al</i> <sup>12</sup> , 2022	Iran	Cross Sectional	60 (E-30, NE-30)	Wet waste processing workers	*****
4	Asri <i>et al</i> <sup>8</sup> , 2020	Malaysia	Cross Sectional	124 (E-76, NE-48)	Rice Mill workers	***
5	Karamkhani <i>et al</i> <sup>20</sup> , 2020	Iran	Cross Sectional	40 (E-20, NE-20)	Solid waste processing workers	*****
6	Saad-Hussein <i>et al</i> <sup>29</sup> , 2021	Egypt	Cross Sectional	166 (E-88, NE-78)	Sawmill workers	*****
7	Saad-Hussein <i>et al</i> <sup>25</sup> , 2016	Egypt	Cross Sectional	290 (E-190, NE-100)	Wheat handlers	*****
8	Saad-Hussein <i>et al</i> <sup>21</sup> , 2016	Egypt	Cross Sectional	375 (E-219, NE-156)	Wheat handlers, Sawmill workers	*****
9	Malik <i>et al</i> <sup>11</sup> , 2014	India	Cross sectional	90 (E-46, NE-44)	Food Grain Workers including farmers	*****
10	Lai <i>et al</i> <sup>22</sup> , 2014	China	Case control	218 (Ca-68, C-150)	Sugar & paper making factory workers	*****
11	Saad-Hussein <i>et al</i> <sup>26</sup> , 2014	Egypt	Cross sectional	286 (E-190, NE-96)	Wheat handlers	*****
12	Saad-Hussein <i>et al</i> <sup>33</sup> , 2014	Egypt	Case control	75 (Ca-35, C -40)	Wheat mill workers	*****
13	Saad-Hussein <i>et al</i> <sup>24</sup> , 2013	Egypt	Cross sectional	122 (E-58, NE-64)	Textile workers	*****
14	Nuntharatanapong <i>et al</i> <sup>32</sup> , 2001	Thailand	Cross sectional	14 (E-10, NE-4)	Animal feed mixers	****
15	Olsen <i>et al</i> <sup>7</sup> , 1988	Denmark	Record based cohort	398 cancer cases	Livestock feed workers	*****
16	Alavanja <i>et al</i> <sup>30</sup> , 1987	Sweden	Record based cohort	2649	Grain millers	*****
17	Hayes <i>et al</i> <sup>31</sup> , 1984	Netherlands	Record based cohort	138 (E-71, NE-67)	Oil press workers	*****

Summary of included studies on occupational exposure to aflatoxins, listing the study identification (author and year), country of study, study design, sample size, occupational group involved, and quality assessment scores. This table provides an overview of the characteristics and methodological quality of each study analysed; E, exposed; NE, non-exposed; Ca, cases; C, controls

**Assessment of exposure:** Assessment of exposure was done using two methods- environmental and biological assessments.

**Environmental assessment:** Seven studies evaluated the environmental levels of aflatoxin in worker environments. They assessed exposure by monitoring settled dust levels (PET bottles, cardboard, metal, plastic), airborne dust, and personal sampling (the sampler located in the breathing zone of the worker), and dermal wipes (1 study) using enzyme-linked immunoassay (ELISA) and high performance liquid chromatography- fluorescence detector (HPLC-FLD). Samplers used to assess were IOM samplers, universal PCXR (Personal Constant-flow X- stream Rate pump) samplers, glass microfibre filter, and air sampling units. Particle size varied from 0.7 micrometre to up to 8 mm.

Period of sampling ranged from 2-8 hours (working hours)<sup>8,12,20-22</sup>. One of the studies considered additional parameters like temperature and relative humidity<sup>12</sup>. One study done at the rice mill area, the average airborne Aflatoxin B1 was 2.22 ng/m<sup>3</sup>±0.07, while for the personal exposure, it was 0.25 ng/m<sup>3</sup>±0.24. Two (2.3%) dermal wipe samples were tested to be positive for aflatoxins among exposed mill workers compared to none among office workers<sup>8</sup>. Details of aflatoxin values in environmental samples are mentioned in table II.

**Biological assessment:** In nine studies, the serum sample was tested to assess the aflatoxin B1 (AFB1) levels. Some studies have taken urine (2 studies) and bronchoalveolar lavage (BAL) (1 study) to evaluate

**Table II.** Summary of studies based on the exposure and outcome

Sl. no.	Study ID	Sample size with subgroup	Exposure assessment		Salient finding	Conclusion
			Sample tested & method of testing	Outcome assessment & Health outcome & method of assessment		
1	Ali <i>et al</i> <sup>23</sup> , 2024	76; E-51 (Rice, wheat, maize. mills workers), NE-25 [rickshaw pullers, housewives, teachers, and businessmen]	Urine AFM1 levels using ELISA	Urine(creatinine) using Biodiagnostic kits	The AFM1 in mill workers' urine was slightly lower than that of the control group, whilst the AFM1 urinary level adjusted for creatinine was higher in mill workers than in the control group. There was no significant difference in the mean level of urinary creatinine between the mill workers & the control group	The study concluded that in specific occupational setting, there was no extra/additional exposure occurred to workers. However, the presence of non-negligible AFM1 levels in both worker & control group necessitates further biomonitoring studies to explore aflatoxin exposure.
2	Gichohi-Wainaina <i>et al</i> <sup>28</sup> , 2023	250(rural farming households with children less than 24 months)	Food samples (maize, sorghum, cassava, groundnut, bambara nut) using ELISA[AFB1]	Weight for height Z-score, weight for age Z-score using anthropometric measurements	AFB1 concentration was associated with lower Weight for height Z scores and weight for age Z scores the highest maximum AFB1 contamination levels from all samples obtained were in maize grain. Mean Aflatoxin levels in Maize grain were 156.5 micrograms per Kg.	Aflatoxin exposure in surveyed population was much higher than previous observations made in Tanzania. As high level of contamination was observed, strategies from health, trade and nutrition sector should be designed and implemented to reduce exposure.
3	Karamkhani <i>et al</i> <sup>12</sup> , 2022	60; E-30 (wet waste processing workers), NE-30 (administrative staff)	Personal and area dust samples and blood samples for AFB1 using High Performance Liquid Chromatography-fluorescence detector (HPLC-FLD).	AFB1/Albumin, LFT, RFT, lipid profile ,antioxidant profile using Biodiagnostic kits	Significant differences between worker & control groups in the biochemical profile tests, (liver and kidney) was observed. On the other hand, the serum triglyceride and total cholesterol concentrations did not show any significant difference. AFB1 exposure caused a significant decrease in the antioxidant capacity. Level of aflatoxin in environment in Spring season was 0.07ng/m3.	The detection of AFB1 in the airborne and settled dust and AFB1-ALB in the serum provide evidence that workers are occupationally exposed to aflatoxin

*Contd...*

Sl. no.	Study ID	Sample size with subgroup	Exposure assessment Sample tested & method of testing	Outcome assessment Health outcome & method of assessment	Salient finding	Conclusion
4	Asri <i>et al</i> <sup>8</sup> , 2020	124, E-76; rice millers, NE-48; office workers	Dermal wipe sample, personal and area samples for AFB1 using ELISA	Lung function test using spirometry	There was a significant difference in mean FEV1 for pre and post shifts between rice millers and non-exposed group the mean contamination level of AFB1 on hands was 0.25 ng/ml detected on two rice millers (2.3%) while non-detectable in non-exposed workers. However, no correlation was observed between AFB1 levels and lung function tests. Mean levels of Aflatoxin in environment surface area t is 2.22 ng/m <sup>3</sup> .	Prolonged Exposure to AFB1 may lead to serious Respiratory health effects. Control measures such as hygiene Practices and wearing suitable personal Protective equipment (PPE) are highly recommended in preventing further exposure and to reduce the levels of AFB1 among the Workers.
5	Karamkhani <i>et al</i> <sup>9</sup> , 2020	40; E-20 [Solid waste processing workers], NE-20 [administrative staff]	Environmental sampling (PET bottle, cardboard and carton, metal and plastic), blood samples using HPLC-FLD	AFB1/Albumin, LFT, RFT, lipid status, antioxidant status and MDA using biodiagnostic kits	Significant difference in the LFT and RFT levels were observed between exposed and unexposed workers. However, no difference was noted in serum triglyceride and total cholesterol concentration. There was a significant reduction in blood antioxidant capacity	The solid waste handlers may be exposed to hazardous levels of Aflatoxin B1. Adverse effects on renal and hepatic system could be due to changes in redox system
6	Saad-Hussein <i>et al</i> <sup>10</sup> , 2021	166; E-88 [furniture workers], NE-78 [not exposed to wood dust in their occupation]	Blood samples using ELISA Environmental sampling (furniture wood)	Liver enzymes and oxidative markers using biodiagnostic kits	Mean duration of exposure was 17±5.3 years. AFB1/ALB, AST, and ALT were significantly higher in furniture workers compared to controls. MDA and GPX levels showed significant elevation in workers compared with controls. While CAT levels show significantly reduced levels in workers compared with controls. Level of Aflatoxin in environment is given in the range of 9200-3500CFU/m <sup>3</sup> .	Wood dust exposure is associated with raised serum levels of AFB1 and oxidative stress.
7	Saad-Hussein <i>et al</i> <sup>11</sup> , 2016	290; E-190 [90 bakers, 100 flour milling workers], NE-100 [not occupationally exposed to wheat dust]	Environmental samples and blood samples using ELISA	Clinical examination, liver enzymes using biodiagnostic kits	The concentration of <i>Aspergillus flavus</i> and <i>Aspergillus niger</i> were higher in bakeries than in the flour mill sections. The serum AFB1-ALB adduct and alp levels were significantly higher in bakers compared to milling workers. The liver enzymes AST and ALT were significantly higher in milling workers and bakers than controls	Chronic occupational exposure to high concentrations of aspergillus in workplaces may cause elevations in serum levels of AFB1 and liver enzymes in workers exposed to flour dust. Hence, worker protection measures should be consistently adopted and enforced at the workplace

Contd...

Sl. no.	Study ID	Sample size with subgroup	Exposure assessment Sample tested & method of testing	Outcome assessment Health outcome & method of assessment	Salient finding	Conclusion
8	Saad-Hussein <i>et al</i> <sup>11</sup> , 2016	375; E-219 [132 -flour workers; 81 wheat mill and 51 bakery workers, 87 sawmill workers], NE-156 [workers not occupationally exposed to organic dust]	Blood samples using ELISA, Questionnaire,	Liver enzymes using biodiagnostic kits, PCR	Years of exposure varied between groups. Flour workers: 15±5.2years exposure; Sawmill workers: 17±5.3years exposure. AFB1/ALB and liver enzymes were significantly elevated in exposed workers compared to controls, and were significantly higher in sawmill workers compared to flour workers.	Organic dust exposure may cause elevation in AFB1/ALB and liver enzymes of exposed workers, and GST gene polymorphism plays an important role in susceptibility to hepatic parenchymal cell injury
9	Malik <i>et al</i> <sup>11</sup> , 2014	90, E- 46 food grain workers/farmer, NE-44	BAL, Blood samples for AFB1 using ELISA, LPCB and SDA culture	Respiratory symptoms, questionnaire	Aflatoxins were detected in 32.6% of food grain workers and 9.1% of non-food grain workers. Significant difference was observed in BAL culture for <i>Aspergillus flavus</i> between exposed and non-exposed. Higher percentage of food grain workers reported respiratory symptoms compared to other group.	Occupational exposure to aflatoxins in food-grain workers was found to be associated with the increased presence of respiratory symptoms
10	Lai <i>et al</i> <sup>22</sup> , 2014	Ca – workers in sugar and paper making factory with HCC-68, C-Workers without HCC 150. E-181 workshop employees and NE-203 who worked outside the workshop	Environmental dust using ELISA, Serum AFB1 albumin adducts were detected using a double antibody sandwich ELISA	Data on HCC Diagnosis from records	AFB1 was detected in 56.35% of samples among cases and 5.9% in control group respectively. Workers with contaminated dust exposure had higher risk of HCC compared to controls (OR-5.24,95%CI-2.77-9.88). Level of Aflatoxin in environment sample is 8 mcg/kg.	The findings indicate that occupational AFB1 airway exposure might be associated with the risk of AFB1-related HCC among this study population
11	Saad-Hussein <i>et al</i> <sup>26</sup> , 2014	286; E-190 [100 flourmill workers, 90 bakers], NE-96 [64 healthy subjects from the national research centre, 32 HCC positive controls from the national cancer institute]	Blood sample for AFB1 Albumin using ELISA	Plasma biomarkers using ELISA, colorimetric assay using kits [AFP, AFU, Arginase]	Bakers had significantly higher levels of AFB1/ALB and AFU than the flourmill workers. There is significant elevation in the serum AFB1/ALB of bakers and flourmill workers compared to the normal controls. The AFB1 levels is found to be highest among HCC cases. Similarly, AFP and AFU were all significantly higher and arginase was lower in HCC cases compared to the other groups.	Wheat handlers exposed to high concentrations of <i>Aspergillus flavus</i> have a high risk of developing elevated serum AFB1/ALB and elevated AFU, suggesting that they are at high risk of developing HCC

Contd....

Sl. no.	Study ID	Sample size with subgroup	Exposure assessment Sample tested & method of testing	Outcome assessment Health outcome & method of assessment	Salient finding	Conclusion
12	Saad-Hussein <i>et al</i> <sup>13</sup> , 2014	75; Ca-35 [wheat flour workers with high AFB1-Albumin adduct serum levels], C-40 [healthy males not occupationally exposed to wheat flour dust]	Blood sample for AFB1 Albumin using ELISA	Liver enzymes, P53, GST, SOD, ZINC and vitamin C using biodiagnostic kits	Mean duration of exposure was 22.4±10.6 years. The levels of AFB1, liver enzymes and serum P53 of the workers were significantly elevated compared to the control group. GST, MDA and SOD were significantly increased in the workers compared to the controls group, while antioxidants, vitamin C and levels of Zn in the workers were significantly decreased compared to the controls.	Oxidative stress of AFB1 elevated the MDA and Liver enzymes in wheat milling workers.
13	Saad-Hussein <i>et al</i> <sup>14</sup> , 2013	122; E-58 [textile workers from the pre spinning, spinning, and weaving departments], NE-64[ administrative staff]	Urine sample for AFMI using HPLC	Skin prick test using ELISA (Aspergillus species), Tumor markers AFP, AFU, IGF-1 using ELISA/ biodiagnostic kits	Mean duration of exposure was 12.0 ± 2.4 years. Positive reactants to <i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , and cotton dust were significantly higher in pre-spinning and spinning workers compared to controls. Urinary AFMI was significantly higher in the pre-spinning, spinning, and weaving groups compared to control. Highly significant increase in levels of serum AFU in textile workers, compared to the control group.	Exposure to fungi had a significant effect on AFMI measurements and tumour biomarkers
14	Nuntharatanapong <i>et al</i> <sup>15</sup> , 2001	14, E-10 [group 1 and group 2; animal feed mixers], NE-4, [other employees]	Environmental (contaminated feed dust sample) and personal dust monitoring for AFB1 using ELISA	Plasma biomarkers (LDH, TNF) using ELISA, Electrophoresis	Samples collected from the control group contained lower levels of aflatoxin than the two exposed groups. A difference in LDH activities in plasma was observed between the exposed worker's controls. LDH1 decreased, whereas the spleen and LDH3 and LDH4, significantly increased in both exposed groups, higher plasma TNF- $\alpha$ levels were also found in both exposed groups, whereas none were detected in controls. Rice bran had 43.9 ng/kg of total aflatoxins, indicating severe contamination. The average aflatoxin values in air samples in exposed areas were 6.25 ng/m <sup>3</sup> and 1.55 ng/m <sup>3</sup> , where as in control area, it was 0.99 ng/m <sup>3</sup>	The observed change in LDH and TNF levels in plasma may be associated with inhalation of mycotoxin and other contamination in food staff

Contd...

Sl. no.	Study ID	Sample size with subgroup	Exposure assessment Sample tested & method of testing	Outcome assessment Health outcome & method of assessment	Salient finding	Conclusion
15	Olsen <i>et al</i> <sup>27</sup> , 1988	398 cases of cancer among workers of 241 livestock feed processing companies	Assumed occupational exposure via respiratory route	Cancer incidence using records [cancer registry]	Elevated risks for liver cancer and cancers of the biliary tract were observed. Increased risks for salivary gland tumours and multiple myeloma were also detected. A decreased risk for lung cancer was observed; despite possible negative confounding due to the smoking, alcohol habits of the employees,	The finding of an elevated risk for liver cancer and cancers of the biliary tract in this population. The increased risks for salivary gland tumours and multiple myeloma may be due to the same exposures. The lung does not seem to be a target organ for the carcinogenic effect of inhaled aflatoxins in humans.
16	Alavanja <i>et al</i> <sup>30</sup> , 1987	2649 (Grain millers, including flour millers and animal feed plant workers)	Exposure assessment not mentioned	Cancer incidence using records [cancer registry]	The overall cancer risk was not increased in this group; however, primary liver cancer was significantly elevated for this group (SIR-238)	The processing and storage of agricultural foodstuffs involve occupational exposures, and this may contribute to different patterns of occupational cancer risk depending on location. Further epidemiologic studies to evaluate the relationship between occupational exposures in this industry and cancer risk are needed.
17	Hayes <i>et al</i> <sup>31</sup> , 1984	138; E-71 [Oil press workers], NE-67 [workers of corn processing plant]	Environment dust monitoring, food residue for AFB1 (method not mentioned)	Mortality due to all causes, CVD and all cancers using records [cancer registry]	250mcg/kg of Aflatoxin was found in environment dust. The residue cakes from peanuts were found to contain concentrations of aflatoxins of about 300-400 mcg/kg. For the entire period of study, the observed mortalities for total-cancer and respiratory cancer were higher than expected in the aflatoxin-exposed group	Aflatoxins in dust may provide potent inflammatory stimulus as well as carcinogenic exposure. Further investigation in this regard is recommended

The table includes the study identification (author and yr), sample size with subgroup details, methods used for exposure assessment, outcome assessment approaches, key salient findings from each study, and the authors' conclusions. AFB1 ALB, aflatoxin B1; AFB1, aflatoxin B1; AFP, alpha-fetoprotein; AFU, alpha-L-fucosidase; ALP, alkaline phosphatase, ALT, aminotransferase; AST, aspartate aminotransferase; Ca, cases, CAT, catalase; C, control; CL, confidence interval; CVD, cardio vascular disease; E, exposure; ELISA, enzyme linked immunosorbent assay; FEV1, forced expiratory volume; GPX, glutathione peroxidase; GSH, glutathione; GST, glutathione S-transferases; HCC, hepatocellular carcinoma; HPLC-FLD, high performance liquid chromatography- fluorescence detector; HPLC, high performance liquid chromatography, IARC, International Agency for Research on Cancer; IGF1, insulin like growth factor; LDH, lactate dehydrogenase; LFT, liver function test; LPCB, direct mount and lactophenol cotton blue; MDA, malondialdehyde; NE, non exposure; NOS, Newcastle-Ottawa Scale; OR, odds ratio; P53, tumor protein p53; PCR, polymerase chain reaction; RFT, renal function test; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SDA, Sabouraud's dextrose agar; SIR, standard incidence ratio; SOD, superoxide dismutase; TAC, total antioxidant capacity; TNF, tumor necrosis factor; Zn, zinc

exposure assessment. The period of sampling ranged mostly during working hours, which is 2-8 h. The most common method used to assess exposure in biological fluids is ELISA, followed by HPLC-FLD. A study conducted in a developing country revealed that aflatoxins were present in the BAL fluid of 32.6 per cent of agricultural workers who handled food grains, compared to 9.1 per cent of workers who did not<sup>11</sup>. Another pilot study showed no significant difference in AflatoxinM1 levels in urine samples of mill workers and the control population in Bangladesh<sup>23</sup>. A similar study that assessed exposure in urine samples showed significantly higher levels among textile workers (pre-spinning-  $554.2 \pm 346.2$  pg/mL, spinning  $-459.1 \pm 781.6$  pg/mL and weaving  $-296.5 \pm 336.5$  pg/mL) compared to controls ( $68.5 \pm 136.8$  pg/mL)<sup>24</sup>. When we compared the levels of aflatoxin across occupational groups, we found that compared to mill workers, bakers had higher amounts of aflatoxins<sup>25,26</sup>. Another similar study by the same investigator compared levels between different occupational groups exposed to aflatoxin and observed that the mean values of aflatoxin in biological samples of sawmill workers were higher compared to flour mill workers<sup>21</sup>. A few research studies attempted to identify the species, primarily identifying *Aspergillus flavus* and *Aspergillus niger*. But more species were also found, including *Aspergillus parasiticus*, *tereus*, and *ochraceus*<sup>24,25</sup>. Few older studies often assumed aflatoxin exposure levels among workers, relying on reference articles rather than direct assessment or quantification of exposure. An earlier study investigated the cancer risk among livestock feed processing workers in Denmark, have assumed a daily exposure of roughly 170ng based on the average concentration of aflatoxin in mixed cattle feed<sup>27</sup>. Another study done among sugar and paper-making workers was assessed aflatoxin exposure in airborne dust and in serum samples of workers to assess the exposure<sup>22</sup>. The mean AFB1 concentration in dust samples from the sugarcane bagasse warehouse, presser workshop, and paper production workshop were  $7.2 \pm 1.30$  µg/kg,  $8 \pm 1.23$  µg/kg and  $8.6 \pm 1.82$  µg/kg, respectively. The mean AFB1 levels were significantly higher in the blood samples of workers ( $38.51 \pm 44.80$  pg/mg albumin) compared to controls ( $15.58 \pm 6.42$  pg/mg albumin).

*Assessment of outcomes:* The majority of the studies concentrated on the effects on the hepatobiliary system by analysing liver function tests. Some studies also evaluated tumour markers, antioxidant levels, renal

function tests, and oxidative marker levels. Cancer incidence and mortality were the main outcomes of interest in many record-based retrospective studies. Few studies also looked into the effects on the respiratory system, which could be due to inhalation of contaminated dust in occupational settings. One recent study explored the effects of occupational exposure to aflatoxins among farming mothers and has assessed weight for age and weight for height (z scores) among their children<sup>28</sup>. Results are summarised in table II.

*Hepatobiliary system:* Of 17 studies included in the review, six studies assessed the association between aflatoxin and the elevation of liver enzymes. A recent study conducted among the waste management workers has observed a statistically significant difference in biochemical profile between the worker and control groups, with higher mean values among workers<sup>20</sup>. The mean values of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) among workers and controls were  $52 \pm 6$  IU/mL vs  $30 \pm 3$  IU/mL and  $61 \pm 7$  IU/mL vs  $30 \pm 4$  IU/mL, respectively<sup>29</sup>. Serum bilirubin values also differed significantly between groups. Similar results were noticed in another study done in waste management workers by the same investigator in 2020. Neither study observed any significant change in serum triglyceride and cholesterol levels<sup>12,20</sup>. In addition to waste management workers, elevated liver enzymes were also observed among flour mill workers, wood dust/sawmill workers, and Bakers compared to controls<sup>25,28</sup>. Risk for liver and hepatobiliary tract cancers was observed among Danish workers (livestock)<sup>27</sup>. Standardized proportional incidence ratio (SPIR) was used to determine the risk of developing cancer among workers with the highest value observed for gallbladder and extrahepatic bile ducts (SPIR 298; 95% CI-109-659), followed by liver (SPIR-246; 95% CI-108-486) including 10-yr latency period. As it was a record-based study with exposure based on assumption, they postulated that the most likely explanation for the elevated risk of cancer could be due to occupational exposure to aflatoxin in animal feeds. Standardized incidence ratio was used to calculate risk in a record-based study (1961-1979) from Sweden among 2,649 male grain millers<sup>30</sup>. Even though the overall cancer incidence was not high among workers, this study observed a significantly higher number of primary hepatic cancers with SIR 238 (95% CI-114-438). As a comprehensive exposure assessment was not done, they used international comparisons to establish aetiologies, which included aflatoxins and pesticides. A study from

China showed that workers in sugar and paper-making factories with a history of exposure to airborne dust had an elevated risk of hepatocellular carcinomas compared to unexposed (OR-5.24, 95% 2.77-9.88)<sup>22</sup>.

Respiratory system: One study<sup>8</sup> has mentioned outcome assessment in terms of lung function tests using Spirometry and respiratory symptoms using a questionnaire. AFB1 detected in the hand wipe sample is 2.3 per cent and not detected in non-exposed workers. 9.2 per cent of exposed workers had respiratory symptoms as compared to 4.2 per cent in non-exposed. While no significant difference in respiratory symptoms was found between rice millers and the control group, the study revealed a significant decrease in mean forced expiratory volume in 1second (FEV1) among rice millers when comparing pre-and post-shift measurements<sup>8</sup>.

One study<sup>11</sup> found a significantly higher prevalence of aflatoxins in BAL samples from food-grain workers (32.6%) compared to non-food-grain workers (9.1%,  $P < 0.01$ ). A substantially higher proportion of food-grain workers exhibited chronic respiratory symptoms compared to non-food-grain workers. These findings led the authors to conclude that occupational exposure to aflatoxins among food-grain workers is associated with an increased risk of respiratory symptoms<sup>11</sup>.

Two studies have assessed outcomes in terms of cancer incidence and mortality based on a cancer registry. In one study<sup>31</sup> among oil press workers, the group exposed to aflatoxin was observed to have higher-than-expected mortality rates for both respiratory and total cancer. Another study<sup>27</sup> conducted among workers at animal feed facilities indicated that although there was the possibility of negative confounding from the smoking habits of employees, a lower incidence of lung cancer was noted, suggesting that the lung may not be a target organ for aflatoxin<sup>27</sup>.

Renal system: Three studies assessed renal function. Studies in waste management employees revealed statistically significant differences in renal function test (RFT), between the worker and control groups<sup>12,20</sup>. The mean values of urea and creatinine among workers and controls were  $51 \pm 1$  mg/dL vs.  $33 \pm 3$  mg/dL, and  $4.2 \pm 0.7$  mg/dL,  $1.6 \pm 0.3$  mg/dL, respectively. Another study<sup>23</sup> conducted among mill workers suggested that there was no additional occupational exposure in the particular environment.

Reproductive system: In a recent study from Tanzania that evaluated how aflatoxin affects children's growth among mothers with farming AFB1 concentration was linked to lower weight for age and weight for height (z scores) in their children.

Effect on biomarkers: Few studies have assessed levels of biomarkers such as tumour necrosis factor alpha (TNF alpha), lactate dehydrogenase (LDH), alkaline phosphate (ALP), alpha-fetoprotein (AFP), alpha-L-fucosidase (AFU), arginase, and insulin-like growth factor (IGF-1) among exposed and non-exposed workers. A case-control study has observed elevated levels of AFB1, AFP, and AFU among HCC. Higher levels of AFB1 were observed in millers and bakers compared to controls<sup>26</sup>. The study concluded that wheat handlers have a high risk of developing elevated serum AFB1/albumin and elevated AFU, suggesting they are at high risk of developing HCC. One study observed elevated levels of spleen and lung liver enzymes such as LDH 3 and LDH4 and decreased levels of LDH1 among animal feed workers compared to controls. The animal feed mixer groups had higher plasma TNF alpha levels ( $86.6 \pm 29.7$  pg/mL and  $107.0 \pm 21.5$  pg/mL), respectively, while the control group had no detectable levels<sup>32</sup>. Another study<sup>24</sup> observed a significant increase in AFU among workers exposed to aflatoxins compared to controls. AFP was significantly higher among weavers compared to workers in pre-spinning, spinning, and control groups. IGF1 levels were significantly lower among workers, however, it was not significantly different between employees and controls<sup>25</sup>.

Oxidative stress markers: In addition to tumour biomarkers, the association between aflatoxins, oxidative stress markers, and antioxidant levels was studied. A study conducted in 2020 among workers in the wood dust industry observed an elevation of oxidative stress markers such as malondialdehyde (MDA) and glutathione peroxidase (GPX) in addition to an elevation of liver enzymes<sup>28</sup>. Also, a reduction in the level of antioxidant enzymes such as catalase was observed among workers compared to controls.

Other studies have demonstrated similar results<sup>12,20</sup>. In both of the studies, AFB1 exposure caused a significant increase in serum MDA concentration and reduced antioxidant levels such as total antioxidant capacity (TAC) and glutathione (GSH).

## Discussion

This systematic review deals with occupational aflatoxin exposure and its health effects among workers. We found that food-grain workers, such as farmers, millers, bakers, handlers, oil pressors and workers in animal husbandry, such as feed mixers, are at a higher risk of occupational exposure to aflatoxins. They have mainly acquired exposure through inhalation of contaminated dust and handling of contaminated grains. Textiles, waste management, sawmills, sugar, and papermaking were the other industries studied. The geographical spread across Asia, Africa, Europe and the Middle East, with the highest number of studies in Egypt, reflects the global nature of exposure with regional variations in risk and outcomes where Egyptian studies highlighted significant hepatobiliary effects and elevated aflatoxin levels linked to organic dust exposure via foodgrain and sawmill workers. Asian studies often pointed out an association with respiratory effects among rice millers and textile workers. European studies on livestock feed and grain mill workers, reveal lower contamination levels despite leading to hepatobiliary cancer.

The influence of climate, occupational practices and type of crops handled often plays a major role in aflatoxin-related health outcomes. Most of the studies have observed higher levels of aflatoxins in biological fluids compared to controls, except for a recent study among mill workers in Bangladesh. However, the study was done on a pilot basis among a small sample size. Since ingestion is the most frequent way that aflatoxins enter the body, many countries have established criteria for the maximum amount of aflatoxins that can be present in food and feed<sup>23</sup>. The European Commission's consumption regulation states that the acceptable levels of aflatoxins and AFB1 in peanuts for direct consumption are 2 µg/kg and 4 µg/kg, respectively. AFB1 in all food items is limited to 10 µg/kg in Japan, while all aflatoxins are allowed up to 20 µg/kg in the USA<sup>13,16</sup>. There is substantial heterogeneity among research on the methodologies used to measure aflatoxin exposure levels, and there is no acceptable threshold for aflatoxin levels in biological fluids or the workplace that can be used to classify them as high or low risk. This is also consistent with findings of an existing review<sup>1,17</sup>. We could not find any multicenter large-scale studies exploring dose-response relationships which could aid in the setting of permissible limits in the working environment. Most of the studies published<sup>12,20,24,26,29,33</sup> were different aspects or components of the same study

done in one industry setting by the same investigators or record-based studies with assumed exposure to aflatoxins without quantification. A study published in Scientific Reports has highlighted that aflatoxins can affect the respiratory mucosal ciliary function and thus impair the protective mechanism against pathogens<sup>34</sup>. Even though we have come across case reports linking occupational exposure to aflatoxins and lung cancer, except for one record-based study in the past, most of the studies included in this review could not establish a dose-response relationship or elevated risk of lung cancer among workers which is not in line with the findings of the existing review on a similar topic. However, those were record-based studies without consideration of confounding factors. Hence, it's difficult to conclude the association between occupational exposure to aflatoxin and respiratory cancers from the existing evidence<sup>17,27</sup>. Inconsistencies across various studies could be due to the study designs adopted, sample size, and consideration of covariates. The primary organ responsible for detoxifying aflatoxins is the liver. Prolonged exposure to aflatoxins can result in DNA adducts, which can cause numerous mutations and epigenetic changes that can eventually cause carcinoma. Also, existing literature supports the immune suppression effect of aflatoxins<sup>4,35,36</sup>. A recent review has explored the effect of aflatoxins on the growth impairment of infants and children, considering that exposure could occur through the transplacental route and later during weaning. It was concluded that exposure to aflatoxins could result in underweight and stunting among children which is similar to our review<sup>4,37,38</sup>. The potential for exposure through ingestion, inhalation, or skin contact by female workers employed in high-risk occupations could pose a serious risk to the health of their children due to transplacental transfer<sup>4,9</sup>. Biomonitoring of stillborn and neonatal tissues further confirms effective transplacental passage of aflatoxin metabolites and co-exposure with other mycotoxins, suggesting potential roles in prematurity and congenital anomalies<sup>39</sup>. The review has identified many research gaps in this topic, which include the absence of large-scale multicentre studies with good study design exploring dose-response relationships, adjusting for confounding variables. Also, the absence of standard methodologies for the assessment of exposure to aflatoxins in the working environment makes it difficult to make meaningful comparisons across studies.

Most information about aflatoxin toxicity comes from studies of experimental animals, which may not

reflect the true aflatoxin exposure of humans and non-experimental animals. The studies included in this review have investigated the actual human exposure to aflatoxins in contaminated occupational environments, and although there was no standard method for the assessment of exposure. Results could have been influenced by the exclusion of a small number of studies that examined mycotoxins generally without mentioning aflatoxins specifically. There could be a possibility of misdiagnosis in record-based cancer mortality data. There could be the presence of other toxins in the working environment, which might have influenced the outcome of the included studies. The control groups selected were mainly administrative workers in the same setup who also would be at risk of exposure to aflatoxins. Most of the studies were cross-sectional studies, and hence, the causal association could not be established in those studies. It is important to recognize that occupational dust may contain several contaminants in addition to aflatoxins, which could also contribute to the observed health effects. Given the lack of regulatory guidelines, active surveillance for aflatoxin in the workplace and among employees needs to be initiated. Most of these cross-sectional studies, as we have seen, were poorly designed and had a smaller sample size. Hence, we recommend multi-centric large-scale studies to assess the dose-response relationship which could further aid in setting permissible levels of aflatoxin. Strategies that help in proper handling and storage facilities could be explored and consistent usage of personal protective equipment should be implemented to reduce the exposure levels among workers.

Workers from high risk occupations such as farmers, grain handlers, poultry workers, animal feed mixers face significant occupational aflatoxin exposure, with biological and environmental assessments revealing associations with hepatic, renal, and respiratory effects, elevated cancer risk markers, and adverse growth outcomes in their children. Therefore, recognizing and addressing these exposures is critical for clinical evaluation, early detection, and prevention of long-term health consequences in at-risk worker populations. This comprehensive understanding will help policymakers, occupational health professionals, and researchers in developing targeted interventions and policies to mitigate workplace aflatoxin exposure risks.

**Financial support & sponsorship:** None.

**Conflicts of Interest:** None.

**Use of Artificial Intelligence (AI)-Assisted Technology for manuscript preparation:** The authors confirm that there was no use of AI-assisted technology for assisting in the writing of the manuscript and no images were manipulated using AI.

## References

- Viegas S, Viegas C, Opliger A. Occupational exposure to mycotoxins: Current knowledge and prospects. *Ann Work Expo Health* 2018; 62 : 923-41.
- Kumar P, Mahato DK, Kamle M, Mohanta TK, Kang SG. Aflatoxins: A global concern for food safety, human health and their management. *Front Microbiol* 2017; 7 : 2170.
- Deng Y, Wang Y, Deng Q, Sun L, Wang R, Wang X, *et al*. Simultaneous quantification of aflatoxin B1, T-2 toxin, ochratoxina and deoxynivalenol in dried seafood products by LC-MS/MS. *Toxins (Basel)* 2020; 12 : 488.
- Nejad BG, Mostafaei Z, Rezaabad AB, Mehravar F, Zarei M, Dehghani A, *et al*. A systematic review with meta-analysis of the relation of aflatoxin B1 to growth impairment in infants/children. *BMC Pediatr* 2023; 23 : 614.
- Mohd-Redzwan S, Jamaluddin R, Abd-Mutalib MS, Ahmad Z. A mini review on aflatoxin exposure in Malaysia: Past, present and future. *Front Microbiol* 2013; 4 : 334.
- Açar Y, Akbulut G. Evaluation of aflatoxins occurrence and exposure in cereal-based baby foods: Anupdate review. *Curr Nutr Rep* 2024; 13 : 59-68.
- deAlmeida L, Williams R, Soares DM, Nesbitt H, Wright G, Erskine W. Aflatoxin levels in maize and peanut and blood in women and children: The case of timor-leste. *Sci Rep* 2019; 9 : 13158.
- Asri AA, Anua SM, Safuan S, Shakri SF. Exposure of aflatoxin B1 (AFB1) in inhalable dust and its respiratory effects among rice millers. *J Health Transl Med* 2020; 18 : 60-71.
- Gong YY, Watson S, Routledge MN. Aflatoxin exposure and associated human health effects, a review of epidemiological studies. *Food Saf (Tokyo)* 2016; 4 : 14-27.
- Pickova D, Ostry V, Toman J, Malir F. Aflatoxins: history, significant milestones, recent data on their toxicity and ways to mitigation. *Toxins (Basel)* 2021; 13 : 399.
- Malik A, Ali S, Shahid M, Bhargava R. Occupational exposure to Aspergillus and aflatoxins among food-grain workers in India. *Int J Occup Environ Health* 2014; 20 : 189-93.
- Karamkhani M, Asilian-Mahabadi H, Daraei B, Seidkhani-Nahal A, Noori-Zadeh A. Route exposure and adverse effects monitoring of aflatoxinB1 in the workers of wet waste management, the role of body redox system modulation. *Ecotoxicol Environ Saf* 2022; 248 : 114305.
- Chatterjee S, Dhole A, Krishnan AA, Banerjee K. Mycotoxin monitoring, regulation and analysis in India: A success story. *Foods* 2023; 12 : 705.
- Marcelloni AM, Pigni D, Chiominto A, Giofrè A, Paba E. Exposure to airborne mycotoxins: The riskiest working environments and tasks. *Ann Work Expo Health* 2024; 68 : 19-35.

15. Vincenzi A, Silva F, Naira L, Fernandes Oliveir CA. Biomarkers of aflatoxin exposure and its relationship with the hepatocellular carcinoma. In: *Aflatoxins - Biochemistry and molecular biology Aflatoxins - Biochemistry and molecular biology*: InTech; 2011.
16. Chen T, Liu J, Li Y, Wei S. Burden of disease associated with dietary exposure to aflatoxins in China in 2020. *Nutrients* 2022; 14 : 1027.
17. Wangia RN, Tang L, Wang JS. Occupational exposure to aflatoxins and health outcomes: A review. *J Environ Sci Health C Environ Carcinog Ecotoxicol Rev* 2019; 37 : 215-34.
18. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 2021; 372 : n71.
19. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, *et al.* Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-p) 2015: Elaboration and explanation. *BMJ* 2015; 350 : g7647.
20. Karamkhani M, Asilian-Mahabadi H, Daraei B, Seidkhani-Nahal A, Noori-Zadeh A. Liver and kidney serum profile abnormalities in workers exposed to aflatoxin B1 in urban solid waste management centers. *Environ Monit Assess* 2020; 192 : 472.
21. Saad-Hussein A, Shahy EM, Shaheen W, Taha MM, Mahdy-Abdallah H, Ibrahim KS, *et al.* Comparative hepatotoxicity of Aflatoxin B1 among workers exposed to different organic dust with emphasis on polymorphism role of glutathione S-transferase gene. *Open Access Maced J Med Sci* 2016; 4 : 312-8.
22. Lai H, Mo X, Yang Y, He K, Xiao J, Liu C, *et al.* Association between aflatoxin B1 occupational airway exposure and risk of hepatocellular carcinoma: A case-control study. *Tumour Biol* 2014; 35 : 9577-84.
23. Ali N, Habib A, Mahmud F, Tuba HR, Degen GH. Aflatoxin M1 analysis in urine of mill workers in Bangladesh: A pilot study. *Toxins (Basel)* 2024; 16 : 45.
24. Saad-Hussein A, Beshir S, Moubarz G, Elserougy S, Ibrahim MI. Effect of occupational exposure to aflatoxins on some liver tumor markers in textile workers. *Am J Ind Med* 2013; 56 : 818-24.
25. Saad-Hussein A, Taha MM, Fadl NN, Awad AH, Mahdy-Abdallah H, Moubarz G, *et al.* Effects of airborne aspergillus on serum aflatoxin B1 and liver enzymes in workers handling wheat flour. *Hum Exp Toxicol* 2016; 35 : 3-9.
26. Saad-Hussein A, Taha MM, Beshir S, Shahy EM, Shaheen W, Elhamshary M. Carcinogenic effects of aflatoxin B1 among wheat handlers. *Int J Occup Environ Health* 2014; 20 : 215-9.
27. Olsen JH, Dragsted L, Autrup H. Cancer risk and occupational exposure to aflatoxins in Denmark. *Br J Cancer* 1988; 58 : 392-6.
28. Gichohi-Wainaina WN, Kimanya M, Muzanila YC, Kumwenda NC, Msere H, Rashidi M, *et al.* Aflatoxin contamination, exposure among rural smallholder farming tanzanian mothers and associations with growth among their children. *Toxins (Basel)* 2023; 15 : 257.
29. Saad-Hussein A, Shahy EM, Shaheen W, Ibrahim KS, Mahdy-Abdallah H, Taha MM, *et al.* Hepatotoxicity of aflatoxin B1 and its oxidative effects in wood dust Egyptian exposed workers. *Arch Environ Occup Health* 2021; 76 : 561-6.
30. Alavanja MC, Malker H, Hayes RB. Occupational cancer risk associated with the storage and bulk handling of agricultural foodstuff. *J Toxicol Environ Health* 1987; 22 : 247-54.
31. Hayes RB, vanNieuwenhuize JP, Raatgever JW, tenKate FJ. Aflatoxin exposures in the industrial setting: An epidemiological study of mortality. *Food Chem Toxicol* 1984; 22 : 39-43.
32. Nuntharatanapong N, Suramana T, Chaemthavorn S, Zupuang K, Ritta E, Semathong S, *et al.* Increase in tumor necrosis factor-alpha and a change in the lactate dehydrogenase isoenzyme pattern in plasma of workers exposed to aflatoxin-contaminated feeds. *Arh Hig Rada Toksikol* 2001; 52 : 291-8.
33. Saad-Hussein A, Abdalla MS, Shousha WG, Moubarz G, Mohamed AH. Oxidative role of aflatoxin B1 on the liver of wheat milling workers. *Open Access Maced J Med Sci* 2014; 2 : 141-6.
34. Lee RJ, Workman AD, Carey RM, Chen B, Rosen PL, Doghramji L, *et al.* Fungal aflatoxins reduce respiratory mucosal ciliary function. *Sci Rep* 2016; 6 : 33221.
35. Passarelli S, Bromage S, Darling AM, Wang JS, Aboud S, Mugusi F, *et al.* Aflatoxin exposure in utero and birth and growth outcomes in Tanzania. *Matern Child Nutr* 2020; 16 : e12917.
36. Mungamuri SK, Mavuduru VA. Role of epigenetic alterations in aflatoxin-induced hepatocellular carcinoma. *Liver Cancer International* 2020; 1 : 41-50.
37. Chen G, Gong YY, Kimanya ME, Shirima CP, Routledge MN. Comparison of urinary aflatoxin M1 and aflatoxin albumin adducts as biomarkers for assessing aflatoxin exposure in Tanzanian children. *Biomarkers* 2018; 23 : 131-6.
38. Mathew G, Pingle S, SP, BR. Assessing aflatoxin exposure: Exploring types of exposure and diverse biomarkers – A mini review. *Curr Fungal Infect Rep* 2024; 18 : 163-71.
39. Fermiano JTA, Ali S, Ullah S, Rezende VT, Rosim RE, Tonin FG, *et al.* Assessment of maternal exposure to mycotoxins during pregnancy through biomarkers in fetal and neonatal tissues. *Toxins (Basel)* 2025; 17 : 518.

*For correspondence:* Dr Geethu Mathew, Department of Occupational Medicine, ICMR-Regional Occupational Health Centre (S), National Institute of Occupational Health, Bengaluru 562 110, Karnataka, India  
e-mail: matgeet@gmail.com