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Poisonous mushrooms of Northeast India: Toxicity, health risks and ethnobotanical insights

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Abstract

Mushroom poisoning poses a significant threat due to the human consumption of wild, poisonous mushrooms endowed with harmful toxins. The ethnic communities in Northeast India frequently encounter adverse effects from consuming poisonous mushrooms, often due to a lack of taxonomic expertise. Many wild mushroom species, such as *Agaricus xanthodermus*, *Amanita phalloides*, *A. virosa*, *Chlorophyllum molybdites*, *Gyromitra infula*, *Inocybe geophylla*, and *Russula nobilis*, are recorded from the region, which are poisonous for human consumption. These mushrooms contain toxic compounds that cause cytotoxic, myotoxic, metabolic, neurotoxic, gastrointestinal disorders, and other adverse reactions. Hence, the poisonous mushrooms of the region should be scientifically explored to identify and distinguish them from the edible ones. This review documents the reported poisonous mushroom species of Northeast India and provides insight into the occurrence of cases of mushroom poisoning in the region.

Keywords – Ethnic communities – mushroom poisoning – toxins – wild edible mushrooms

Introduction

Mushrooms are fleshy, spongy, spore-producing macrofungi, mostly belonging to Basidiomycetes and Ascomycetes, and prefer mostly damp and dark environment for their growth. According to archaeological evidence, fungi have been documented in fossil records from the Silurian period (Taylor et al. 2015). About 2–3 million fungal species have been estimated worldwide (Niskanen et al. 2023), but very few species have been identified as poisonous (Chen et al. 2014). Due to their great nutritional value and potential to treat diseases, mushrooms are regarded as an essential food component (Das et al. 2014). Therefore, in every corner of the earth, edible mushrooms have been foraged from the wild, cultivated, and used commercially (Okhuoya et al. 2010). Wild edible mushrooms (WEM) are cheap food sources, rich in nutrients, and frequently referred to as "poor man's meat", as many species are readily available in the wild.

In India, mushrooms have long been a staple food in many tribes' diets and trade practices (Tanti et al. 2011). Northeast India, consisting of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, accounts for one of the world's 36 biodiversity hotspots and comprises diverse flora and fauna. High relative humidity (80–90%) in the region allows a rich variety of macrofungi to thrive. Mycophilic ethnic tribes in the plains and hilly areas, such as Bodo, Garo, and Khasi, frequently use mushrooms that they harvest from natural habitats for their day-to-

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day food requirements and as a source of traditional remedies (Khaund & Joshi 2013, Ao et al. 2016). Since time immemorial, human mushroom poisoning has been documented and mentioned in ancient sacred books like the Rigveda and Atharvaveda (Jha & Tripathi 2012). The large number and variety of mushroom species make the distinction between edible and poisonous mushrooms difficult (Adhikari 2004). Mushroom poisoning, also known as 'mycetism', is caused by ingesting some mushrooms containing harmful constituents (Hansepi & Teron 2018). Mushroom poisoning is still a severe problem for food safety and human health, with acute toxicity, morbidity, and fatality widespread in different corners of the world. Moreover, several edible species may sometimes prove hazardous to some people in different conditions while remaining harmless to others (White et al. 2019). Although Northeast India has a wide variety of mushrooms, widespread usage is limited due to inadequate awareness. The utilisation of indigenous knowledge for wild mushroom identification, consumption, poisoning prevention, information transfer mechanisms, and commercial potential has not yet been thoroughly studied. In addition, global warming, habitat loss, urbanization, and overexploitation have resulted in risks to the rich store of wild mushrooms in this highly sensitive region (Karlson-Stiber & Persson 2003, Kalita 2016, Verma et al. 2019). Although there have been a few studies on wild edible mushrooms from various regions of Northeast India (Hrudayanath & Sameer 2014), literature focusing on the poisonous mushrooms of the region is rare. This review attempts to point out the reported poisonous mushroom species of Northeast India and the causes behind frequent mushroom poisoning cases, and encourages further research on them.

Traditional methods of Northeastern ethnic communities to distinguish poisonous mushrooms

Scientific investigations authenticating traditional practices to distinguish poisonous mushrooms are still lacking. Usually, locals ensure the safe use of macrofungi by distinguishing edible from toxic species during collection using a variety of parameters, including sight, smell, touch, taste, and substrate (Das 2010, Das et al. 2014, Khumlianlal et al. 2022). Edible mushrooms have a fruity, meaty, or enticing aroma, while those with bright colours are likely toxic (Hansepi & Teron 2018). When mushrooms are stored in rice and turn the rice black, such mushrooms are considered poisonous (Borah et al. 2018). Generally, insects and animals avoid poisonous mushrooms. Excrement-grown mushrooms as well as mushrooms that have been kept for more than 2–3 days and contain microfungi infestations, are considered poisonous (Panda & Swain 2011).

Traditional indicators used by ethnic communities play a significant role in distinguishing edible macrofungi from poisonous ones. Mushroom collectors in the Karbi community consider mushrooms with caps that have gills and a pleasing odour for non-poisonous; On the contrary, mushrooms consisting of a stalk with a ring (annulus) are believed to be toxic. If the colour of the water changes to green, yellow, or black after soaking it overnight or cooking, then the macrofungus is considered non-edible (Longvah & Deosthale 1998). Off-season edible mushrooms are also suspected to be toxic. Those macrofungi that, when kept in the dark, illuminate under a flash of light are not consumed. Edible macrofungi that emit an unflavoured odour at maturity are only collected and consumed in the young stage. Toxic substances are sources of unpleasant fragrances; mushrooms growing on trees are avoided because they may have accumulated harmful material from their host (Tiewsoh et al. 2022). Macrofungi with reticulate or net-like structures under the cap or on the stalk surface and bright-coloured fruiting bodies are also considered toxic. Many mushrooms look similar in appearance, and the constraint lies in differentiating them from one another. Compared to others, wood macrofungi can be easily distinguished by the substrate on which they have grown. Hence, much attention and caution are required in the collection process (Tanti et al. 2011, Khaund & Joshi 2013, Das et al. 2014).

Mushroom poisoning

Most mushroom poisoning cases have been reported during the monsoon season in Northeast India, as wild mushrooms proliferate enormously during this time. *Amanita phalloides* is one of the deadliest mushroom species, with more than 90% of deaths caused by poisoning in many unreported instances (Karlson-Stiber & Persson 2003). In India, most cases of mushroom poisoning have been

reported from *Amanita phalloides*, along with reports from some species of *Conocybe*, *Galerina*, and *Lepiota* (Verma et al. 2019). Of the existing mushroom species, only a few species are confirmed to be harmful to humans (Paul et al. 2019), while most of the other species' toxicity profiles have not been studied. Distinct geographical locations favour the growth of poisonous mushrooms, such as *Amanita*, *Galerina*, and *Lepiota* species in different pockets of Northeast India (Barman et al. 2018). Easy accessibility of these mushroom species containing toxic compounds such as amatoxin and phallotoxin results in liver toxicity and gastroenteritis, accounting for more than 30% of the mortality cases in the region (Diaz 2016). In recent times, many cases from Northeast India have been reported of people frequently admitted to hospitals and deaths due to poisonous mushroom consumption (Saha et al. 2023). Lack of proper knowledge of identification is the primary cause behind most cases. Unwanted species growing alongside the collected mushrooms are often uprooted unknowingly, and lack of knowledge about the morphological differences between the species results in most of the fatalities (Hansepi & Teron 2021). The fruiting body produces spores containing poisonous compounds that start acting at the gastrointestinal level, resulting in stomach discomfort once the poison is retained. Passage of toxins into the bloodstream can be fatal, affecting vital organs like the liver and kidney, and the person may even succumb to death. Carcinogenicity, altered respiratory and heart rates, and renal failure are the ill effects of most toxic mushrooms (Sharma et al. 2013). Some mushrooms, also called toadstools, contain poisons that are harmful even when eaten in modest amounts. Secondary metabolites produced by some mushroom species are potentially poisonous and hallucinogenic. Additionally, bioluminescent mushrooms indicate that they should not be consumed. Most mushroom poisonings and fatalities are caused by hepatotoxin (Tiewsoh et al. 2022), amatoxin, and nephrotoxin-containing mushrooms, such as *Cortinarius* species, due to acute renal disorder and failure (Baniasad et al. 2014). Mushroom poisoning can occur in response to many factors, such as consuming toxic mushrooms, an immunological response to mushroom-derived antigens, or due to overeating of mushrooms (Das et al. 2014). To avoid toxication and health problems caused by poisonous mushrooms, it is crucial to identify mushrooms used for medicinal or culinary purposes.

Poisonous mushrooms reported from Northeast India

Cases of mushroom poisoning are very frequent in the northeastern part of the country, and every year, sporadic death cases arise associated with them (Barman et al. 2018, Pandita et al. 2021, Tiewsoh et al. 2022, Saha et al. 2023). However, the pattern and magnitude of incidents are difficult to trace due to a lack of clear information. Pandita et al. (2021) reported 53 cases in 5 years (2014-2019), mostly from five districts of Meghalaya, and found that the age group of 11–20 years was most affected. Over 100 mushroom poisoning cases have occurred since 2022 in different parts of north-east India. Although no extensive research was done to ascertain the fatality rates of mushroom poisoning in India, these rates range from 1–21%, with the north-eastern states reporting about 9% of the cases (Saha et al. 2023). In Assam, a case series revealed significant mortality in patients under 10 years (83%) or beyond 50 years (100%) due to consumption of poisonous mushrooms (Pandita et al. 2021).

Hansepi & Teron (2021) reported cases of mushroom mysticism in Karbi Hills and identified these poisonous mushrooms as *Amanita bisporigera* G.F. Atk., *Chlorophyllum molybdites* (G. Mey.) Massee, *Coprinopsis atramentaria* (Bull.) Redhead, Vilgalys & Moncalvo, and *Inocybe geophylla* P. Kumm. Similarly, out of 25 mushroom species studied by Bhattacharjee et al. (2015), some species like *Polyozellus multiplex* (Underw.) Murrill, *Pycnoporus sanguineus* (L.) Murrill, *Stropharia aeruginosa* (Curtis) Quél., and *Xylaria polymorpha* (Pers.) Grev. were reported as poisonous in the Indo-Bangladesh region of Northeast India. Out of Ascomycota members, including *Gyromitra infula* (Schaeff.) Quél., and *Hypomyces chrysospermus* Tul. & C. Tul.; and Basidiomycota members like *Agaricus xanthodermus, Amanita flavoconia, Amanita francheti* (Boud.) Fayod, *Boletus calopus* Pers., *Boletus erythropus* Pers., *Galerina marginata* (Batsch) Kühner, *Lepiota cristata* (Bolton) P. Kumm., *Paxillus involutus* (Batsch) Fr., *Pholiota squarrosa* (Vahl) P. Kumm., *Scleroderma areolatum* Ehrenb., *S. cepa* Pers., and *S. verrucosum* (Bull.) Pers., 126 species studied were poisonous (Das 2010). Ao (2019) reported 10 poisonous mushroom species in Nagaland, which

include *Agaricus moelleri* Wasser, *A. xanthodermus*, *Amanita cokeri* E.-J. Gilbert & Kühner ex E.-J. Gilbert, *A. flavoconia*, *A. phalloides*, *A. virosa*, *Lepiota felina*, *L. lilacea*, and *Russula nobilis*. *Amanita muscaria* and *A. verna* have a hallucinogenic effect upon ingestion. The presence of orellanine toxin in *Cortinarius* sp. causes renal failure upon consumption (Barman et al. 2018). Similarly, Paul et al. (2019) reported *Hypholoma lateritium* (Schaeff.) P. Kumm. (= *Hypholoma sublateritium*), *Phallus multicolor* (Berk. & Broome) Cooke, and *Scleroderma citrinum* as poisonous mushroom species (Fig. 1; Table 1).

Fig. 1- Photographs of some poisonous mushrooms: a *Agaricus moelleri*. b *Amanita bisporigera*. c *Boletus calopus*. d *Coprinopsis atramentaria*. e *Chlorophyllum molybdites*. f *Galerina marginata*. g *Gyromitra infula*. h *Hypholoma lateritium*. i *Hypomyces chrysospermus*. j *Inocybe geophylla*. k *Lepiota cristata*. l *Paxillus involutus*. m *Pholiota squarrosa*. n *Polyozellus multiplex*. o *Russula nobilis*. p *Scleroderma areolatum*. q *Stropharia aeruginosa* and r *Xylaria polymorpha* (Source:

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Table 1 List of reported poisonous mushrooms in Northeast India

Sl. No.	Poisonous mushrooms	Family	Major toxins present	Reported Locations	References
1.	*Agaricus moelleri*	Agaricaceae	Gyromitrin	Nagaland	Enjalbert et al. (2004), Ao et al. (2016), Ao (2019)
2.	*Agaricus xanthodermus*	Agaricaceae	Phenol, gyromitrin	Sikkim	Das (2010), Taylor & Hefle (2017), Ao (2019)
3.	*Amanita bisporigera*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Assam, Mizoram	Enjalbert et al. (2004), Bhattacharjee et al. (2015), Hansepi & Teron (2021), Malsawmtluanga et al. (2024)
4.	*Amanita cokeri*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Nagaland	Ao et al. (2016), Ao (2019), Lallawmsanga & Carrasco (2022)
5.	*Amanita flavoconia*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Sikkim, Nagaland	Enjalbert et al. (2004), Ao (2019), Das (2010)
6.	*Amanita franchetii*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Sikkim	Enjalbert et al. (2004), Wong & Ng (2006), Das (2010)
7.	*Amanita muscaria*	Amanitaceae	Ibotenic acid, muscarine	Sikkim	Enjalbert et al. (2004), Barman et al. (2018), Das (2010)
8.	*Amanita phalloides*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Sikkim, Nagaland	Wong & Ng (2006), Garcia et al. (2015), Ao et al. (2016), Ao (2019)
9.	*Amanita verna*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Sikkim	Das (2010), Dutta et al. (2018), Yu (2022)
10.	*Amanita virosa*	Amanitaceae	Amatoxins, phallotoxins, virotoxins	Sikkim, Nagaland, Mizoram	Enjalbert et al. (2004), Ao et al. (2016), Ao (2019), Malsawmtluanga et al. (2024)
11.	*Boletus calopus*	Boletaceae	Coprin, muscarine, bufotoxin	Sikkim	Das (2010)
12.	*Boletus erythropus*	Boletaceae	Coprin, muscarine, bufotoxin	Sikkim	Das (2010)
13.	*Chlorophyllum molybdites*	Agaricaceae	Molybdophyllysin	Assam	Ko¨ppel (1993), Su et al. (2013), Bhattacharjee et al. (2015), Hansepi & Teron (2021)
14.	*Coprinopsis atramentaria*	Psathyrellaceae	Coprin	Assam	Bhattacharjee et al. (2015), Hansepi & Teron 2021
15.	*Galerina marginata*	Strophariaceae	Amanitin	Sikkim	Ko¨ppel (1993), Das (2010)
16.	*Gyromitra infula*	Discinaceae,	Gyromitrin	Sikkim	Das (2010), Lallawmsanga & Carrasco (2022)
17.	*Hypholoma lateritium*	Strophariaceae	Triterpenoids	Assam	Borah et al. (2018), Paul et al. (2019)
18.	*Hypomyces chrysospermus*	Hypocreaceae	Amatoxins	Sikkim	Konno (1995), Das (2010)
19.	*Inocybe geophylla*	Inocybaceae	Muscarine, psilocybin, psilocin, aeruginascin	Assam	Bhattacharjee et al. (2015), Hansepi & Teron (2021)
20.	*Lepiota cristata*	Agaricaceae	Amatoxins, virotoxins	Sikkim	Konno (1995), Das (2010)

Table 1 Continued.

Sl. No.	Poisonous mushrooms	Family	Major toxins present	Reported Locations	References
21.	*Lepiota felina*	Agaricaceae	Amatoxins, virotoxins	Nagaland	Ao (2019), Lallawmsanga & Carrasco (2022)
22.	*Lepiota lilacea*	Agaricaceae	Amatoxins, virotoxins	Nagaland	Ao (2019), Lallawmsanga & Carrasco (2022)
23.	*Paxillus involutus*	Paxillaceae	Muscarine	Sikkim	Konno (1995), Das (2010)
24.	*Pholiota squarrosa*	Strophariaceae	Phenylpropanoids	Sikkim	Konno (1995), Das (2010)
25.	*Polyozellus multiplex*	Thelephoraceae	Polyozellin	Tripura, Mizoram, Meghalaya, Assam	Bhattacharjee et al. (2015), Paul & Sarma (2022), Alam et al. (2022), Lallawmsanga & Carrasco (2022)
26.	*Pycnoporus sanguineus*	Polyporaceae	Cinnabarin	Tripura, Mizoram, Meghalaya, Assam	Paul & Sarma (2022), Lallawmsanga & Carrasco (2022)
27.	*Russula nobilis*	Russulaceae	Clitidine	Nagaland	Ao (2019), Boxshall et al. (2021), Lallawmsanga & Carrasco (2022)
28.	*Scleroderma areolatum*	Sclerodermataceae	Trichloroethylene	Sikkim	Konno (1995), Das (2010)
29.	*Scleroderma cepa*	Sclerodermataceae	Trichloroethylene	Sikkim	Das (2010), Alam et al. (2022), Lallawmsanga & Carrasco (2022)
30.	*Scleroderma citrinum*	Sclerodermataceae	Methanol, triterpenoid	Assam	Borah et al. (2018), Paul et al. (2019)
31.	*Scleroderma verrucosum*	Sclerodermataceae	Trichloroethylene	Sikkim	Das (2010), Ao (2019), Lallawmsanga & Carrasco (2022)
32.	*Stropharia aeruginosa*	Strophariaceae	Aflatoxins, ochratoxin, fumonisin	Tripura, Mizoram, Meghalaya, Assam	Bhattacharjee et al. (2015), Paul & Sarma (2022), Alam et al. (2022), Lallawmsanga & Carrasco (2022)
33.	*Stropharia stercoraria*	Strophariaceae	Aflatoxins, 3-nitropropionic acid	Tripura, Mizoram, Meghalaya, Assam	Diaz (2016), Lallawmsanga & Carrasco (2022)
34.	*Xylaria polymorpha*	Xylariaceae	Amanitin, phalloidin	Tripura, Mizoram, Meghalaya, Assam	Bhattacharjee et al. (2015), Debnath et al. (2018), Lallawmsanga & Carrasco (2022)

Symptoms and consequences of poisoning

Consumption of poisonous mushrooms causes problems in the abdominal area in most cases (Figure 2). When trehalose-containing mushrooms are consumed, trehalose-intolerant people may experience stomach discomfort and diarrhoea as they lack the trehalase enzyme (Chen & Gibney 2023). Immunological responses to the antigens of poisonous mushrooms may result in food allergies, intolerance effects, or hemolytic anaemia, and inhalation of the spores of such mushrooms can cause allergic responses in the respiratory tract (Alam et al. 2022). Raw mushrooms contain many toxic compounds, and eating them raw as salads may cause gastrointestinal problems (Diaz 2016). Due to its hepato-renal toxicity, *Amanita phalloides* poisoning is regarded as the most severe of all mushroom species' poisonings, causing acute liver failure due to disruption of RNA polymerase II (Saha et al. 2023). Furthermore, cooking or freezing cannot eliminate poisonous components like

amatoxin. Symptoms often start to show up 6 to 8 hours after consumption, and many times, patients suffer from liver failure if not supported with treatments immediately (Diaz 2005). Within 20 minutes to 4 hours after the consumption of poisonous mushrooms, symptoms such as nausea, vomiting, cramps, and diarrhoea occur (Sharma et al. 2013).

The clinical symptoms and consequences of mushroom poisoning are classified into six major classes (White et al. 2019). Cytotoxic mushroom poisoning causes hepatotoxicity with symptoms like severe gastrointestinal effects like nausea, vomiting, abdominal pain, secondary dehydration, and diarrhoea, which may lead to complete liver failure. Direct renal damage has been reported upon consuming mushrooms containing aminohexadienoic acid. Neurotoxic mushroom poisoning results in central nervous system (CNS) effects, illusions (audio-visual), and hallucinations in most cases. Myotoxic mushroom poisoning shows rhabdomyolysis as the primary feature. Symptoms like weakness, stiffness of the leg, and myoglobinuria are very common (Yu 2022). Metabolic and endocrine-related toxicity of mushroom poisoning results in blocking gamma-aminobutyric acid (GABA) synthesis, resulting in multi-organ failure effects. Gastrointestinal irritant mushroom poisoning also causes variable gastrointestinal effects such as nausea, vomiting, diarrhoea, and dehydration (Lagrange & Vernoux 2020). Other miscellaneous adverse reactions to mushroom poisoning include reddening, swelling, and burning sensations with extreme abdominal pain (Taylor & Hefle 2017).

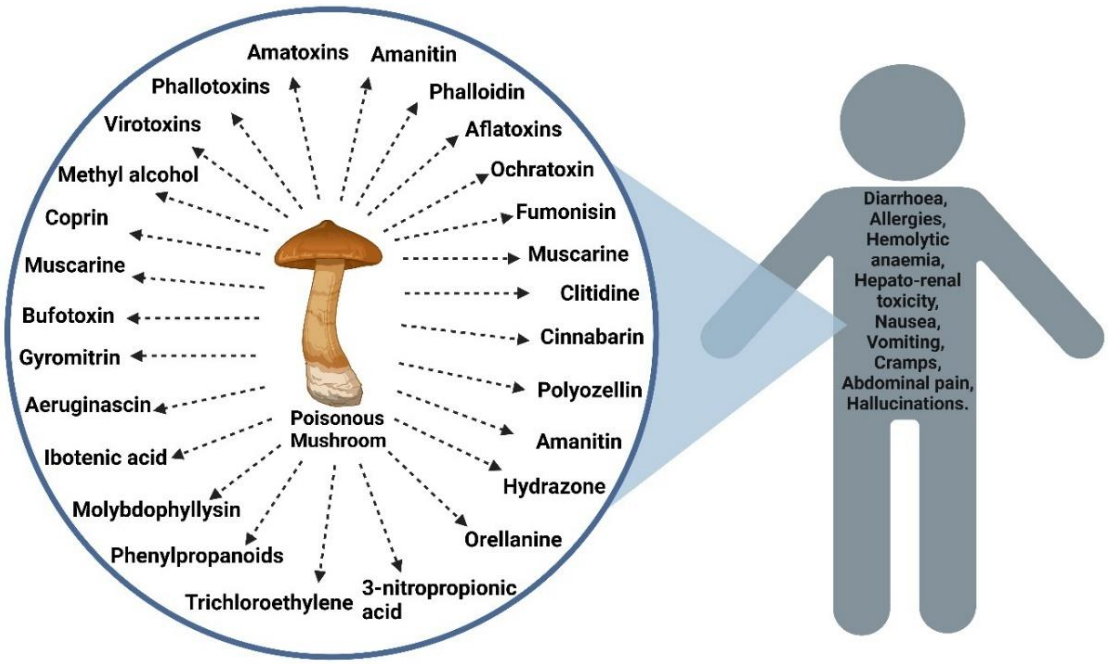

Fig. 2 – Toxic constituents of various poisonous mushrooms and their probable effect on human health on consumption (Created with Biorender.com).

Amanita poisoning should be considered in the differential diagnosis of severe gastroenteritis and renal failure. Early hospitalisation, gastric lavage, hydration, penicillin, and silymarin therapy with hepatorenal support are the main components of management, and delaying treatment might result in a fatality rate of about 100% (Yilmaz et al. 2015). The majority of poisonous mushrooms, including *Amanita rubescens*, *A. spissa*, *A. strobiliformis*, *Boletus erythropus*, *B. huridus*, *Entoloma clypeatum*, *Lactarius* spp., and *Russula* spp., are edible if the poisonous compounds are deactivated by heating (Mas 2005).

Toxic constituents of poisonous mushrooms and indigenous knowledge associated with their prevention

Amatoxin-containing mushrooms are notorious for their high rates of morbidity and fatality from delayed gastroenteritis and liver poisoning. They are widespread in the north-eastern part of India, particularly during the summer monsoon months, when the wild varieties are plentiful and often mistaken for the edible varieties (Pandita et al. 2021). Two primary categories of toxins are found in toxic mushroom species, including *Amanita*, *Galerina*, and *Lepiota*, namely amatoxins and phallotoxins. The main toxic ingredients, amanitin and α,β amanitin, are responsible for toxicity in amanitin-containing mushrooms (Boxshall et al. 2021). Amatoxins are 10–20 times more toxic than phallotoxins as they are orally active, while phallotoxins are active only when administered intravenously (Mas 2005). Toxins of just 10 mg in these poisonous mushrooms are sufficient to cause fatalities (Ko¨ppel 1993). Cytotoxic mushroom poisoning is caused by amatoxins (*Amanita phalloides*), amino hexadienoic acid (*Amanita smithiana*), and orellanine (*Cortinarius* spp). Neurotoxic mushroom poisoning is caused by psilocybins (*Psilocybe* spp.), muscarines (*Inocybe* spp.), and ibotenic acid (*Amanita muscaria*) (White et al. 2019), while toxins associated with myotoxic mushroom poisoning are carboxylic acid (*Russula subnigrans*) and saponaceolide B (*Tricholoma equestre).* Metabolic or endocrine toxicity poisoning is caused by gyromitrins (*Gyromitra* spp.), coprines (*Coprinus* spp.*),* polyporic acid (*Hapalopilus rutilans*), and trichothecenes (*Podostroma cornu-damae*) (Konno 1995). Gastrointestinal irritant mushroom poisoning results from toxins such as acromelic acid (*Clitocybe acromelalga*), and hydrocyanic acid (*Pleurocybella porrigens*) (White et al. 2019).

The ethnic traditions of Northeast India are enriched with indigenous knowledge to identify, prepare, and alleviate the toxic constituents of poisonous mushrooms if consumed or before consumption. Karbi tribes avoid cooking terrestrial and epiphytic mushrooms as precautionary measures against mushroom poisoning. In cases of poisoning, they use fresh or dried fruits of *Antidesma* sp., *Garcinian lanceaefolia*, *Gracinia* sp., and *Hibiscus sabdariffa* as home remedies (Borah et al. 2018). The Khasi people of Meghalaya insert a small, red hot iron rod in the centre of a bowl of fried mushrooms to eliminate the toxins (Borthakur & Joshi 2019). Similarly, Biates considers mushrooms toxic when curry cooked with brinjals turns dark green. If someone consumes mushrooms and has nausea, vomiting, chest pain, or diarrhoea, they are given copper or silver coin-dipped water for drinking. In many cases, patients were given dry, raw fish to eat to induce vomiting to eliminate the poison. Some preventive measures, like not eating raw mushrooms, selecting only known edible mushrooms, collecting only identified ones, eating mushrooms in good condition, proper cooking, and avoiding overconsumption, can help to minimise the cases of mushroom poisoning. At first, a small amount of mushroom must be consumed, as even some known edible species, like morels, sometimes cause illness in some people (Sharma et al. 2013). By educating the public, mushroom poisoning can be avoided. People must be aware of the dangers of mixing up mushrooms as the season begins. At any time, if there is even the remotest possibility that a mushroom may be dangerous, it should be avoided. Genomic markers should be developed for the DNA barcoding of mushrooms, allowing identification of the poisonous taxa (Ao 2019, Kakoti et al. 2021, Gogoi et al. 2023). However, the availability of rapid test kits or the development of mobile-based applications will be more helpful to identify poisonous mushrooms in field conditions.

Conclusions and prospects

Northeast India, being the hub of wild mushrooms with diverse species, has yet to be scientifically explored to its full potential. The proper identification, characterisation, and edibility status of the mushroom should be studied. It is the need of the hour for proper distinction between poisonous mushrooms, as a high number of cases from this region have been reported for mushroom poisoning. Monsoon month marks the widespread blooming of mushrooms, including the poisonous ones. During this time, many poisoning cases are reported, while most remain unreported and undocumented, making proper estimation of the cases difficult. Adequate measures and primary treatments can alleviate most of the fatal cases. Hence, on-time medical treatments are necessary to

save most of the fatalities, and identification of the cause of poisoning is necessary. The medicinal, nutritional, and health-beneficial properties of many mushroom species are still unknown. The indigenous knowledge associated with WEM, their medicinal properties, methods to identify the poisonous species, and ethnic measures to reduce the ill effects of poisonous mushrooms must be documented. The major challenges we have experienced so far in identifying poisonous mushrooms may be solved by whole genome sequencing and other advanced tools and techniques, which can provide a more accurate and rapid identification of toxic species. In terms of taxonomy, specific, dependable, and distinguishable traits of toxic mushrooms might aid in identifying them and preventing the consumption of deadly mushrooms. Concerning clinical therapy, the more we understand how toxins affect the human body, the more accurate therapeutic options might be developed to reduce the frequency of lethality. Biodiversity loss throughout most of India's northeastern states poses a threat to wild mushroom diversity due to land use changes, urbanisation, air pollution, population increases, and deforestation. Thus, it has become essential to identify and record scientifically the WEM that are steadily disappearing. The review aims to strengthen our current knowledge of poisonous mushroom species in the region and emphasise the need for more research in this field.

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Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose

Author contribution

BJP and RKN had the idea for the article, BJP performed the literature search and data analysis, and BJP, AKD, and NA drafted and/or critically revised the work.

References

Adhikari MK. 2004 – Mushroom poisoning and its state in Nepal. Plant Resources Bulletin 25, 56–58.

Alam S, Nisar M, Bano SA, Ahmad T. 2022 – Impact of aerial fungal spores on human health. In: Ahmed T, Hashmi MZ, editors. Hazardous Environmental Micro-pollutants, Health Impacts and Allied Treatment Technologies. Cham: Springer International Publishing 219–240. Doi 10.1007/978-3-030-96523-5_10

Ao T. Deb CR. 2019 – Wild mushrooms of Nagaland, India - An important bioresource. Studies in Fungi 4(1), 61 –78. Doi 10.5943/sif/4/1/9

Ao T, Seb J, Ajungla T, Deb CR. 2016 – Diversity of wild mushrooms in Nagaland, India. Open Journal of Forestry 6 (5), 404 –419. Doi 10.4236/ojf.2016.65032

Baniasad N, Oghabian Z, Mehrpour O. 2014 – Hepatotoxicity due to mushroom poisoning: a case report. International Journal of Medical Toxicology and Forensic Medicine 4(2(Spring)), 68–73. Doi 10.22037/ijmtfm.v4i2(Spring).4915

Barman B, Warjri S, Lynrah K, Phukan P et al. 2018 – *Amanita* nephrotoxic syndrome: Presumptive first case report on the Indian subcontinent. Indian Journal of Nephrology 28(2), 174. Doi 10.4103/ijn.IJN_353_16

Bhattacharjee J, Bhattacharjee D, Paul T, Kumar A, Chowdhury S. 2015 – Diversity of mushrooms in Indo-Bangladesh region of North-East India. Journal of the Andaman Science Association 19(1), 75–82. ISSN 0970-4183

Borah N, Semwal RL, Garkoti SC. 2018 – Ethnomycological knowledge of three indigenous communities of Assam, India. Indian Journal of Traditional Knowledges 17(2), 327–335.

Borthakur M, Joshi SR. 2019 – Wild Mushrooms as functional foods: the significance of inherent perilous metabolites. In: New and Future Developments in Microbial Biotechnology and Bioengineering, Elsevier, p. 1–12. Doi 10.1016/B978-0-444-63504-4.00001-3

Boxshall A-G, Birch JL, Lebel T, Symonds MRE et al. 2021 – A field-based investigation of simple phenol variation in Australian *Agaricus xanthodermus*. Mycologia 113(6), 1123–1135. Doi 10.1080/00275514.2021.1936851

Chen A, Gibney PA. 2023 – Dietary trehalose as a bioactive nutrient. Nutrients 15(6), 1393. Doi 10.3390/nu15061393w

Chen Z, Zhang P, Zhang Z. 2014 – Investigation and analysis of 102 mushroom poisoning cases in Southern China from 1994 to 2012. Fungal Diversity 64(1), 123–131. Doi 10.1007/s13225-013-0260-7

Das K, Lamo A, Paul B, Jha LK. 2014 – Ethnomycological knowledge on wild edible mushroom of Khasi tribes of Meghalaya, North-Eastern India. European Academic Research 2, 3433–3443.

Das K. 2010 – Diversity and conservation of wild mushrooms in Sikkim with special reference to Barsey Rhododendron Sanctuary. NeBIO 1(2), 1–13.

Debnath S, Majumdar K, Das P, Saha AK. 2018 – New distribution record of five species of *Xylaria* from Tripura, Northeast India. Research & Reviews: A Journal of Life Sciences 8(1), 1–10. ISSN: 2249-8656

Diaz JH. 2005 – Evolving global epidemiology, syndromic classification, general management, and prevention of unknown mushroom poisonings. Critical Care Medicine 33(2), 419–426. Doi 10.1097/01.CCM.0000153530.32162.B7

Diaz JH. 2016 – Mistaken mushroom poisonings. Wilderness & Environmental Medicine 27(2), 330–335. Doi 10.1016/j.wem.2015.12.015

Dutta A, Das AK, Pegu AK, Kalita BC. 2018 – Early hydration therapy in mushroom poisoning improves mortality and morbidity. Journal of the Indian Society of Toxicology 14(1), 11–16. http://dx.doi.org/10.31736/jist/v14.i1.2018.11%E2%80%9316

Enjalbert F, Cassanas G, Rapior S, Renault C et al. 2004 – Amatoxins in wood-rotting *Galerina marginata*. Mycologia 96(4), 720 –729. Doi 10.1080/15572536.2005.11832920

Garcia J, Costa VM, Carvalho A, Baptista P et al. 2015 – *Amanita phalloides* poisoning: Mechanisms of toxicity and treatment. Food and Chemical Toxicology 86, 41–55. Doi 10.1016/j.fct.2015.09.008

Gogoi I, Borthakur A, Neog B. 2023 – Ethnomycological knowledge, nutritional and nutraceutical potential of wild edible macrofungi of Northeast India. Studies in Fungi 8(1), 8–12. Doi 10.48130/SIF-2023-0012

Hansepi P, Teron R. 2018 – Eschewing poisons. Current Science 115(7), 1328–1333. https://www.jstor.org/stable/26978406

Hansepi P, Teron R. 2021 – Wild mushrooms and cases of mycetism among the people of Karbi Hills, Assam of Northeast India. In: Current Biological Research 54–70. ISBN:978-93-5566-144-9

Hrudayanath T, Sameer KS. 2014 – Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. African Journal of Biotechnology 13(4), 523–545. Doi 10.5897/AJB2013.13446

Jha SK, Tripathi NN. 2012 – Recent scenario in diversity, distribution and applied value of macrofungi: a review. International Journal of Universal Pharmacy and Life Sciences 2, 102–125.

Kakoti M, Hazarika DJ, Kumar A, Barooah M, Modi MK et al. 2021 – Genetic diversity and DNA barcoding of wild mushrooms from Northeast India. Iranian Journal of Science and Technology 45(2), 469 –479. Doi 10.1007/s40995-021-01067-7

Kalita K. 2016 – Documentation of wild edible mushrooms from Meghalaya, Northeast India. Current Research in Environmental & Applied Mycology 6(4), 238–247. Doi 10.5943/cream/6/4/1

Karlson-Stiber C, Persson H. 2003 – Cytotoxic fungi - an overview. Toxicon 42(4), 339–349. Doi 10.1016/S0041-0101(03)00238-1

Khaund P, Joshi SR. 2013 – Wild edible macrofungal species consumed by the Khasi tribe of Meghalaya, India. Indian Journal of Natural Products and Resources 2, 197–204. ISSN: 0976-0512

Khumlianlal J, Sharma KC, Singh LM, Mukherjee PK et al. 2022 – Nutritional profiling and antioxidant property of three wild edible mushrooms from North East India. Molecules 27(17), 5423. Doi 10.3390/molecules27175423

Ko¨ppel C. 1993 – Clinical symptomatology and management of mushroom poisoning. Toxicon 31(12), 1513–1540. Doi 10.1016/0041-0101(93)90337-I

Konno K. 1995 – Biologically active components of poisonous mushrooms. Food Reviews International 11(1), 83–107. Doi 10.1080/87559129509541021

Lagrange E, Vernoux J-P. 2020 – Warning on false or true morels and button mushrooms with potential toxicity linked to hydrazinic toxins: an update. Toxins 12(8), 482. Doi 10.3390/toxins12080482

Lallawmsanga A, Carrasco BJ. 2022 – Chapter 1. Diversity of the fungi kingdom: molecular tools to distinguish mushrooms considered safe and unsafe for human health. In: Stojkovic D, Barros L, editors. Food Chemistry, Function and Analysis. Cambridge: Royal Society of Chemistry 1–26. Doi 10.1039/9781839167522-00001

Longvah T, Deosthale YG. 1998 – Compositional and nutritional studies on edible wild mushroom from Northeast India. Food Chemistry 63(3), 331–334. Doi 10.1016/S0308-8146(98)00026-0

Mas A. 2005 – Mushrooms, amatoxins and the liver. Journal of Hepatology 42(2), 166–169. Doi 10.1016/j.jhep.2004.12.003

Malsawmtluanga CD, Lalbiaknunga J, Laldinkima C. 2024 – Detection and quantification of Amatoxin in wild mushrooms from North-East India using HPLC-PDA method for food safety purposes. Toxicon 251, 108134.

Niskanen T, Lücking R, Dahlberg A, Gaya E et al. 2023 – Pushing the frontiers of biodiversity research: Unveiling the global diversity, distribution, and conservation of fungi. Annual Review of Environment and Resources 48(1), 149–176.

Okhuoya J, Akpaja E, Osemwegie O, Oghenekaro A. 2010 – Nigerian mushrooms: underutilized non-wood forest resources. Journal of Applied Sciences and Environmental Management 14(1), 43–54. Doi 10.4314/jasem.v14i1.56488

Panda A, Swain K. 2011 – Traditional uses and medicinal potential of *Cordyceps sinensis* of Sikkim. Journal of Ayurveda and Integrative Medicine 2(1), 9. Doi 10.4103/0975-9476.78183

Pandita K, Topno N, Thappa D. 2021 – Mushroom poisoning and outcome of patients admitted in a tertiary care hospital in North East India. Journal of Medicine in the Tropics 23(1), 29. Doi 10.4103/jomt.jomt_53_20

Paul M, Sarma TC. 2022 – Chapter-6 Significance of macrofungi among various ethnic tribes residing in and around various forest areas of Assam: an ethnomycological survey. Current Research and Innovations in Plant Pathology 77–86. Doi 10.22271/ed.book.1645

Paul M, Sarma TC, Deka DC. 2019 – Macrofungal diversity of some districts of Assam, India with special reference to their uses. Asian Journal of Conservation Biology 8(2), 115–125. ISSN:2278-7666

Saha A, Das D, Dutta A, Pegu AK. 2023 – Clinical profile of patients presenting with mushroom toxicity in a tertiary care setup in Northeast India: with special focus on model for end-stage liver disease score as a predictor of disease outcome. International Journal of Advances in Medicine 10(6), 456–460. Doi 10.18203/2349-3933.ijam20231452

Sharma J, Malakar M, Sandiguria E, and Das J. 2013 – An expressive study of mushroom poisoning cases in Lakhimpur district of Assam. International Journal of Advancements in Research & Technology 2(9), 82–88. ISSN 2278-7763.

Su Z, Wang P, Yuan W, Li S. 2013 – Chemical Constituents from the Fruit Body of *Chlorophyllum Molybdites*. Natural Product Communications 8, 1934578X1300800. https://doi.org/10.1177/1934578X1300800910

Tanti B, Gurung L, Sarma GC. 2011 – Wild edible fungal resource used by the ethnic tribes of Nagaland, India. Indian Journal of Traditional Knowledge 10(3), 512–515. ISSN: 0975-1068

Taylor TN, Krings M, Taylor EL. 2015 – Fossil fungi. Academic Press, London 382.

Taylor SL, Hefle SL. 2017 – Naturally occurring toxicants in foods. In: Foodborne Diseases: Elsevier 327–344. Doi 10.1016/B978-0-12-385007-2.00016-4

Tiewsoh I, Bhattacharya P, Barman B, Barman H. 2022 – Delayed liver toxicity and delayed gastroenteritis: A 5 year retrospective analysis of the cause of death in Mushroom poisoning. Journal of Family Medicine and Primary Care 11(5), 1963. Doi 10.4103/jfmpc.jfmpc_1806_21

Verma N, Bhalla A, Singh S. 2019 – Mushroom poisoning. In: Principles and Practice of Critical Care Toxicology 367–373. Doi: 10.5005/jp/books/18181_42

White J, Weinstein SA, De Haro L, Bédry R et al. 2019 – Mushroom poisoning: A proposed new clinical classification. Toxicon 157, 53–65. Doi 10.1016/j.toxicon.2018.11.007

Wong JH, Ng TB. 2006 – Toxins from basidiomycete fungi (mushroom): amatoxins, phallotoxins, and virotoxins. In: Handbook of Biologically Active Peptides: Elsevier 131–135. Doi 10.1016/B978-012369442-3/50023-4

Yilmaz I, Ermis F, Akata I, Kaya E. 2015 – A Case Study: What Doses of *Amanita phalloides* and Amatoxins Are Lethal to Humans? Wilderness & Environmental Medicine 26(4), 491–496. Doi 10.1016/j.wem.2015.08.002

Yu X. 2022 – Six groups of poisonous mushrooms: classified according to clinical symptoms. Highlights in Science, Engineering and Technology 19, 216–222. Doi 10.54097/hset.v19i.2853