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Introduction to Veterinary Toxicology

The production and utilization of hazardous chemicals in both developed and developing countries have increased significantly over the past few decades. With the world population continuing to grow, the demand for food is rising; consequently, the use of pesticides and other potentially toxic chemicals is also expected to increase. Recent data exemplifies this trend: In Malaysia, the agrochemicals market was estimated at USD 679.59 million in 2024 and is projected to reach USD 849.33 million by 2029, growing at a compound annual growth rate (CAGR) of 4.56% during that period (Figure 1.1).

Industrial growth will also require a greater variety and amount of industrial chemicals and metallic compounds that are potentially toxic. The combined interactions of population growth, urbanization, and industrialization, coupled with poor sanitation, malnutrition, inadequate health care, and lack of regulatory control over the use of potentially dangerous chemicals, particularly in developing countries, will undoubtedly have significant impacts on the environment and subsequently on human health (Landrigan et al., 2018; Fuller et al., 2022; Kuddus et al., 2020; Briffa et al., 2020). Thus, urgent and decisive action is required to ameliorate the situation before it gets worse and unmanageable. The least one can do is to identify and understand the properties of any potentially toxic chemical or substance they are handling. Therefore, sufficient data on the toxicological properties of chemicals and their hazardous effects on the environment and human health should be made readily accessible to the general public.

Toxicology, as a scientific discipline, traces its roots back thousands of years – its earliest documentation being in ancient texts from China, Egypt, and India, where naturally derived poisons from plants and animals were used for both medicinal and malicious purposes. Over time, the study of toxic substances evolved from a primitive understanding of symptoms into a complex science that now encompasses molecular biology, chemistry, veterinary medicine, environmental science, and even social policy (Figure 1.2).

In today's context, veterinary toxicology has taken on a new urgency. The growing interconnection between animal and human health, accelerated by climate change, globalization, and transboundary trade, has placed toxicants at the forefront of One Health concerns. This is especially critical in tropical countries, where high humidity, intense rainfall, and pest proliferation encourage frequent use of agrochemicals – often with limited regulatory oversight. Unfortunately, the lack of comprehensive toxicovigilance systems in many developing nations makes animals – both domesticated and wild – early victims of unmonitored chemical exposure.

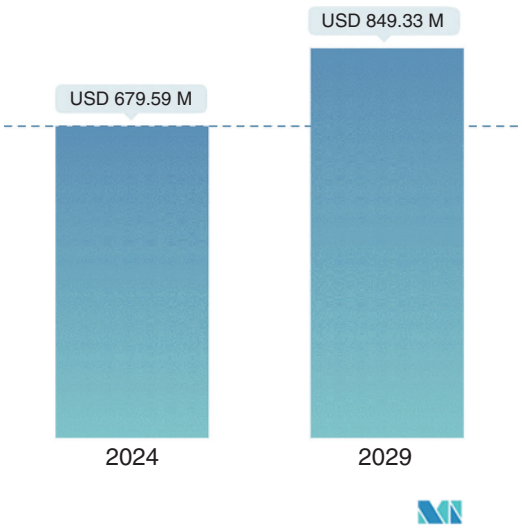


Figure 1.1 Agrochemical market size for Malaysia. *Source:* Malaysia Agrochemicals Market Size & Share Analysis - Growth Trends and Forecast (2025–2030)/ Mordor Intelligence.

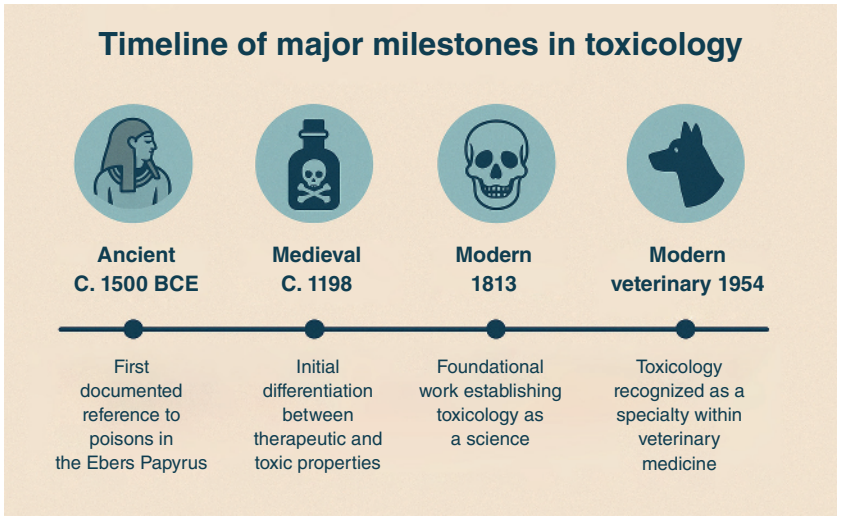


Figure 1.2 Timeline infographic of major milestones in toxicology (ancient → modern veterinary).

From a veterinary perspective, the presence of chemical contaminants in water sources, feed, pasturelands, or air has profound implications. In livestock, subclinical levels of mycotoxins can reduce reproductive efficiency and immune competence, leading to economic losses that remain hidden for years. In poultry and aquaculture, feed contamination can decimate entire production cycles. Meanwhile, wildlife face cumulative risks from bioaccumulated toxins such as organochlorines and heavy metals, particularly in ecologically sensitive regions like wetlands, mangrove belts, and marine sanctuaries.

The impact is not just biological – it is also economic and societal. In regions where animal husbandry contributes significantly to food security and rural livelihood, mass poisoning events can cripple income streams and food supply chains. The most alarming aspect is that many of these exposures are preventable through education, regulation, and better diagnostic infrastructure. This book seeks to fill that gap – not just by presenting the science of poisons, but also by contextualizing it within the tropical realities faced by veterinarians, researchers, and policymakers alike.

Moreover, the integration of modern toxicology into veterinary curricula and diagnostic services is still uneven across countries. There is a pressing need to strengthen regional toxicology laboratories, develop locally relevant reference values, and train more veterinary professionals in diagnostic toxicology – especially those working in field settings or in remote rural regions. Without these investments, many poisoning cases will go undiagnosed or misdiagnosed, and valuable lessons will be lost.

Veterinary toxicology must also evolve to respond to twenty-first-century challenges: climate-driven emergence of new toxic plants, the increasing use of synthetic supplements in animal feed, and the potential for pharmaceutical residues in the environment due to improper disposal of veterinary drugs. These complex challenges require a new generation of veterinarians who are not just diagnosticians but also advocates for safe chemical practices and sentinels of ecosystem health.

What Is a Poison?

A poison is defined as any chemical agent that can cause a deleterious response in a biological system or is capable of seriously affecting normal biological function or destroying life. It is a relative term because it requires definition of the biological system in which the deleterious effect is produced and the circumstances and conditions under which exposure to the poison occurs (Gupta, 2018; Hayes & Kruger, 2021). Feed-grade urea is a good example of this. Although urea is used as a feed ingredient as a substitute for natural protein in cattle, it is poisonous and highly lethal under certain nutritional conditions or improper utilization. For this reason, urea is normally included in cattle rations at the rate of approximately 1% of the total ration to avoid the occurrence of urea poisoning in cattle (Plumlee, 2013).

The term poison has a harsh meaning and historical significance. Toxicologists prefer to use the term toxicant because substances intended for use as feed additives, agricultural chemicals, or therapeutic drugs become poisons only when they are mishandled (Klaassen, 2021). Poisons can be of biological origin, such as the aflatoxins from the fungus *Aspergillus flavus*; nicotine from tobacco; muscarine from the poisonous mushroom *Amanita muscaria*; chemicals intended for human use, such as therapeutic drugs and agricultural chemicals; or naturally occurring chemical substances like lead and copper (Gupta, 2018). The term toxin is used to describe poisons released through biological processes, such as

Table 1.1 Conversion of percentage to parts per million (ppm) and parts per billion (ppb).

Percentage	Parts per million (ppm)
1	10,000
0.1	1,000
0.01	100
0.001	10
0.0001	1
0.00001	0.1 ppm = 100 ppb
0.000001	0.01 ppm = 10 ppb
0.0000001	0.001 ppm = 1 ppb
ppb – (parts per billion)	

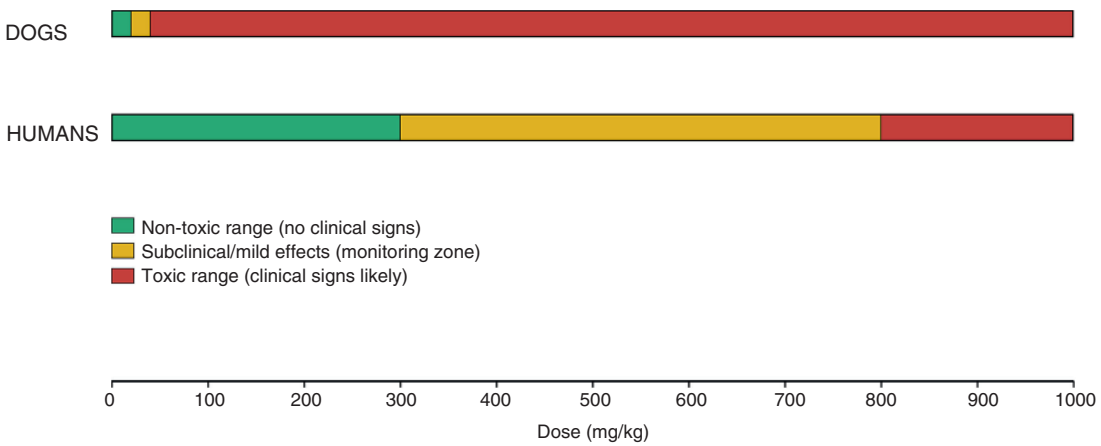
the endotoxins and exotoxins released by bacteria, phytotoxins from plants, and zootoxins from animals. These toxins are generally referred to as biotoxins.

The introduction of any new chemical, whether intended for use in humans, agriculture, or industry, is subjected to rigorous and stringent safety evaluations to determine its potential hazards. These hazardous effects are usually evaluated using experimental animals such as rats and primates. A few terminologies are used in safety testing. One of them is the median lethal dose, abbreviated LD_{50}, which is the minimum dose required to kill 50% of the population (Hayes & Kruger, 2021).

Toxicologists must understand the nature and effects of the poison, the biological system and environment in which it occurs, and the level of contamination or concentration of the toxicant in the biological system, environment, or in food or water to relate with the clinical symptoms exhibited in any case of suspected poisoning. The level of contamination or concentration of the toxicant is usually expressed as parts per million (ppm) or parts per billion (ppb). In metric units, 1 ppm is equal to 1 mg/kg and 1 ppb is equal to 1 μg/kg. In simple terms, 1 ppm is one part of substance X in 999,999 parts of substance Y on a weight-per-weight basis. The concentration of a toxicant can also be expressed as a percentage on a weight-per-weight basis, especially when dealing with high concentrations. The relationship between percentage and ppm is given in Table 1.1. To convert percentage to ppm or vice versa, the decimal point is moved four places to the right or left, respectively (Gupta, 2018).

In veterinary toxicology, identifying what constitutes a poison becomes more complex due to the diversity of species involved. A compound that is harmless to one species may be fatal to another, which emphasizes the importance of species-specific risk assessments. For example, grapes and raisins, which are innocuous to humans, can cause acute renal failure in dogs, while theobromine in chocolate can cause multiple organ failure in dogs (Plumlee, 2013). *Lilium* spp. (true lilies) are highly nephrotoxic to cats, even in minute amounts. Avocado contains persin, which is toxic to birds and some ruminants but safe for humans. These examples reflect the critical need to evaluate toxicants in the context of the affected species' physiology (Figure 1.3).

Equally important is the route of exposure, which can significantly affect toxicity. A compound may be lethal when ingested but relatively harmless on dermal exposure. This is particularly relevant in field



Dogs: mild signs ≥20 mg/kg; cardiotoxic 40–50 mg/kg; seizures ≥60 mg/kg; LD50 ~100–200 mg/kg (Merck Vet Manual). Humans tolerate far higher doses; LD50 ≈1000 mg/kg (est. human literature). Conceptual bands only.

Figure 1.3 Example of a toxic vs. nontoxic doses of substances across species.

conditions where animals may encounter substances in contaminated soil, water, or vegetation. For instance, organophosphate insecticides can cause cholinergic overstimulation if absorbed through the skin in livestock, especially when improperly diluted or applied during hot weather that promotes dermal absorption (Gupta, 2018; Klaassen, 2021).

The form of the compound – its chemical state – also plays a pivotal role. Elemental mercury is far less toxic when ingested than methylmercury, which readily crosses the blood–brain barrier. Similarly, ferrous sulfate, an iron supplement, is safe at therapeutic doses but potentially fatal if accidentally ingested by piglets or puppies in large amounts (Plumlee, 2013).

Understanding poisons also demands consideration of the animal's health status. Nutritional deficiencies, dehydration, pregnancy, or preexisting disease may all predispose an animal to increased susceptibility. For example, ruminants suffering from molybdenum deficiency are far more prone to chronic copper poisoning due to impaired excretion (Gupta, 2018).

Finally, the term "poison" in public discourse often carries fear and finality, but toxicologists recognize that it is often a matter of context, dose, and preparedness. With proper awareness, even potentially lethal substances can be handled safely and put to productive use. The goal is not to eliminate all toxicants from animal environments – an impossible task – but to understand, anticipate, and manage the risks they present.

What Is Toxicology?

Toxicology, as a discipline, fundamentally revolves around the principle that "the dose makes the poison." This emphasizes that any substance, even water or oxygen, can exert harmful effects if exposure exceeds safe thresholds (Hayes & Kruger, 2021; Klaassen, 2021). Understanding the pathways of exposure – whether ingestion, inhalation, or dermal absorption – is essential in assessing risk and

guiding a clinical response. The severity and manifestation of toxicosis often depend not only on dose and route but also on the species, age, health status, and environmental context of the affected animal (Gupta, 2018).

It is subdivided into:

Environmental toxicology deals with the toxic effects of chemicals contaminating the environment (atmosphere, food, and water) as either accidental or occupational hazards (Hayes & Kruger, 2021).

Economic toxicology deals with the hazards of chemicals purposely applied to living organisms to achieve a specific purpose. This includes the toxic effects of:

- therapeutic drugs for human and veterinary use
- chemicals used as food preservatives and cosmetics
- pesticides and herbicides used in agriculture (Gupta, 2018; Peterson and Talcott, 2013)

Forensic toxicology addresses the diagnosis, treatment, and legal consequences of poisoning – whether intentional or accidental.

In the veterinary context, toxicology is not merely an academic discipline – it is an essential clinical tool that informs diagnosis, treatment, prevention, and even policy formulation. Understanding how toxicants behave in biological systems is vital to addressing common scenarios encountered in practice, such as adverse drug reactions, environmental poisonings, or unexplained deaths in livestock herds (Plumlee, 2013).

One of the cornerstones of toxicological assessment is the ADME model: absorption, distribution, metabolism, and excretion. These four processes determine how a substance moves through and interacts with an animal's body. Each step varies significantly among species, age groups, and physiological states (Klaassen, 2021). For example, the gastrointestinal absorption of fat-soluble toxicants like organochlorines is enhanced in neonates due to increased gut permeability, while metabolic detoxification pathways may be underdeveloped in young animals, increasing their susceptibility (Figure 1.4).

Absorption refers to the route and efficiency by which a toxicant enters the bloodstream – through ingestion, inhalation, dermal contact, or injection. Distribution determines where the toxicant goes – whether it accumulates in fat, crosses the blood–brain barrier, or binds to plasma proteins. Metabolism often transforms lipophilic compounds into hydrophilic metabolites for easier excretion, though in some cases, these metabolites may be more toxic than the parent compound (e.g., acetaminophen in cats; Plumlee, 2013). Excretion occurs mainly through urine, bile, sweat, or milk – posing secondary risks to nursing offspring and humans consuming animal products (Figure 1.5).

Another critical concept is toxicodynamics – the interaction between the toxicant and cellular targets. Some agents inhibit enzymes, disrupt cell membranes, or trigger oxidative damage. Aflatoxins, for example, bind to DNA and cause mutations, making them both acutely hepatotoxic and chronically carcinogenic (Gupta, 2018). Ionophores like monensin disrupt ion gradients across membranes, affecting skeletal and cardiac muscle cells, particularly in horses (Peterson and Talcott, 2013).

Veterinary toxicology also interfaces with risk assessment and hazard characterization. A hazard is the inherent potential of a substance to cause harm, whereas risk is the likelihood of that harm occurring under specific exposure conditions. Thus, while copper is an essential trace element, it becomes

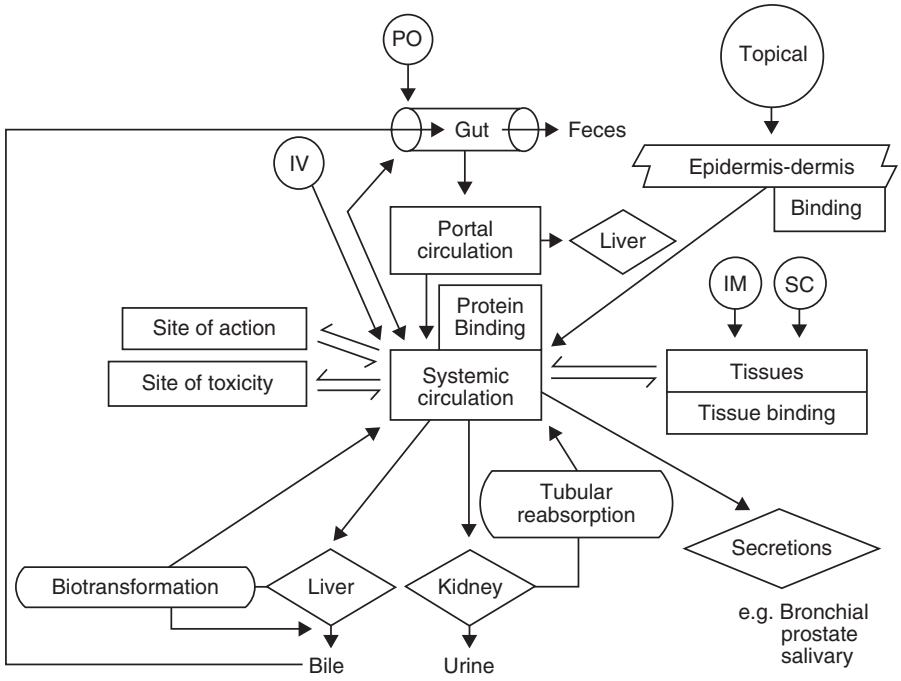
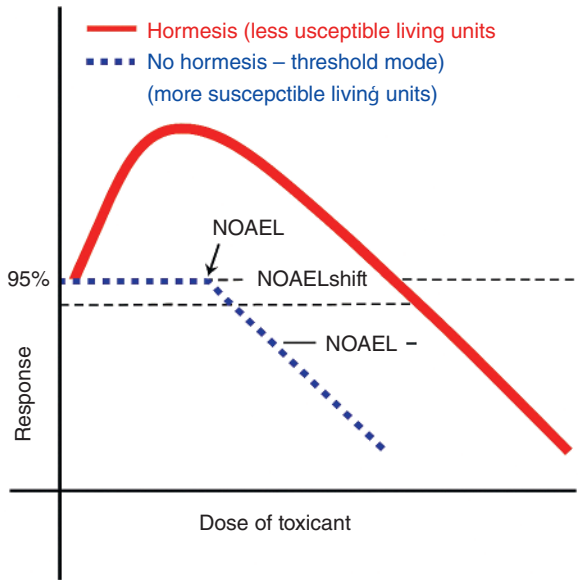


Figure 1.4 Basic schema by which drug is absorbed, distributed, metabolized, and excreted from the body. These processes are those that form the basis for developing pharmacokinetic models (Riviere and Papich, 2018).

Figure 1.5 Dose-response curve illustration (e.g., hormesis and NOAEL). *Source:* Author's original figure (conceptual basis consistent with standard toxicology texts).



hazardous at certain thresholds – particularly in sheep, which are genetically less efficient at copper excretion (Hayes & Kruger, 2021).

Emerging branches of toxicology further enrich its relevance. Ecotoxicology evaluates how toxicants affect animal populations and ecosystems, such as pesticide runoff impacting aquatic fauna (Klaassen, 2021). Pharmacovigilance and residue toxicology ensure that therapeutic agents do not persist in meat, milk, or eggs beyond acceptable limits, protecting consumers (WHO, 2019). Nanotoxicology is also gaining traction, as nanoparticles used in animal feed or diagnostics may behave differently at the molecular level, warranting fresh scrutiny (Peterson and Talcott, 2013).

Importantly, toxicology serves not only animals but also the communities that depend on them. During environmental disasters – oil spills, chemical plant explosions, or flooding – veterinary toxicologists play a vital role in assessing exposure risks and mitigating fallout for both animals and food chains. They also contribute to One Health frameworks, linking animal and human toxicological surveillance to predict and prevent cross-species exposure to harmful substances (Rumbeiha, 2012).

Ultimately, veterinary toxicology is both a preventive and reactive discipline. It enables the development of withdrawal intervals, safe feeding guidelines, poisoning management protocols, and regulatory benchmarks. It also guides veterinarians to think critically when faced with atypical clinical presentations – recognizing that toxicoses may masquerade as infectious, metabolic, or nutritional diseases (Gupta, 2018; Plumlee, 2013).

Relevance to Wildlife, Livestock, and Companion Animals Globally

Veterinary toxicology plays a critical role in safeguarding animal health across all major species categories. In wildlife, exposure to environmental pollutants such as lead, mercury, or organochlorine pesticides can disrupt reproductive systems, impair neurologic function, and even threaten species conservation efforts (Klaassen, 2021). For example, marine mammals and raptors have been widely documented to suffer from bioaccumulation of persistent toxicants (Gupta, 2018).

In livestock, the improper use of agrochemicals, contaminated feed, or inadequate withdrawal periods can lead to poisoning events that compromise not only animal welfare but also food safety and public health (Peterson and Talcott, 2013). Meanwhile, companion animals face poisoning risks due to their close proximity to humans. Common household items such as chocolate, xylitol, antifreeze (ethylene glycol), and certain medications can be highly toxic to pets (Plumlee, 2013; Figure 1.6).

Thus, a global perspective on toxicological threats is essential, especially as human activity continues to shape the health of animal populations across different ecological zones.

Wildlife: Sentinels of Environmental Health

Wildlife species are often the first to exhibit the effects of environmental contamination, making them invaluable biological sentinels. In the tropics, waterbirds inhabiting mangrove and estuarine ecosystems accumulate mercury and other heavy metals from mining runoff and industrial waste (Hayes & Kruger, 2021). Raptors, such as hawks and eagles, suffer from secondary poisoning after consuming prey that have ingested rodenticides or insecticide-laced carrion – a phenomenon well-documented in both tropical and temperate countries (Ogada et al., 2012).

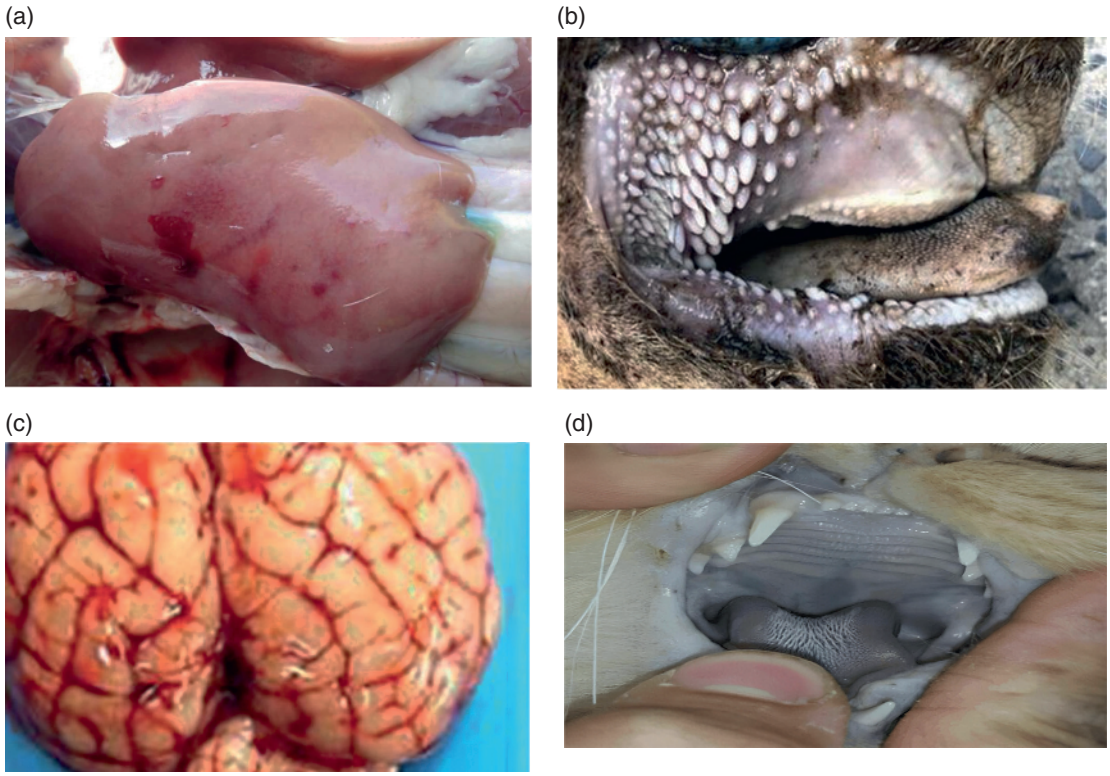


Figure 1.6 Comparative photos of toxicoses in different animals (details will be in subsequent chapters). (a) Aflatoxicosis (broiler) — pale, greasy liver with hemorrhages. (b) Nitrate poisoning (cattle) — muddy/cyanotic oral mucosa from methemoglobinemia. (c) Organophosphate poisoning (sheep) — congested meninges with hemorrhages. (d) Acetaminophen toxicity (cat) — cyanotic gums due to methemoglobinemia. *Source:* (a) Cide Intelligence Solutions / https://www.veterinariadigital.com/en/post_blog/aflatoxicosis-in-broilers/ / last accessed on Dec 17, 2025; (b) Flock & Herd / https://www.flockandherd.net.au/cattle/ireader/nitrate-toxicity-cattle.html / last accessed on Dec 17, 2025; (c) Rizzo et al. (2024) / The Scientific Electronic Library Online (SciELO) / CC BY 4.0; (d) Pet Health Club (2024) / Independent Vetcare Ltd.

One of the most striking examples is the decline of vulture populations in South Asia due to exposure to diclofenac, a nonsteroidal anti-inflammatory drug (NSAID) used in cattle. Although effective in livestock, diclofenac causes acute renal failure in vultures that scavenge on treated carcasses. The impact has been catastrophic, with population declines exceeding 95% in some regions (Green et al., 2004; Oaks et al., 2004; Shultz et al., 2004).

In aquatic wildlife, algal blooms driven by agricultural runoff can lead to the production of biotoxins such as microcystins. These toxins are fatal to fish, turtles, and marine mammals and can enter the food chain, posing risks to larger predators, including humans (Gupta, 2018).

In tropical rainforests, indigenous animals like fruit bats and primates are at risk of ingesting naturally toxic plants or fungal metabolites, especially during dry seasons when food is scarce. Bioaccumulation and the biomagnification of persistent pollutants are long-term ecological threats, particularly for top predators with slow reproductive rates (Hayes & Kruger, 2021) (Figures 1.7 and 1.8).

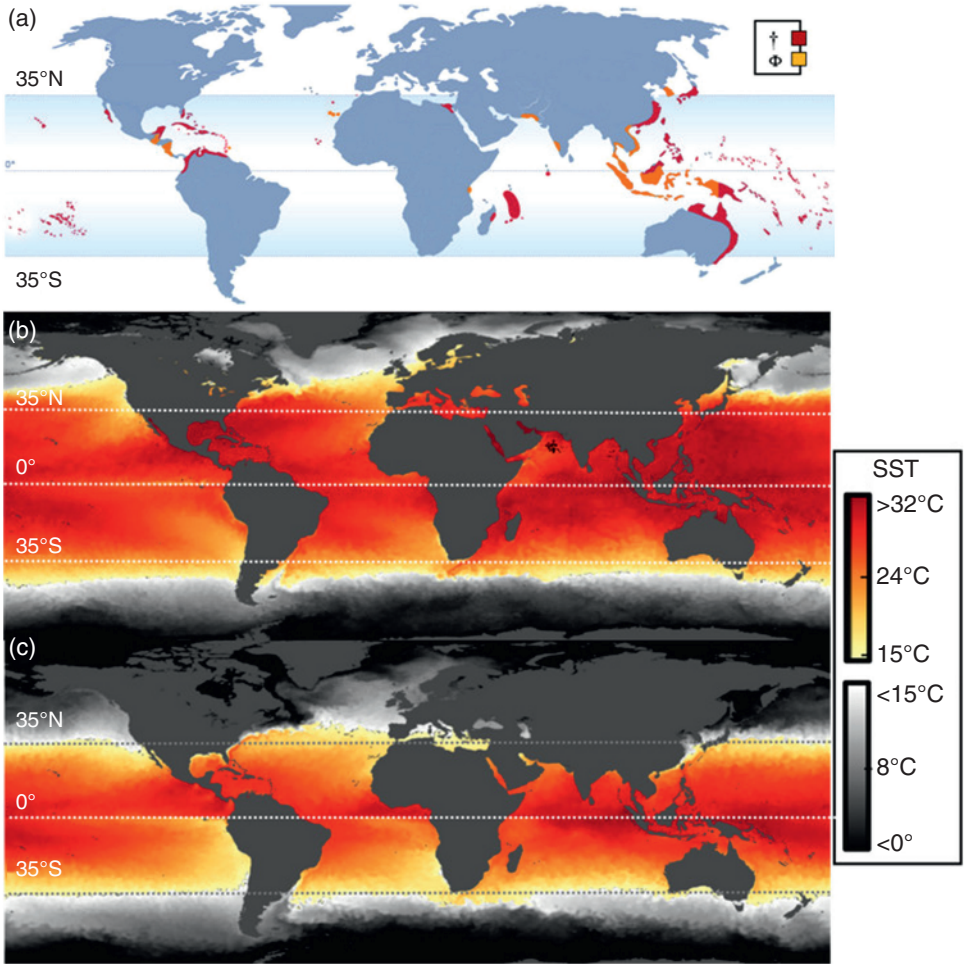


Figure 1.7 Global distribution of ciguatera fish poisoning and associated sea-surface temperatures (SSTs): (a) global map showing regions where ciguatera fish poisoning has been reported (mainly tropical and subtropical coastal/island areas); (b) global SST distribution under warmer conditions; and (c) global SST distribution under cooler conditions, illustrating the temperature envelope associated with the reported geographic distribution.

Livestock: Productivity and Food Chain Security

In livestock systems – especially in tropical developing countries – poor feed storage, weak regulation, and inadequate farmer training are major contributors to toxicoses. Mycotoxins such as aflatoxins, fumonisins, and zearalenone contaminate feed grains stored in humid conditions. Chronic exposure leads to immunosuppression, hepatotoxicity, reduced fertility, and stunted growth, often without overt clinical signs (Warnatzsch et al., 2020; Peterson and Talcott, 2013).

Ruminants are susceptible to nitrate and nitrite poisoning when consuming forage heavily fertilized with nitrogenous compounds, especially after drought or cloudy weather that impairs photosynthesis

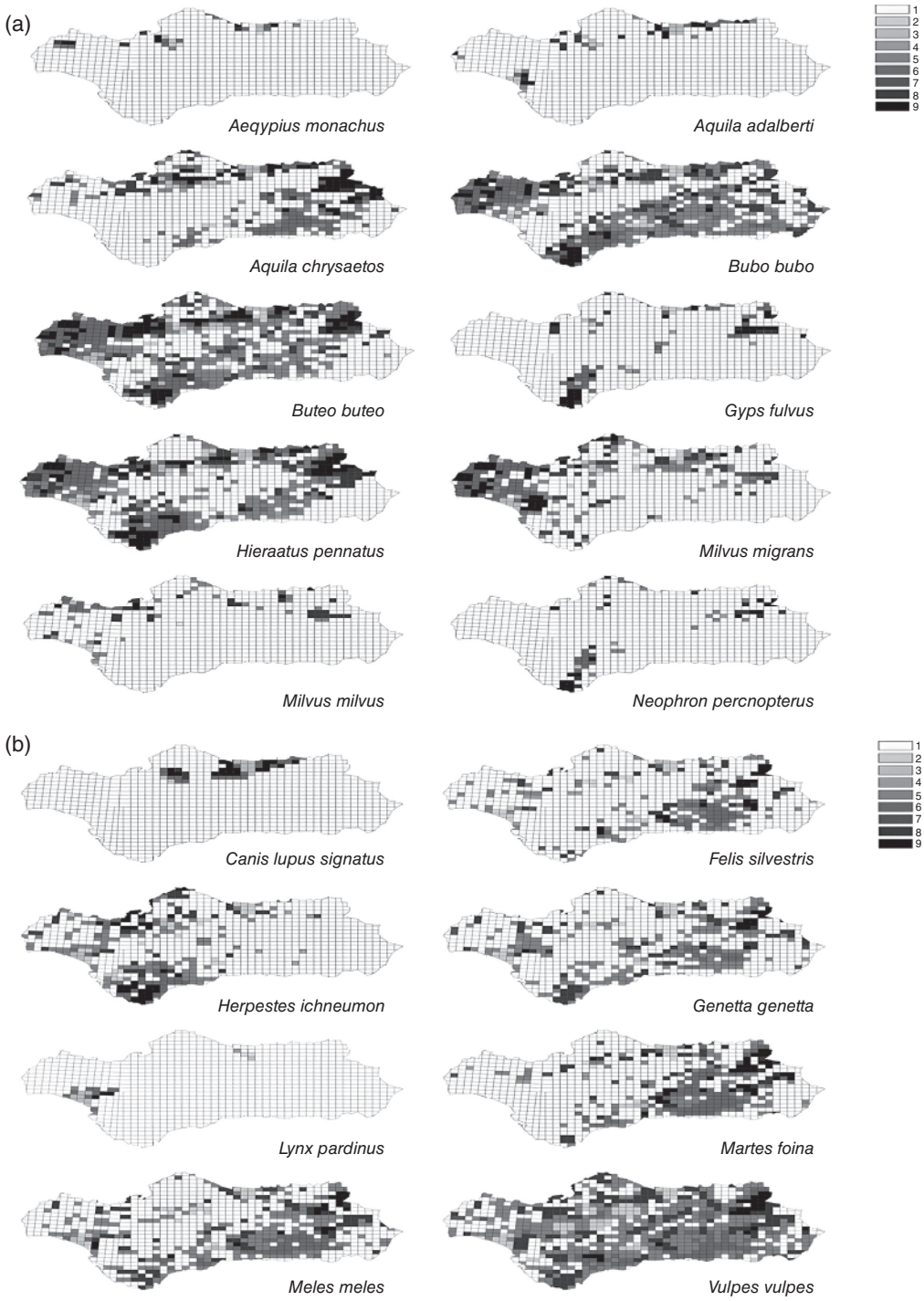


Figure 1.8 Conflict zones for wildlife poisoning incidents in specific regions. (a) Regional overview map highlighting conflict-affected areas associated with reported wildlife poisoning incidents; (b) zoomed-in/hotspot view showing clustering of incidents within the conflict zone(s) for clearer geographic interpretation.

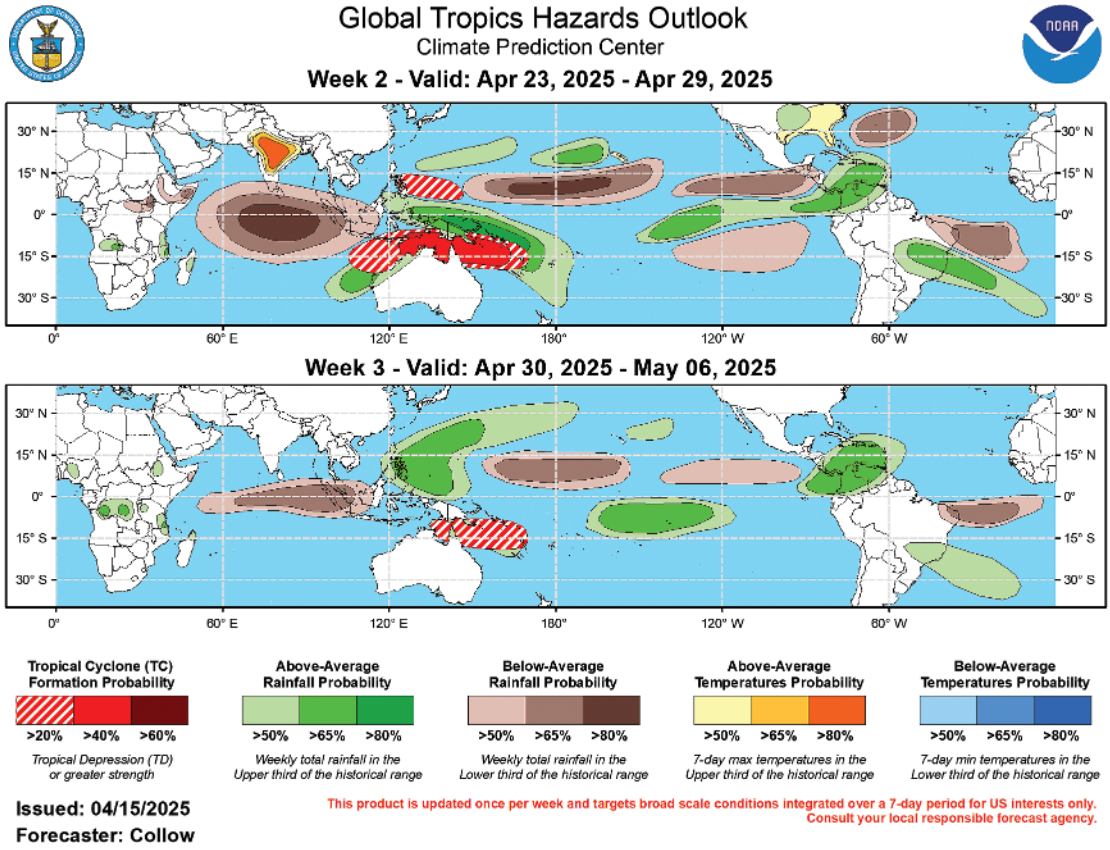


Figure 1.9 NOAA's forecast of climate-related hazards across the global tropics. *Source:* Weeks 2–3 Global Tropics Hazards Outlook/NOAA/Public Domain.

(Gupta, 2018). In tropical pastures, the presence of toxic plants such as *Lantana camara* or *Indigofera* species can result in hepatic and neurological toxicoses, respectively (Klaassen, 2021).

A unique challenge in tropical livestock farming is the accidental exposure to pesticides used for tick and pest control. Improper dilution, frequency, or use of banned organophosphates and carbamates can result in subacute toxicity that manifests as poor weight gain, photosensitization, or sudden death. These cases often go unreported or misdiagnosed due to the lack of diagnostic labs (FAO, 2021).

Moreover, failure to observe appropriate withdrawal periods for drugs like ivermectin, oxytetracycline, or albendazole results in detectable residues in meat and milk – posing public health concerns and leading to rejected export shipments in countries with strict residue surveillance systems (WHO, 2019) (Figure 1.9).

Companion Animals: Hidden Dangers in the Home

Pets, particularly dogs and cats, are frequently exposed to substances not intended for them. Common culprits include xylitol-containing gum, acetaminophen, grapes and raisins, essential oils, and nonprescription

NSAIDs (Plumlee, 2013). Many of these exposures are unintentional – owners may offer foods or medications that are safe for humans but deadly for animals.

Cats, due to their unique glucuronidation pathways, are highly susceptible to certain drugs and chemicals. A single tablet of acetaminophen can induce methemoglobinemia and hepatotoxicity in a cat. Similarly, ingestion of lilies – even licking pollen – can cause fatal acute kidney injury.

In dogs, chocolate toxicosis remains common. Theobromine levels in dark chocolate can cause tachycardia, tremors, and seizures. Antifreeze (ethylene glycol) toxicity is another notorious household hazard, with just a few milliliters being fatal due to oxalate crystal formation in the kidneys (Peterson and Talcott, 2013).

In multi-pet households, exposure to topical flea medications intended for dogs, such as permethrin-based products, can lead to life-threatening seizures in cats that groom each other. These scenarios emphasize the need for pet-specific toxicology education for both owners and clinicians.

Zoonotic and Public Health Implications

Veterinary toxicology is intricately tied to public health. Toxins that affect animals often have implications for humans through milk, meat, eggs, or water contamination. This is particularly crucial in rural settings where livestock and humans share the same water sources. Cyanobacteria blooms in stagnant ponds, for instance, pose risks not only to livestock but also to families using the water for washing or drinking (Hayes & Kruger, 2021).

In tropical zones, backyard poultry is often treated with antibiotics or pesticides without veterinary guidance. These birds, if slaughtered or consumed without observing withdrawal periods, become vectors for antimicrobial resistance (AMR) and chemical residues (WHO, 2019).

Moreover, the improper disposal of veterinary pharmaceuticals – especially in commercial farms – can lead to environmental contamination, bioaccumulation, and antibiotic leaching into soil and waterways. This contributes to the broader global issue of environmental toxicology and One Health disruption (Rumbeiha, 2012; OIE, 2021).

Terminologies in Toxicology

There are several terminologies one should be familiar with when dealing with poisons or incidents of poisoning. The effect of the toxicant on a biological system is described as toxic, but the disease state following exposure to a toxicant is termed toxicosis (Gupta, 2018; Klaassen, 2021). For example, excessive hemorrhage is a toxic effect of warfarin, but a dog poisoned with this rodenticide is described as suffering warfarin toxicosis. The term toxicity refers to the amount of toxicant required to trigger toxic effects under a specific set of conditions.

The toxicity of a compound is normally expressed in terms of the average or LD_{50}, which indicates the smallest dose required to produce a lethal effect in 50% of the population (Hayes & Kruger, 2021).

Key Terms Explained

Toxicant: A man-made or naturally occurring substance that causes harm when introduced into a living organism. Example: Carbofuran is a toxicant that causes acute cholinergic crisis in birds and mammals (Peterson and Talcott, 2013).

Table 1.2 Definitions and species-specific real-world examples for key toxicological terms.

Term	Definition	Real-world example (by species)
Toxin	A toxic substance produced by a living organism	Botulinum toxin causing paralysis in horses
Toxicant	A toxic substance produced by human activities	Rodenticide ingestion in dogs
Toxicity	The degree to which a substance is harmful	Higher toxicity of lilies in cats vs. dogs
Toxicosis	Disease caused by exposure to a toxin or toxicant	Organophosphate toxicosis in small ruminants
Hazard	The potential of a substance to cause harm	Storage of chocolate in homes with dogs
Risk	The likelihood of harm occurring under conditions of exposure	Risk of nitrate poisoning increases during drought in cattle
Dose	The amount of a substance required to cause harm	Acetaminophen overdose causing methemoglobinemia in cats
LD_{50}	The dose lethal to 50% of a test population	LD_{50} of sodium nitrite in pigs is ~175 mg/kg

Toxin: A specific subclass of toxicants that are produced by living organisms. Example: Botulinum toxin from *Clostridium botulinum* is one of the most potent biological toxins known (Klaassen, 2021).

Poison: A general term referring to any substance that can cause harm. In veterinary medicine, its use is typically reserved for substances that are clearly harmful in small quantities. Example: A rodenticide like zinc phosphide is termed a poison because of its lethality in minute doses (Gupta, 2018).

Toxicosis: The clinical condition resulting from exposure to a toxicant. Example: A horse suffering from monensin ingestion is said to have ionophore toxicosis (Plumlee, 2013).

Toxicity: A quantitative measurement of how poisonous a substance is – often expressed through metrics like LD_{50} or NOAEL (No Observed Adverse Effect Level; Hayes & Kruger, 2021).

Hazard: The inherent potential of a substance to cause harm. Example: Even water can be a hazard under conditions of overhydration, leading to electrolyte imbalances (Klaassen, 2021).

Risk: The probability that harm will occur from a particular exposure scenario. Example: The hazard of aflatoxin in cattle feed may be high, but the risk is low if feed storage is optimized (FAO, 2021) (Table 1.2).

Classification of Degrees of Toxicity

Toxic substances may be classified based on their degrees of toxicity. Six degrees of toxicity, in decreasing order, are described as follows: (i) extremely toxic, (ii) highly toxic, (iii) moderately toxic, (iv) slightly toxic, (v) practically nontoxic, and (vi) relatively harmless (Gupta, 2018; Hayes & Kruger, 2021). In order to differentiate these categories, the estimated lethal dose for man, dog, and cow in common units of measurement are tabulated in Table 1.3.

Toxicity classifications are crucial for understanding how much of a substance it takes to cause harm or death in various species. This allows veterinarians, farmers, and pet owners to anticipate risk and design appropriate safety measures in drug administration, feed formulation, pest control, and environmental exposure (Peterson and Talcott, 2013).

Table 1.3 Degree of toxicity and estimated single-dose oral lethality with household-volume equivalents in humans, a 20-kg dog, and a 450-kg cow.

			Lethal dose (volume)		
Toxicity rating	**Category dose**	**Single oral**	**Man**	**Dog (20 kg)**	**Cow (450 kg)**
1	Extremely toxic	1 mg or less/kg	A taste or 1 grain	0.004 teaspoon	0.09 teaspoon
2	Highly toxic	1–5 mg/kg or 4 mL	1 teaspoon	0.2 teaspoon	4.5 teaspoons
3	Moderately toxic	50–500 mg/kg	1 oz	2 teaspoons	1 cup
4	Slightly toxic	0.5–5 g/kg	1 pint	0.45 cup	2.5 quarts
5	Practically nontoxic	0.5–15 g/kg	1 quart	1.34 cups	2 gallons
6	Relatively harmless	>15 g/kg	1 quart	>1.34 cups	>2 gallons

Toxicity categories span from extremely toxic (≤1 mg/kg; "a taste" in humans) to relatively harmless (>15 g/kg), with approximate teaspoon–cup–gallon conversions provided for rapid clinical reference.
Sources: Gupta (2018); Hayes and Kruger (2021).

One of the most widely used benchmarks for classifying toxicity is the LD_{50}, which refers to the amount of a substance (typically in mg/kg body weight) that will kill 50% of a population upon a single exposure. The smaller the LD_{50}, the more toxic the substance (Klaassen, 2021).

Examples Across Species

- Permethrin (in cats): Extremely toxic – LD_{50} <100 mg/kg; even topical exposure can be fatal due to poor hepatic metabolism (Plumlee, 2013).
- Chocolate (in dogs): Moderately toxic – Theobromine LD_{50} ~300 mg/kg; a few squares of dark chocolate can induce seizures (Plumlee, 2013).
- Monensin (in horses): Highly toxic – LD_{50} ~1.4 mg/kg; a dose tolerated by ruminants can be fatal to equines (Plumlee, 2013).
- Copper (in sheep): Slightly toxic to moderately toxic depending on breed; predisposing dietary factors affect accumulation.
- Table salt (in dogs): Practically nontoxic in low quantities, but ingestion >4 g/kg can lead to hypernatremia and seizures (Gupta, 2018).

Why LD_{50} Isn't Everything

Although LD_{50} is a useful starting point, it's not always the best indicator of clinical toxicity:

- Sublethal toxicity: Chronic exposure to a toxicant may not cause death but may induce severe organ damage over time (e.g., aflatoxin B1 causing chronic liver failure in poultry; Hayes & Kruger, 2021).
- Species variability: The same compound may be highly toxic in one species and virtually harmless in another (e.g., xylitol is safe for humans but hepatotoxic in dogs; Plumlee, 2013).

- Formulation effects: Some drugs or poisons are more harmful depending on how they're formulated (e.g., injectable vs. oral ivermectin).

Veterinary Application of Toxicity Classes

Toxicity classifications guide veterinarians in choosing safe treatment options. For example:

- A drug with a narrow therapeutic index (difference between effective dose and toxic dose) must be dosed with caution – like digoxin or aminoglycosides.
- Feed additives like ionophores (monensin, salinomycin) are used safely in poultry and ruminants, but are fatal in equines (Peterson and Talcott, 2013).
- Knowing a substance's toxicity class helps in triage: An animal exposed to something in the "extremely toxic" class needs urgent decontamination, supportive care, and possibly antidotal therapy (Klaassen, 2021).

Classification of Toxic Reactions

Toxic reactions may be classified as acute, subacute, or chronic, based on the rate of onset of symptoms as well as the rate and duration of exposure to the poison or toxic agent (Gupta, 2018; Hayes & Kruger, 2021). In acute toxicity, symptoms that result in death typically develop rapidly following a single or sudden intake of a toxic dose. For example, ingestion of a large amount of phenobarbital, a central nervous system depressant, can lead to profound respiratory depression and death within hours. Similarly, death can occur within minutes of exposure to carbon monoxide or hydrogen cyanide, both of which impair cellular respiration (Klaassen, 2021). Carbon monoxide binds to hemoglobin with nearly 300 times the affinity of oxygen, while cyanide forms a stable complex with cytochrome oxidase enzymes, halting oxidative phosphorylation.

The difference between acute and subacute toxicity is based on the frequency and concentration of exposure. In subacute cases, the individual is subjected to repeated exposures over hours or days to doses insufficient to cause toxicity if administered once (Peterson and Talcott, 2013). For instance, a farmer spraying organophosphate pesticides over several days without proper protection may accumulate toxic levels via skin or respiratory absorption.

Chronic toxicity results from repeated or continuous exposure over weeks or months to substances with long biological half-lives (Gupta, 2018). These include heavy metals like lead, mercury, and copper, which accumulate in tissues and may not be efficiently excreted. A classic example is lead poisoning in children and livestock due to ingestion of contaminated materials like old paint chips.

Notably, chronic toxicity is not limited to slow-excreting compounds. Substances like benzene, although rapidly metabolized, can still lead to cumulative hematopoietic damage upon repeated exposure, impairing bone marrow function and increasing leukemia risk (Hayes & Kruger, 2021). Benzene toxicity exemplifies how both acute and chronic presentations can result from the same agent under different exposure conditions.

Toxic Reactions Are Not One-Size-Fits-All

The nature, intensity, and duration of exposure determine the clinical, pathological, and public health implications of a toxic reaction. A comprehensive classification is essential for diagnosis, management, and prevention.

Acute Toxicity: The Rapid Kill

Veterinary examples:

- Strychnine in dogs: Causes rapid-onset seizures and death (Plumlee, 2013).
- Ionophore toxicity in horses: Acute cardiac failure from contaminated poultry feed (Peterson and Talcott, 2013).
- Zinc phosphide ingestion: Produces phosphine gas in the stomach, causing fatal pulmonary and cardiac collapse (Gupta, 2018).

These cases require immediate decontamination and aggressive supportive care, such as administration of activated charcoal, oxygen, and specific antidotes where applicable.

Subacute Toxicity: The Stealth Threat

Veterinary examples:

- Organophosphate exposure in livestock or humans: Subclinical cholinergic syndrome from repeated dermal/inhalational absorption (Hayes & Kruger, 2021).
- Blue-green algae (cyanobacteria) ingestion in cattle: Causes progressive liver damage.
- Subacute aflatoxicosis in pigs and poultry: Leads to suppressed immunity and stunted growth.

These conditions often mimic infectious or nutritional deficiencies, making early recognition and differentiation vital.

Chronic Toxicity: The Slow Poison

Chronic toxicoses are insidious and may only be detected after irreversible damage is done. This is especially true in food-producing animals, where residues pose risks to consumers.

Veterinary examples:

- Copper accumulation in sheep: Often unnoticed until sudden hepatic failure (Gupta, 2018).
- Lead poisoning in cattle: Progressive ataxia and rumen stasis after ingestion of batteries (Hayes & Kruger, 2021).
- Mycotoxin ingestion: Reproductive and hepatic dysfunction in pigs and poultry.
- Pyrrolizidine alkaloid exposure in horses: Liver fibrosis and photosensitization from chronic plant ingestion (e.g., *Senecio* spp.) (Figure 1.10).

Other Types of Toxic Reactions Worth Mentioning

- Delayed toxicity: Effects manifest days or weeks post-exposure. *Example:* Organophosphate-induced axonopathy (Klaassen, 2021).
- Idiosyncratic reactions: Non-dose-dependent and unpredictable. *Example:* Sulfonamide-induced keratoconjunctivitis in genetically predisposed Dobermans.

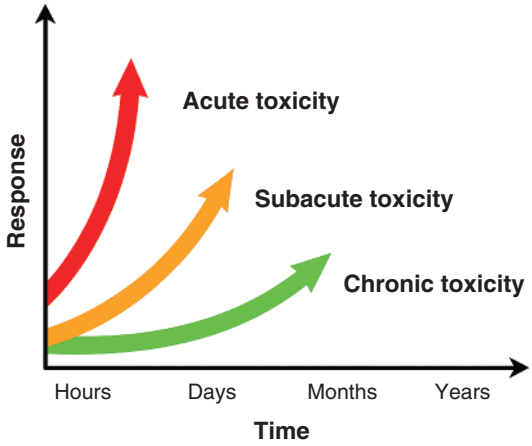


Figure 1.10 Timeline diagram of acute vs. subacute vs. chronic toxicity.

Table 1.4 Comparative table of common veterinary toxicants by reaction type (selected).

Reaction type	Toxicant	Species affected	Example/clinical sign
Hepatotoxic	Aflatoxin	Poultry, dogs	Liver enlargement, hepatic necrosis
Nephrotoxic	Ethylene glycol	Dogs, cats	Acute renal failure, crystalluria
Neurotoxic	Organophosphates	Cattle, sheep, dogs	Salivation, tremors, seizures
Hemotoxic	Zinc	Dogs, birds	Hemolytic anemia, vomiting
Respiratory	Paraquat	Cats, dogs	Pulmonary fibrosis, dyspnea
Cardiotoxic	Oleander	Ruminants, horses	Arrhythmias, sudden death
Gastrointestinal	NSAIDs (e.g., Ibuprofen)	Dogs	Gastric ulceration, vomiting, diarrhea

- Carcinogenicity and teratogenicity: Long-term exposure may lead to cancer or birth defects. *Example:* Aflatoxin B1 and dioxins as chronic mutagens and teratogens (Table 1.4).

The Role of Veterinary Toxicologists in Tropical Practice

Veterinary toxicologists occupy a unique space at the intersection of animal health, public health, and ecosystem management (Peterson and Talcott, 2013). In tropical regions, their role becomes even more significant due to frequent pesticide usage, climate-sensitive toxic exposures, and limited veterinary infrastructure. They conduct outbreak investigations, contribute to establishing maximum residue limits (MRLs), and help shape regulatory frameworks for drug safety (WHO, 2019; Rumbeiha, 2012). Their responsibilities span teaching, diagnostics, field investigation, and policy advocacy. For example, after monsoon flooding in parts of Southeast Asia, toxicologists played a key role in tracking aflatoxin contamination in feed and advising on emergency decontamination protocols (FAO, 2021). Furthermore,

they collaborate with environmental agencies to assess lead or mercury contamination in livestock areas near mining zones. In academia, they publish vital data on indigenous plant toxicants and provide evidence for updating veterinary drug withdrawal times.

One of the primary responsibilities of veterinary toxicologists in the tropics is outbreak investigation and diagnosis. When livestock die suddenly or wildlife exhibits unexplained morbidity, toxicologists are often the first responders, tasked with identifying the causative agent and tracing its source. They utilize a blend of clinical acumen, analytical chemistry, pathology, and epidemiology to determine whether a toxicant is involved and to advise on treatment, decontamination, or culling protocols.

In addition to reactive roles, these professionals engage in preventive strategies. This includes setting MRLs for drugs and pesticides, advising on safe withdrawal periods, and training farmers and veterinarians in the safe handling of agrochemicals, feed additives, and pharmaceuticals. Their input is essential when formulating national guidelines for veterinary drug registration, feed-safety monitoring, and environmental toxin surveillance.

Moreover, veterinary toxicologists play key roles in disaster response. In flood-prone tropical countries, disasters often mobilize toxic contaminants, including pesticides, sewage, and industrial effluents. Toxicologists help assess risk to animals, secure water supplies, and prevent secondary outbreaks caused by toxin-induced immunosuppression.

They also contribute to the One Health movement, supporting joint surveillance systems with physicians, environmental scientists, and public health experts to tackle cross-species threats such as lead poisoning, zoonotic pesticide residues, or marine biotoxins.

In academia and research, they advance knowledge by conducting studies on indigenous toxic plants, emerging contaminants, and locally used herbal preparations, ensuring that veterinary medicine in tropical zones is supported by evidence-based toxicology (Figure 1.11).

Figure 1.11 Veterinary toxicologists' role across fieldwork, policy, research, and diagnostics.

Emerging Toxic Threats in Tropical Countries

The toxicological landscape in tropical regions is changing rapidly. Once dominated by classical pesticide and plant toxicities, today's threats are increasingly diverse, often stemming from the very changes meant to drive development – urbanization, intensification of agriculture, and globalization of trade.

As agriculture intensifies in the tropics, toxic exposures are becoming more diverse and harder to regulate. Key threats include mycotoxins, nitrate accumulation during droughts, and cyanobacterial blooms (World Bank, 2022). For instance, recent studies in the Philippines, Malaysia, and Ghana have linked changing rainfall patterns to rising aflatoxin levels in stored corn and poultry feed (Warnatzsch et al., 2020). Additionally, misuse of growth promoters and antiparasitics – especially in smallholder farms – can lead to tissue residues and AMR (WHO, 2019). Tropical countries also face a growing influx of counterfeit veterinary drugs. These often contain banned substances or incorrect dosages, exacerbating toxicity risks in both animals and humans (OIE, 2021). Another overlooked issue is urban pet poisoning. With increased indoor pet keeping, there's been a documented rise in accidental exposures to detergents, rodenticides, and essential oils (Pet Poison Helpline, 2023). Veterinary toxicologists are vital in researching these evolving hazards and advising both local veterinarians and policymakers.

One of the most prominent threats is antimicrobial and anthelmintic resistance arising from sublethal chemical exposure. In many tropical countries, veterinary drugs are available over the counter without prescription, leading to unregulated use. Animals are often overdosed or treated with unapproved substances, resulting in cumulative toxicoses and long-term tissue damage. Additionally, improper disposal of expired drugs and syringes contaminates soil and water, affecting both animals and humans.

Climate change is also altering the dynamics of toxic exposures. Increased rainfall and humidity facilitate the growth of mycotoxin-producing fungi in feed and grain. Drought, meanwhile, may lead to nitrate accumulation in plants and sudden outbreaks of nitrate poisoning in ruminants. Warmer waters in coastal zones promote the spread of harmful algal blooms (HABs) that affect fish, turtles, and marine mammals through ingestion of cyanotoxins and saxitoxins.

The rise in urban animal keeping – especially backyard poultry and goats – creates new interfaces between animals, humans, and toxicants. Household chemicals, improperly stored rodenticides, and cleaning agents present a growing threat to both animals and children in low-income tropical settlements.

Also alarming is the increased use of nonconventional feed ingredients such as palm kernel cake, fermented food waste, or herbal mixtures whose toxicological profiles are not well studied. In these contexts, veterinary toxicologists are called upon to investigate adverse effects that range from organ damage to reproductive failure.

Finally, cross-border movement of counterfeit veterinary products has introduced a shadow market of unregistered, poorly formulated drugs and pesticides. These not only lack efficacy but may contain contaminants that are directly toxic to animals.

The solution lies in strengthening toxicovigilance systems, building local laboratory capacity, and investing in collaborative research between tropical nations to generate region-specific toxicological data.

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