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Prevalence of toxin exposure in regions of Saudi Arabia: A systematic review and meta-analysis

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Abstract:

Poisoning is a growing significant concern globally. The increased use of industrial and household chemicals, together with widespread consumption of pharmaceuticals and processed foods, elevates the risk of toxic exposure worldwide. This study aimed to assess the frequency of toxic exposure by examining poisoning events in different regions of Saudi Arabia. A systematic literature review was conducted using PubMed, Web of Science, Scopus, and Google Scholar to identify studies on toxins and their prevalence in Saudi Arabia from 2004 to 2024. A meta-analysis was performed using R software, and the AXIS risk of bias was evaluated. Eighteen studies met the inclusion criteria for the systematic review, and eleven of these contributed data to the meta-analysis. Pooled prevalence for synthetic drugs was: cannabis 0.40 (95% confidence interval [CI]: 0.13–0.75), amphetamines 0.34 (95% CI: 0.05–0.85), and solvents 0.04 (95% CI: 0.02–0.07). Pooled prevalence for industrial chemicals was: chemical poisoning 0.16 (95% CI: 0.10–0.25), drug overdose 0.51 (95% CI: 0.38–0.65), and food 0.26 (95% CI: 0.22–0.29). Pooled prevalence for natural toxins was: carbon monoxide 0.76 (95% CI: 0.66–0.85), botulinum 0.42 (95% CI: 0.20–0.67), and scorpion stings 0.72 (95% CI: 0.24–0.95). The study highlights the diverse substances that cause acute poisoning in Saudi Arabia, with regional variations in toxin types and associated risks. Carbon monoxide was the most prevalent natural toxin (0.76), followed by scorpion stings (0.72). Drug overdose showed the highest prevalence of synthetic and chemical agents (0.51). Other notable toxins included botulinum (0.42), cannabis (0.40), and amphetamines (0.34). Industrial chemicals (0.16) and food-related toxins (0.26) also contributed to the issue. The findings highlight the need for public education programs on safe chemical and drug use. The future research should focus on risk factors, prevention, and the improvement of access to medical care.

Keywords:

Exposure, prevalence, Saudi Arabia, toxins

Introduction

In addition to naturally occurring harmful bacteria, industrialization has widely introduced various pollutants and toxins that contribute to health risk.[1] Globalization is aggravating this problem of contamination of the environment.

The term toxins refer to manmade or indigenous chemicals or biological contaminants found in the environment that can be harmful to humans and ecosystems.[2] These could be industrial chemicals, agricultural pesticides, pharmaceutical residues, polyfluoroalkyl substances, emerging pathogens and their antibiotic resistance genes, plastic waste, nanomaterials, and other external pollutants present in the environment.[3,4] However, the risks associated with these pollutants are not well documented.

One of the biggest problems facing Healthcare is acute poisoning, which

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results from exposure to these harmful substances. This is one of the leading causes of illness and mortality in the United States. According to the European institutions, poisoning accounts for nearly 1% of all emergency department admissions, which is concerning because of the potentially fatal consequences.[5] An international multicentre cross-sectional study conducted on children below 18 years old found that unintentional acute poisoning by exposure to therapeutics or household products or pesticides was common in South America and Eastern Mediterranean regions, intentional acute poisoning owing to psychotropic therapeutics was common in North America and the Western Pacific region indicating a substantial epidemiological as well as differences in pollutants responsible for acute poisoning in various countries of the world.[6]

Saudi Arabia, a fast-developing country, having made significant economic and social progress, but now faces a new spectrum of medical issues from toxins. New synthetic intoxicants such as khat, magic mushrooms, more recent psychiatric drugs, medicinal herbs, dietary supplements, and new classes of drugs of dependence, such as synthetic cannabinoids and flavonoids, are among toxins that sometimes lead to hospitalization.[7-9] Saudi Arabia's data show that although hospital admissions for poisoning account for < 1% of emergency visits, the seriousness and potentially lethal consequences of these emergencies are extremely concerning.[10]

In Saudi Arabia, some of the environmental toxins were found to be region specific varying from one region to another. The paucity of systematic study emphasizes the importance of developing management procedures for these poisons. The aim of this study was to systematically review the available literature to assess the prevalent patterns of toxins in the different regions of Saudi Arabia and identify the types of toxins, including emerging substances responsible for acute poisoning.

Methodology

Literature search

The present study search on toxins in Saudi Arabia was conducted according to PRISMA-systematic review and meta-analysis guidelines.[11] A comprehensive electronic search was done on multiple databases, including PubMed, Web of Science, Scopus, and Google Scholar, covering the period from January 01, 2004, to December 31, 2024. Relevant studies were identified using specific keywords: ("toxins" OR "pollutants" OR "acute poisoning") AND ("emergency department" OR "hospital admissions") AND ("Saudi Arabia" OR "KSA"). For PubMed, Medical Subject Headings terms were also included to find relevant studies: ("Toxins" OR "Toxicology" OR "Poisoning" OR "Chemical Exposure" OR "Environmental Toxins" OR "Toxic Substances") AND ("Emergency Department Admissions" OR "Emergency Care" OR "Hospital Admissions" OR "Healthcare Utilization") AND ("Saudi Arabia" OR "Regional Variation" OR "Geographical Distribution") AND ("Prevalence" OR "Epidemiology" OR "Public Health" OR "Risk Factors" OR "Clinical Outcomes"). The search strategy for Scopus included: (toxin * OR poison * OR venom * OR overdose OR "chemical exposure" OR "environmental toxin*") AND ("emergency department" OR "emergency room" OR "emergency care" OR "hospital admission*") AND ("Saudi Arabia" OR "KSA" OR "Arabian Peninsula"). Web of Science included: ("Toxins" OR "Toxicology" OR "Poisoning" OR "Chemical Exposure" OR "Environmental Toxins" OR "Toxic Substances") AND ("Emergency Department Admissions" OR "Emergency Care" OR "Hospital Admissions" OR "Healthcare Utilization") AND ("Saudi Arabia" OR "Regional Variation" OR "Geographical Distribution") AND ("Prevalence" OR "Epidemiology" OR "Public Health" OR "Risk Factors" OR "Clinical Outcomes").

To identify other similar studies, we explored the search engine, Google scholar and then reviewed the references of the publications to find comparable studies.

Eligibility criteria

The following criteria were used for inclusion of studies in this systematic review and meta-analysis:

Study design

studies eligible were to be observational, including cross-sectional, retrospective, prospective, and case-control studies, with relevant clinical data.

Population

Studies involving pediatric and adults exposed to toxins, regardless of whether or not hospitalization was necessary, were considered.

Intervention (s) or exposure (s)

Exposure to diverse toxic substances, from environmental, household, and synthetic intoxicants to accidental poisonings, and occupational or industrial exposure.

Comparator (s) or control (s)

Not applicable.

Outcomes

The outcome of interest was "type" of the toxin (environmental, household, synthetic intoxicants, accidental poisonings, and occupational or industrial toxins etc.) and Prevalence/frequency of the toxin.

For this review, we included prevalence studies that were only conducted in Saudi Arabia, published in English with accessible full-text articles.

Inclusion criteria for meta-analysis

Studies reporting proportions with clear methodology, and defined population with extractable data.

Exclusion criteria

Interventional studies, case reports, case series, studies with incomplete or unavailable data, narratives and reviews. Research conducted outside Saudi Arabia or involving nonhuman subjects was also excluded. In addition, duplicate studies or those with overlapping data were not considered.

Selection and screening

The three stages of the screening process were carried out independently by two researchers using a reference management tool. As part of the screening procedure, the abstract and title were examined initially using the eligibility criteria. The second step entailed evaluating full-text screening to establish inclusion and exclusion criteria. Finally, the researcher used a predesigned data collection form to independently extract relevant data from the included studies. Any discrepancies in the information gathered were resolved by discussion.

Data collection

A standardized data extraction framework was utilized to systematically collect relevant information from the included studies. Key study characteristics recorded, included were author's name, year of publication, study design, geographical location, sample size, and participant's age distribution and location in Saudi Arabia. Demographic data, toxin exposure characteristics, and clinical outcomes were extracted. Any discrepancies in data extraction were independently reviewed and resolved through consensus among reviewers.

Risk of bias analysis

The included studies were assessed for various risk of bias (ROB) for cross-sectional studies using AXIS tool containing 20 questions.[12] The answers were rated as Yes (high risk) and No (low risk) and if the answer was not clear, it was rated as Unclear.

Statistical analysis

Traditional meta-analysis was performed using R-software (RStudio Inc., Aukland, New Zealand). Statistical heterogeneity was assessed using Chi-square test (statistical heterogeneity) and I^2 test (heterogeneity size). According to the origin of heterogeneity, a subgroup analysis was performed. If there was no statistical heterogeneity between the studies ($P > 0.1$ or $I^2 < 50\%$), a fixed effect model was applied. If statistical heterogeneity could be detected among the studies, a random effect model ($P < 0.1$ or $I^2 > 50\%$) was employed, and then a subgroup analysis was done to determine the source of the heterogeneity. Studies that reported the data as proportion were included in the meta-analysis, and prevalence was estimated along with 95% confidence interval (CI).[13]

Results

Literature search

A summary of the systematic literature review and article selection process is shown in PRISMA diagram [Figure 1]. Initially, 370 research articles were selected from English databases. Eleven duplicate documents were removed, and the remaining 359 research documents were selected based on title and abstract for further screening. For full-text analysis, 300 documents that did not meet the inclusion criteria were excluded, and 59 documents were selected. Finally, based on inclusion and exclusion criteria, 18 research papers were included for the review and meta-analysis, 11 of which were included in the meta-analysis, which provided data for estimating the prevalence. The characteristics of the studies are described in Table 1.

Synthetic drugs group meta-analysis

Out of 18 studies, 4 papers studied synthetic drugs or substance abuse in different geographical locations, including King Saud University Medical City,[14] RiyadhKing Abdulaziz University, Jeddah,[15] secondary school children, Abha City[16] and Al-Baha Psychiatric Hospital, Al-Baha.[17] In 4 studies, a total sample size of 1500 subjects were included. Synthetic drugs such as cannabis, amphetamine, and glue or solvents were found to be commonly used in substance abuse. One study reported the use of alcohol and hashish,[14] 2 studies reported cannabis use[14,16] and 3 studies reported the use of amphetamines.[15-17] Based on the drug studied, the synthetic drugs were divided into 3 subgroups – cannabis, amphetamine, and solvents. The cannabis subgroup included 4 articles with 1483 subjects who consumed cannabis with effect size ranging from 0.13 to 0.75. The heterogeneity test showed high heterogeneity and statistical significance ($\chi^2 = 199.86$, degree of freedom [DF] =3, $I^2 = 98.5\%$, $P < 0.001$).[14-17] The amphetamine sub-group includes 4 articles with 901 subjects with effect size ranging from 0.05 to 0.85. The heterogeneity test showed high heterogeneity and statistical significance ($\chi^2 = 187.62$, DF = 2, $I^2 = 98.9\%$, $P < 0.0001$].[14-16] The solvent group has only one study with an effect size of 0.04 (95% CI - 0.02–0.07).[16] The Chi-square test for overall subgroup difference is 14.29; DF 2; $P = 0.0008$), indicating significant statistical difference and effect size consistent in different subgroups [Figure 2 and Table 1].

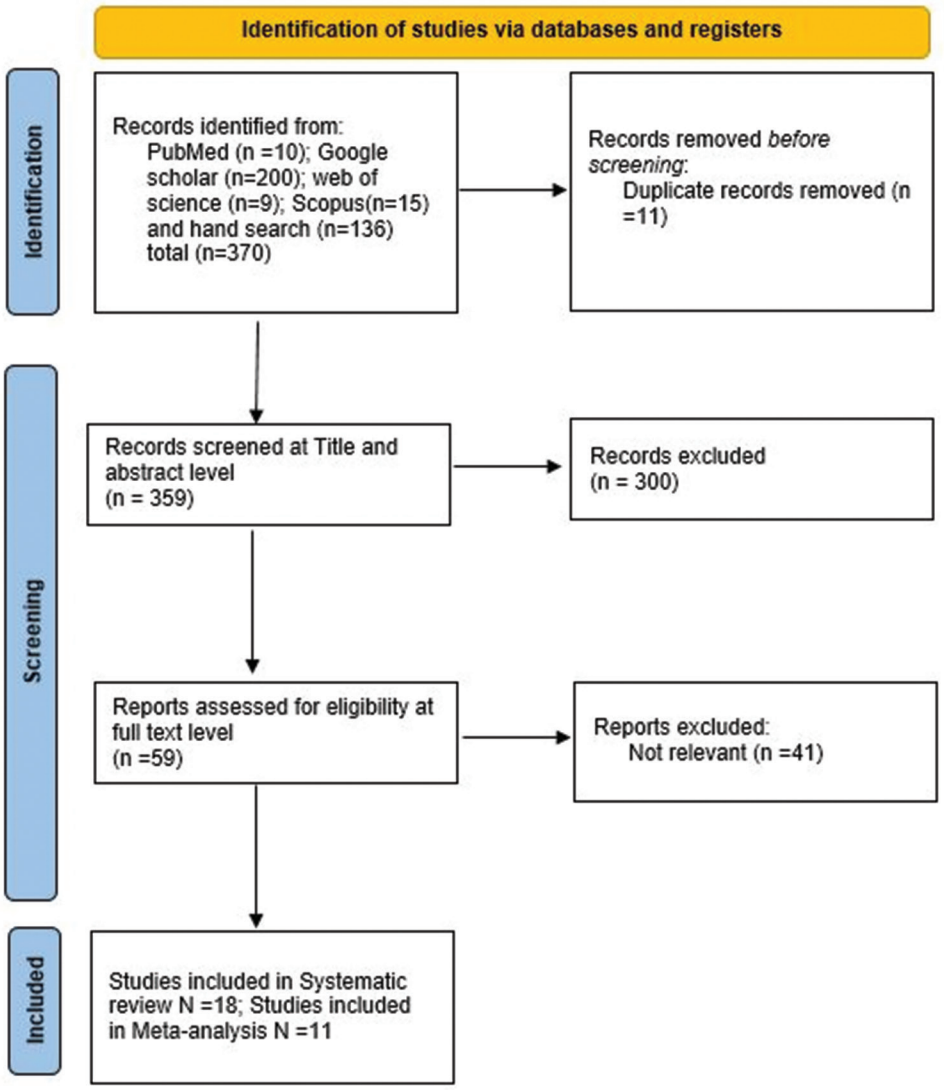

Figure 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram

Industrial chemical and pesticide group meta-analysis

Nine included research which studied industrial chemical and pesticide pollutants in different geographical locations including King Saud University Medical City, Riyadh,[18] tertiary hospitals, Al-Baha Province,[19] King Abdulaziz Medical City, Riyadh,[20] preschool children, Jeddah City,[21] pediatric hospitals, Riyadh[22] King Khaled University Hospital, Riyadh,[23] Jeddah[24] and, King Fahd Hospital of the University, Dammam.[25] A total sample size of 5150 subjects consisting of preschool children, primary school children, adolescents, and adults were included. Chemical poisoning by methanol or homemade alcohol was found to be highly prevalent in adults.[18-21] In preschool and school-age children, pesticides, home cleaning products, and cosmetics were found to cause unintended poisoning.[21-23] In addition, drug overdose and organophosphates were found to cause acute poisoning.[20,24,25] For meta-analysis, the present group was divided into three subgroups-chemical subgroup, drug subgroup, and food poisoning subgroup. The chemical subgroup included 7 studies with 4077 participants with effect size ranging from 0.1 to 0.25. The heterogeneity test showed high variability and statistical significance (χ^2 = 343.4, DF = 6, I^2 = 98.3%, $P < 0.0001$).[19,21-27] The Synthetic drug subgroup included 2 studies with 793 participants and pooled effect size 0.51; 95% CI ~ 0.38–0.65. The heterogeneity test showed high variability and statistical significance (χ^2 = 20.57, DF = 1, I^2 = 95.1%, $P < 0.0001$).[19,22] The food subgroup had only one study with an effect size of 0.26 (95% CI - 0.22–0.29)[19] [Figure 3 and Table 1].

Natural toxins group meta-analysis

Four included research that studied natural toxins such as botulinum toxin, snake and scorpion bites and carbon

Table 1: Characteristics of each study included in this systematic review

Author	Year of publication	Study design	Location	Sample size	Age bracket
Alageel *et al*.[14]*	2023	Retrospective chart review	ED of King Saud University Medical City in Riyadh	532	21–30 years
Mahsoon *et al*.[15]*	2023	Cross sectional (self-administered questionnaire)	Jeddah	379	19–23 years
Al-Musa and Al-Montashri[16]*	2016	Cross-sectional (self-administered questionnaire)	Abha City (Secondary School)	350	16–19 years
Youssef *et al*.[17]*	2016	Case-control study	Al-Baha Psychiatric Hospital	239	18–45 years
Alhusain *et al*.[18]	2024	Retrospective study	ED of King Abdulaziz Medical City, Riyadh	23	Adult patients
Beigh *et al*.[19]*	2023	Retrospective, cross-sectional	Al-Baha, Western Saudi Arabia	622	1–>40 years old
Alghafees *et al*.[20]*	2022	Retrospective	Tertiary care Center, Riyadh	1505	492 adults and 1013 children
Salem *et al*.[21]*	2021	Retrospective	Jeddah Poison Center	171	Preschool children
Alruwaili *et al*.[22]	2019	Prospective, descriptive cross-sectional study	Two pediatric emergency departments in Riyadh	1035	<12 years old
Alghadeer *et al*.[23]	2018	Retrospective cross-sectional	Pediatric ED in Riyadh	735	<6 years
Alzahrani *et al*.[24]	2017	Retrospective	Jeddah	994	Children <5 years
Al Jumaan *et al*.[25]	2015	Retrospective	Dammam	50	>18 years
Alharthy *et al*.[26]*	2024	Retrospective, cross-sectional	ED of King Abdullah Specialist Children's Hospital, Riyadh	85	Adult and pediatric patients
Gul Dar *et al*.[27]*	2024	Retrospective review of medical records	Riyadh	8	12–38 years
Jarrar and Al-Rowaily[28]*	2008	Retrospective	ED in Aljouf (2005–2006)	1449	15–30 years
Al-Asmari and Al-Saif[29]*	2004	Retrospective	ED of Armed Forces Hospital in Riyadh (April 1986–2000)	251	2 months–101 years
Alsanosy *et al*.[30]	2013	Cross-sectional	Jazan Region (Secondary School)	3923	10–18 years
Al-Sadoon *et al*.[31]	2021	Retrospective	EDs throughout Saudi Arabia (2015–2018)	14,697	25–64 years

*Studies included in the meta-analysis. ED=Emergency department

monoxide in different geographical locations, including King Abdullah Specialist Children's Hospital, Riyadh,[26] Riyadh First Health Cluster Hospitals, Riyadh,[27] Medical Centres, Al-Jouf Province[28] Armed Forces Hospital, Riyadh.[29] 1793 subjects were included in this group. Scorpion stings or the released venom containing catecholamines and pro-inflammatory substances were found to be highly prevalent. The sting on the lower limbs led to local pain and systematic toxicity that required emergency department admissions.[28,29,32] Food poisoning, especially consumption of mayonnaise, led to food-borne botulism.[27] In addition, subjects exposed to carbon monoxide developed delayed neuropsychiatric sequelae.[26] For meta-analysis, the present group was divided into three subgroups – carbon monoxide poisoning subgroup, botulinum subgroup, and Scorpion sting subgroup. The carbon monoxide poisoning and botulinum sub-group had only one study each with an effect size of 0.76 (95% CI - 0.66–0.85) and 0.42 (95% CI - 0.20–0.67), respectively.[26,27] The Scorpion sting subgroup included 2 studies with 1700 participants and pooled effect size 0.72; 95% CI - 0.24–0.95. The heterogeneity test showed high variability and statistical significance (χ^2 = 342.4, DF = 1, I^2 = 99.7%, $P < 0.0001$)[28,29] [Figure 4 and Table 1].

Risk of bias analysis

Cross-sectional studies' RoB analyses showed that the included research publications had sufficient qualitative standards. Nevertheless, cross-sectional studies did not show a clear follow-up protocol time to assess the outcomes [Table 2].

Discussion

Poisoning is one of the major public health concerns in Saudi Arabia. It remains a substantial and growing threat to global public health, accounting for a significant proportion of hospital admissions. Initiating preventive measures requires knowledge of the kind and severity of poisoning.[32] The present study was conducted to identify toxins that are highly prevalent in different regions of Saudi Arabia.

In this study, the most prevalent finding was methanol or homemade alcohol poisoning. Methanol poisoning

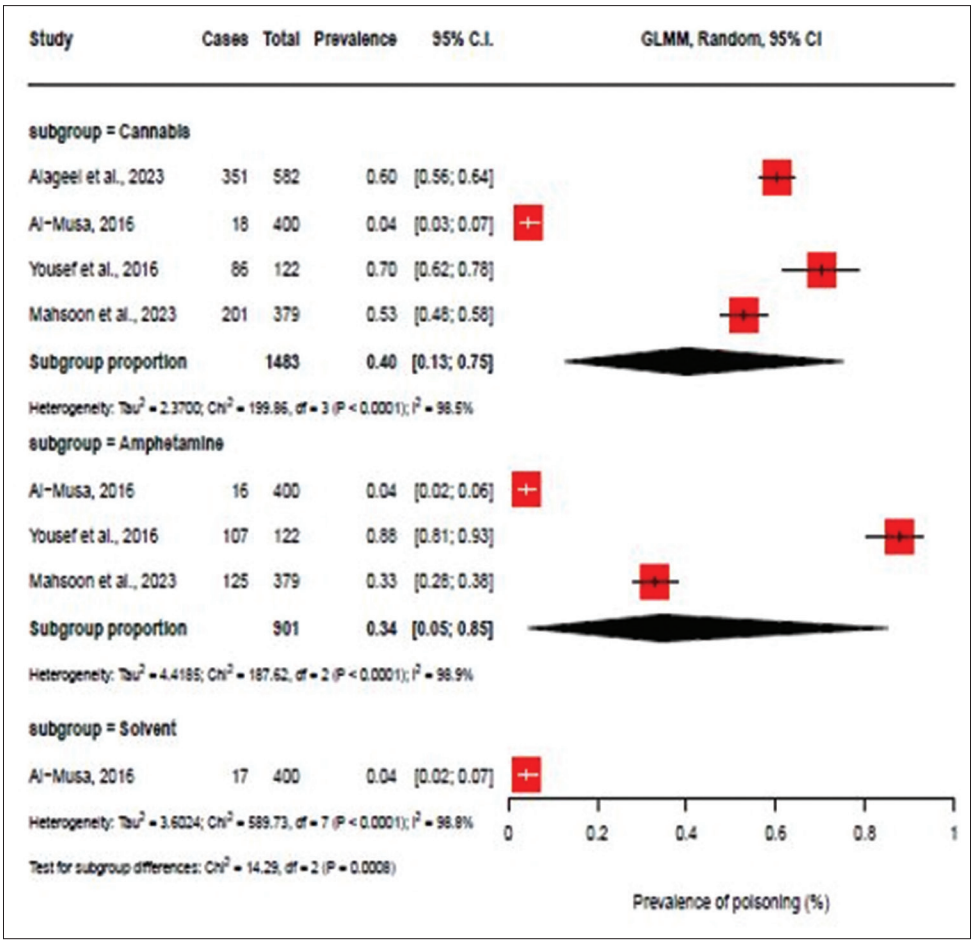

Figure 2: Forest plot for prevalence of poisoning due to synthetic drugs

occurs as a result of the accumulation of formaldehyde and formic acid leading to visual impairment and brain damage in a few cases.[17,18,21] Numerous investigations have documented metabolic acidosis and visual abnormalities resulting from methanol poisoning, with an incidence of between 30% and 60% hospital admissions.[33] A key component of methanol poisoning therapy protocols is the prompt correction of metabolic acidosis and the removal of formate. Various antidotes, such as ethanol and fomepizole are used to treat methanol poisoning in an attempt to reduce the amount of formate generated by methanol metabolism.[33,34] The present study findings showed that cannabis smoking was highly prevalent among adolescents. A study conducted in Abha city showed that approximately 8.8% of adolescents smoked cannabis; this is followed by glue/solvents and amphetamines.[15] Several studies found that between 1% and 60% of people use cannabis, depending on their age and geographic location. Adolescents were found to use cannabis at higher rates than adults. G-protein couple cannabinoid receptor 1 (CB1R) down regulation and desensitization are associated with regular cannabis use, and CB1R levels remain low for 3–4 weeks following cessation of use.[35] During this period, abusers are admitted to the emergency room with poor vital signs, reduced appetite, and high metabolic rates.[34]

Microbial food-borne sickness or food poisoning, is a common occurrence everywhere, Saudi Arabia, not excluded.[36] However, the majority of patients recover from food-borne illnesses without medical attention or long-term complications. Numerous microorganisms are capable of causing food-borne illness.[37] Salmonella is the most prevalent bacterium that causes food-borne illnesses globally, and its incidence is rising annually in Saudi Arabia as well. According to the current study's findings, Clostridium botulinum and Salmonella are accountable for a number of food-related issues that affect people of all ages, but particularly youngsters.[19,27] In addition, this study discovered that men were marginally more likely to be affected than women by poisoning, particularly those between the ages of 1 and 10 years. This is corroborated by a prior study that found male patients were more likely to have had food-borne diseases than female patients.[37]

Children are curious and explore by frequently putting things in their mouths with no thought of consequence.

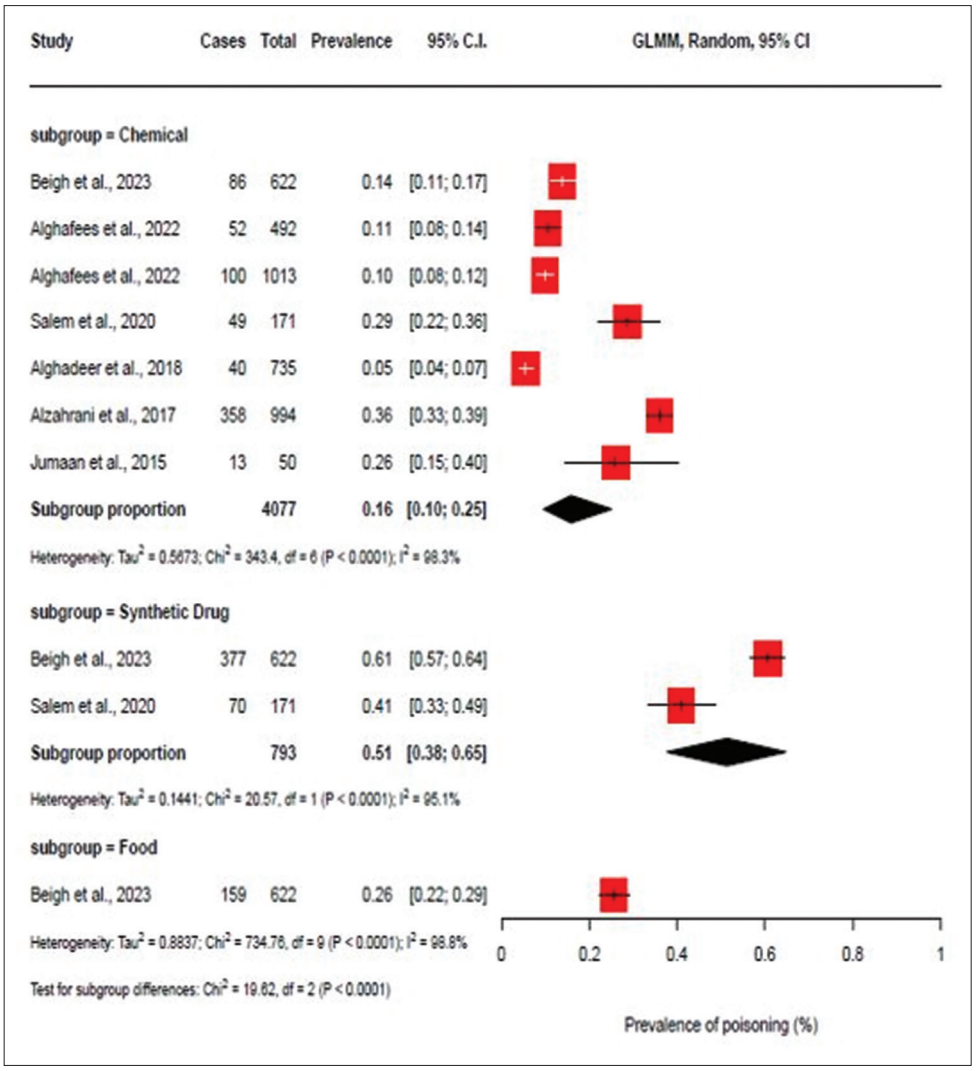

Figure 3: Forest plot for prevalence of poisoning due to industrial chemicals and pesticides

This age group is the most vulnerable to inadvertent ingestion of poisons or pharmaceuticals. Because of the easy access to dangerous substances, and the absence of adult supervision they are exposed to and may ingest high levels of toxins.[9] The primary mode of poisoning in 78.4% of cases was oral and unintentional in the majority of cases involving children under the age of five.[20,22] Public education initiatives and programs about poisoning and drug overdose must be a priority to prevent such incidents. The implementation of a comprehensive community education program is advised to increase awareness of the dangers these substances pose and to encourage parents to keep chemicals and prescriptions out of the reach of small children.

Nonetheless, the percentage of deliberate poisoning cases brought on by drug overdose was mostly seen in adults and children of > 13 years. According to the AAPCC's 2019 annual report, 13.1% of all poisoning cases were thought to involve suicidal intent.[38] A review of food-borne pathogens conducted in Greece revealed that many cases of hospitalization and even death were caused by food poisoning.[39] According to a cross-sectional survey carried out in Jizan, Saudi Arabia, Khat chewing was prevalent among students of that region, with gender, peer influence, and cigarette smoking significantly associated.[30] According to a retrospective study on envenomation and the bite rate by venomous snakes in Saudi Arabia, majority of the cases were released from hospital following treatment, with only a small number of fatal cases. According to the study, delaying the necessary treatment can result in serious morbidity and death.[31]

The implications of the findings from this review have significant relevance for both clinical practice and public health policy. Given the challenges in comparative analysis because of the diversity of the selected studies, healthcare practitioners and policymakers must exercise

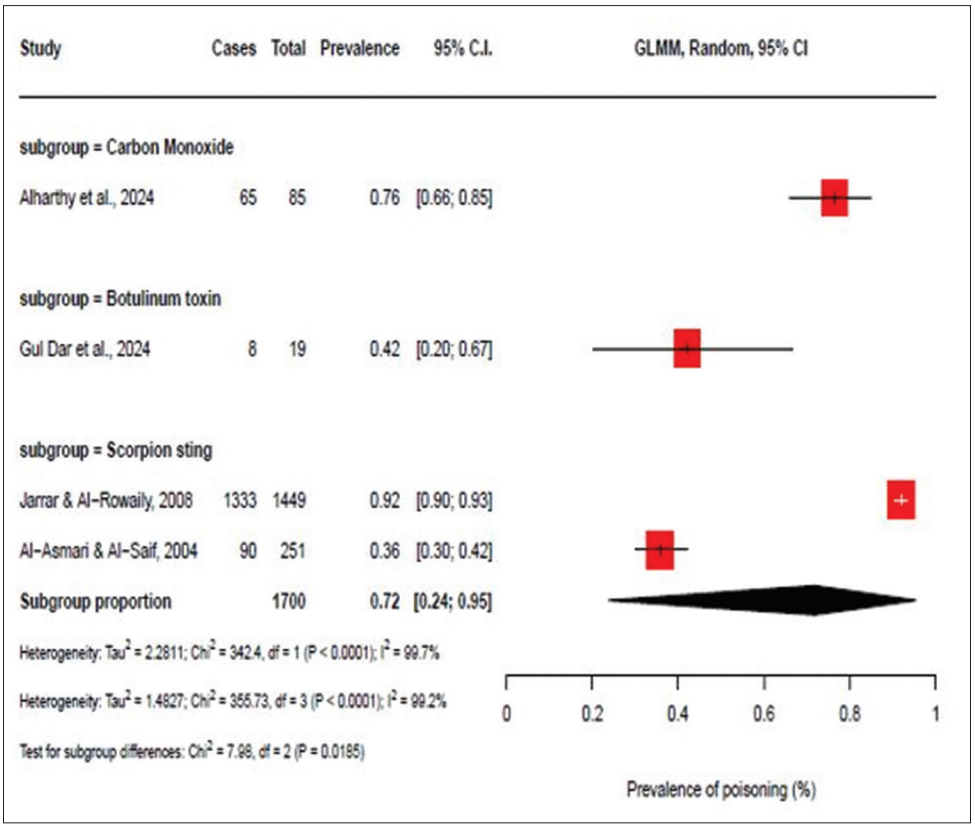

Figure 4: Forest plot for prevalence of poisoning due to natural toxins

caution when interpreting the results. The lack of comprehensive toxicology data, particularly in pediatric cases, underscores the need for improved reporting and surveillance systems. Addressing these gaps could enhance the effectiveness of poisoning prevention strategies and emergency response protocols in the different regions in Saudi Arabia.

From a policy perspective, the findings highlight the necessity of establishing a centralized, accessible toxicology database that integrates hospital reports, follow-up records, and exposure causes. This would facilitate better monitoring of cases of poisoning and improve healthcare interventions. In addition, targeted awareness campaigns should be developed to educate the public on the risks of exposure to toxins, particularly for vulnerable populations such as children.

For future research, it is crucial to conduct more standardized and regionally inclusive studies to allow for meaningful comparative analyses. Researchers should prioritize accessing hospital toxicology records where possible and incorporate long-term follow-up data to assess patient outcomes comprehensively. Moreover, exploring the socioeconomic and environmental factors that influence toxin exposure could provide deeper insights into prevention strategies.

The limitations of the evidence included in this review must be critically examined. The reliance solely on published literature introduces potential biases, as unpublished or hospital-specific data may offer a more comprehensive picture of toxin exposure patterns. In addition, the lack of detailed causes of exposure and follow-up data weakens the ability to draw strong conclusions about risk factors and long-term health outcomes. Moreover, the exclusion of studies that lacked physical or chemical confirmation of toxins in this study was intended to ensure high reliability of the pooled results. However, this criterion was later removed to broaden the scope of the review and include a more comprehensive range of cases of poisoning reported in Saudi Arabia. The removal of this exclusion criterion introduced a potential limitation that of reducing the reliability and specificity of the pooled findings. Studies based solely on clinical diagnosis without laboratory confirmation could lead to misclassification bias, where nontoxic exposures are erroneously included as poisoning cases. This could affect the accuracy of prevalence estimates and the strength of conclusions drawn regarding toxin-specific risks. Future systematic reviews should consider a stratified analysis to differentiate between clinically-confirmed incidences and self-administered questionnaires, allowing for a more refined interpretation of poisoning trends in Saudi Arabia.

Table 2: Risk of bias assessment for each study included in this systematic review using 20-question Axis tool

Axis Tool Questions	Alageel *et al.*, 2023[14]	Mahsoon *et al.*[15]	Al-Musa and Al-Montashri, 2016[16]	Youssef *et al.*, 2016[17]	Alhusain *et al.*, 2024[18]	Beigh *et al.*, 2023[19]	Alghafees *et al.*, 2022[20]	Salem *et al.*, 2021[21]	Alruwaili *et al.*, 2019[22]
Were the study's goals and objectives well presented?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the study's structure suitable for achieving the intended goal(s)?	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the sample size appropriate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the target group specified with precision? (Was the subject of the study made clear?)	Yes	No	No	No	No	No	No	Yes	Yes
Has the target/reference individuals under study been accurately represented by the sample framework, which was drawn from a suitable demographic base?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Was it conceivable that the people chosen for the study would be a good representation of the target or reference population?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have steps been taken to address and classify non-responders been taken?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Did the risk variable and outcome information collected fit the study's objectives?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the risk component and outcome factors appropriately quantified using prior tested, piloted, or reported measurements?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is it evident how the statistical significance such as P-values and CI values or precision estimations were determined?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the procedures—including statistical procedures—described in detail enough to allow for their replication?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were basic facts sufficiently explained?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does the response percentage pose questions regarding nonresponse bias?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was data pertaining to nonresponders explained, if applicable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was there internal consistency in the results?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the findings for all the experiments mentioned in the methodology presented?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the results sufficient to support the study's discussions and inferences?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the study's limitations discussed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have the author's interpretations of the data been impacted by any financial sponsors or conflict of interest?	No	No	No	No	No	No	No	Yes	Yes
Did participants give their ethical permission or consent?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Axis Tool Questions	Alghadeer *et al.*, 2018[23]	Alzahrani *et al.*, 2017[24]	Al Jumaan *et al.*, 2015[25]	Alharthy *et al.*, 2024[26]	Gul Dar *et al.*, 2024[27]	Jarrar and Al-Rowaily, 2008[28]	Al-Asmari and Al-Saif, 2004[29]	Alsanosy *et al.*[30]	Al-Sadoon *et al.*, 2021[31]
Were the study's goals and objectives well presented?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the study's structure suitable for achieving the intended goal(s)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the sample size appropriate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the target group specified with precision? (Was the subject of the study made clear?)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Has the target/reference individuals under study been accurately	No	No	No	No	Yes	Yes	Yes	Yes	Yes

Contd...

Table 2: Contd...

Axis Tool Questions	Alghadeer *et al.*, 2018[23]	Alzahrani *et al.*, 2017[24]	Al Jumaan *et al.*, 2015[25]	Alharthy *et al.*, 2024[26]	Gul Dar *et al.*, 2024[27]	Jarrar and Al-Rowaily, 2008[28]	Al-Asmari and Al-Saif, 2004[29]	Alsanosy *et al.*[30]	Al-Sadoon *et al.*, 2021[31]
represented by the sample framework, which was drawn from a suitable demographic base?									
Was it conceivable that the people chosen for the study would be a good representation of the target or reference population?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have steps been taken to address and classify non-responders been taken?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Did the risk variable and outcome information collected fit the study's objectives?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the risk component and outcome factors appropriately quantified using prior tested, piloted, or reported measurements?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is it evident how the statistical significance such as P-values and CI values or precision estimations were determined?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear
Were the procedures—including statistical procedures—described in detail enough to allow for their replication?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were basic facts sufficiently explained?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does the response percentage pose questions regarding nonresponse bias?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was data pertaining to nonresponders explained, if applicable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was there internal consistency in the results?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the findings for all the experiments mentioned in the methodology presented?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the results sufficient to support the study's discussions and inferences?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the study's limitations discussed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have the author's interpretations of the data been impacted by any financial sponsors or conflict of interest?	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
Did participants give their ethical permission or consent?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Regarding the systematic review process itself, several limitations should be acknowledged. The exclusion of hospital toxicology records owing to data inaccessibility may have led to an incomplete representation of poisoning cases. In addition, variability in study methodologies and reporting standards across the selected articles could impact the reliability of the findings. It is essential to recognize these limitations and assess their potential impact to ensure that conclusions drawn from the review are interpreted with appropriate caution.

Conclusion

This review provides a holistic overview of acute poisoning cases in different regions of Saudi Arabia, highlighting the significant impact of synthetic drugs, industrial chemicals, pesticides, and natural toxins on public health. Synthetic drug abuse, particularly involving cannabis and amphetamines, still remains a serious public health issue, contributing to psychiatric disorders, road accidents, and societal harm. Industrial

chemicals, such as methanol, and pesticides used in households continue to pose significant risks, especially to children, and adults in workplace settings. Although less common, natural toxins, including scorpion envenomation, food-borne botulism, and carbon monoxide poisoning, add to the casualty list of healthcare services.

Identifying high-risk populations, evaluating prevention programs, and optimizing treatment protocols should be prioritized in future studies. National approach to a stricter policy and regional community education is important to reduce the impact of toxins and safeguard public health across Saudi Arabia.

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Conflicts of interest
There are no conflicts of interest.

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