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# Reptiles in Decline: Eco-Toxicological Prospective

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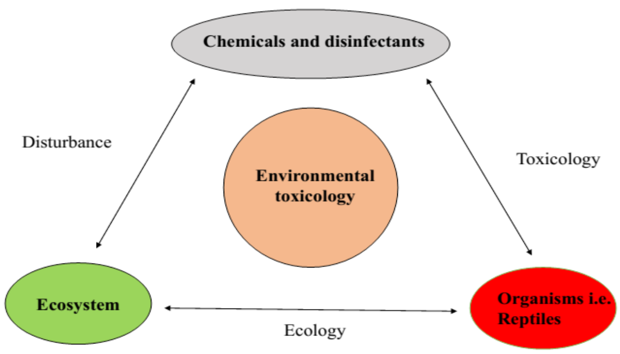
**Keywords:** Reptiles; Chemicals; COVID-19; Ecosystem; Biodiversity; Toxicity.

**Abstract**

Chemical fumes/sprays are one of the risk factors, which challenging the reptile population's welfare. Worldwide the reptiles and amphibians are vanishing at an alarming rate. The causes are unclear in most cases, although they are believed to be caused by human-made contamination of the environment. According to recent studies, most herbicides/pesticides in the aquatic setting can destroy animal endocrine systems. Also, they are persistent and accumulate in organisms' fat deposits and increasing density as they lift up the food chain. Most of these chemical substances can have negative consequences by interacting with both the body's hormones and chemical messengers in some ways. Furthermore, the current COVID-19 pandemic has prompted governments worldwide to spray chemicals to stop the virus from spreading, which poses additional risks. Thereby when spraying these chemicals, precautionary measures should be taken to maintain the ecosystem's balance. The authors highlight the pressing research gap related to the ecotoxicology of reptilian and amphibian populations.

**Graphical abstract**




**Highlights:**

- Worldwide, reptiles are vanishing at an alarming rate.
- Chemical fumes/sprays are one of the risk factors, which challenging the reptile population's welfare.
- COVID-19 pandemic has prompted governments worldwide to spray chemicals to stop the virus from spreading, which poses an additional threat

  The ecosystem balance is at risk, which mandates precautionary measures during chemical sprays.

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## Introduction

Natural and sustained ecosystems are dramatically affected by the extensive use of different chemicals, such as herbicides/pesticides, over time. Annually tons of pesticides and other chemical substances are releasing into the environment, destroying the wildlife on a large scale. Direct and indirect application of toxic materials reducing the environmental quality on all levels, particularly diminishing the biodiversity of flora and fauna **Figure 1** [1].

Currently, most vertebrates, including amphibians and reptiles experiencing a drastic decline worldwide. There are many reasons for that was observed, whereas anthropogenic factors playing a prevailing role. Regarding the report of the International Union for the Conservation of Nature ("IUCN"), about 30 % of the world's amphibian and reptile species are threatened or susceptible to extinction (IUCN 2011).

The contribution of amphibians and reptiles to nature is undoubtedly crucial. For example, they are essential elements between the trophic chains of the aquatic and terrestrial prey-predator interaction [2,3,4]. Furthermore, they are important in controlling insect pests such as mosquitoes, and many snakes prey on rodents that prevent crop damage [5], and the presence of lizards even aids in the reduction of human exposure to Lyme disease [6]. Herpetic species are also playing an important role as a bioindicator of environmental health due to their highly permeable skin membranes and complex life cycles that make them sensitive to any environmental fluctuations [7,8].

According to many studies, agricultural chemicals (pesticides), particularly cholinesterase, damage species physiological and lead to their decline via sub-lethal toxicity and death [9]. Some recent studies reported a rapid decrease in the reptile population [10]. The reasons for the reptiles' decline include habitat loss and degradation, climate change, and pollution [11]. Despite well-recognized data gaps, understanding the effect of toxins on reptiles remains a problem [12]. Previous researches concentrated solely on assessing the body loads of different poisons in reptile field samples. [13]. Toxicology's specific risks and demographic consequences on reptiles are unclear and understudied [14]. Another main factor that causes reptile extinction is chemical pollution [11]. Furthermore, data on reptile toxicity is lacking, and our knowledge of pollutants exposure is currently limited [15]. For example, in the United States, federal pesticide registration laws (such as the Federal Insecticide, Fungicide, and Rodenticide Act) do not mandate reptile screening, as is mandated globally [16]. In some cases, reptiles are more susceptible to toxins than birds or mammals [15]. As a result, more research on pesticide toxicity in reptiles is urgently needed to assess pesticide risk to the environment.

## Methods

Google Scholar, Pubmed, SciHub, WHO, and Pubchem were used to search for research articles on the topic of interest for systematic analysis of scientific literature. Various terminologies were used to make it easier to find relevant articles in search engines and databases. Disinfectants, chemicals, reptiles, amphibians, ecology, disinfectant environmental effects, disinfectant effect on wildlife, COVID19, and various other terms were frequently used. To ensure that the literature was covered, the authors looked through the reference lists of the included studies. All full-text reports were examined to see if they met the criteria for inclusion. Those articles were mostly included in the study, which focused on the potential consequences of chemicals to reptiles and amphibians. The majority of the papers included in this study were recently published. However, some of the earlier published articles were also cited to clarify the essence of chemicals, disinfectants, and their effects on reptiles, as no relevant recent scientific work on the subjects involved.

### Exposure to chemicals

Contamination of reptiles may occur through dietary supplements, water, skin, or respiratory routes. However, the soil could also play as a potential source of pollution in geckos and other squamates [17, 18]. The dermal interaction of reptiles has been well studied, but the routes of chemical absorption are challenging to compare, rendering mechanistic understanding of chemical-specific toxicity difficult [19,20, 21].

While dermal exposure may be required for reptiles, the epidermis' thickness and permeability, which contains a considerable quantity of lipids and keratins, may decrease or eliminate interactions via the dermal route [22,23]. Though, lipid content, rather than keratin, is more likely to affect skin permeability through the increasing barrier to water flow [24,25]. The epidermis of lizards with high lipid content prevents water loss, thereby increasing the lipophilic material absorption. On the other hand, the lizard epidermis is permeable to water-soluble toxins due to its low lipid content. However, the permeability of the lizard epidermis to various toxins is not thoroughly investigated [26].

### Chemical threats for reptiles

The chemical which can patiently cause a threat to reptiles are following;

### Chemical-based Baits

The Whitaker stated in 1984-85 that lizards are unlikely to consume pesticide-laced vegetables. In Australia, some lizard species have been discovered that consume the carrot bait used by rabbits [27]. In Mauritius, Telfair skinks were observed picking up bits of raw carrot bait as tiny insects attracted them to oat baits [28] .They ate only the rain-softened ones, indicating a passing attraction. The squamates can also use natural fruits as food and drink nectar and honeydew [29]. Although some species consume canned fruits, such as pear, others do not [30,31]. Honey and syrups are also eaten by some captive geckos and skinks [30]. As a result, there is concern that some of the baits-based jams employed in rabbit poisoning procedures may be ingested by geckos and skinks, putting their lives in danger.

### Sodium mono-fluoroacetate (1080)

Pest-poisoning operations involving 1080 do not specifically affect lizards, but if they ingest sub-lethal doses of 1080, they can become highly vulnerable to physiological stress and predation. If lizards (both insectivorous and predatory) eat insects poisoned by baits, they risk secondary poisoning [32]. discovered that lizards that only consumed insects or other infected animals could not absorb a sufficient amount of toxins to cause death [32]. Snakes are the only species that have been known to cause secondary poisoning. Gopher snakes fed 1080-poisoned rodents regurgitated the rodents on a daily basis but displayed no other symptoms of poisoning [33]. after ingesting mice poisoned with fluoroacetamide (1081), a toxin similar to 1080, the other snake species revealed no evidence of secondary poisoning [34].

### Strychnine

Strychnine's acute toxicity in reptiles has no known LD50 values. According to the only reference on secondary poisoning in reptiles, five out of twelve gopher snakes perished after being given strychnine-tainted rats [33]. Strychnine, on the other hand, is significantly more toxic to bullfrogs than 1080. Tucker and Crabtree [35].

### Anticoagulants

Anticoagulant toxicity in reptiles has no available data on LD50. However, skinks were spotted eating rain-softened Talon 20P pellet baits during rabbit eradication on Round Island, Mauritius. The active ingredient in Talon 20P, brodifacoum, was found in the bodies of those who were later discovered dead [28]. Despite the deaths of over 100 skinks, the island was still overrun with them. Talon 20P, which was aerially sown to eradicate rats and rabbits on Stanley Island, did not appear to diminish the population of lizards [36]. Insectivorous and predatory lizards may be poisoned if anticoagulants are used; however, no instances of secondary poisoning in lizards have been made [28]. In the single instance of secondary poisoning in reptiles, gopher snakes did not react to rodents infected with three first-generation anticoagulants Warfarin, Diphacin, or Prolin [33]. However, the blood coagulation chemistry of humans and reptiles differs [28]. Merton concluded that brodifacoum damaged body temperature regulation rather than blood coagulation, leading them to perish from overheating when exposed to high ambient temperatures because the majority of the skinks with brodifacoum residues on Round Island did not exhibit internal bleeding.

### Insecticides

[37]. found much evidence that organochlorine pesticides, including DDT, Dieldrin, Endrin, and Heptachlor, killed lizards and other reptiles. It has been suggested that the effects of these pesticides are more sensitive in reptiles than in birds and mammals. On the other hand, reptiles took longer to die than other animals, despite receiving lower doses. However, according to estimates, two lizard populations have experienced overall mortality due to the application of Heptachlor [37].

Among the results, which Hall did not cover, are the discovery of DDT and other organochlorine residues in Australian lizards [38,39]. and the mortality of Australian lizards following chlordane termite control spraying [37,40]. Also, many birds and rats in New Zealand have been found to have DDT and other insecticide residues, but not in the lizards [41]. After a spraying campaign in Ivory Coast to combat human sleeping sickness, endosulfan residues were discovered in house-dwelling lizards, but no population changes were identified [42,43]. found that several organophosphate pesticides such as parathion, methyl parathion, azinphos-methyl, and Malathion, killed iguanid lizards their LD50 was close to that of birds and mammals in the United States. Because of a lack of invertebrate prey, snake activity was decreased by aminocarb, and a carbamate was used to track spruce budworms in Canada [44].

### Chemical's toxicity in reptiles

Freshwater turtles and tortoises are on the verge of extinction; moreover, they are critically endangered and included in the Red List of IUCN [45]. Organochlorine pesticides released by a chemical spill have contaminated the alligator ecosystem in Lake Apopka, Florida (USA). In larvae and juvenile alligators, changes in enzyme activity, sex hormone levels, irregular genital anatomy, and abnormally tiny phalluses were discovered **[**46**,**47]. Because these chemicals are thought to cause androgen receptor deficiency, the population-level impacts observed in alligators are most likely the result of endocrine dysfunction [48]. The common snapping turtle is Canada's biggest aquatic turtle (Chelydra serpentina). Snapping turtle eggs from the Great Lakes have a high concentration of fat-soluble pollutants, which are consumed as food, whereas PCBs, dioxins, furans, and organochlorine pesticides are among them. The most polluted areas have the highest rates of aberrant growth, along with unfertilized eggs or malformed animals [49].

Furthermore, a connection has been established between tainted eggs and poor developmental outcomes [50]. In the kidney and liver of the Indian garden lizard, the phytopesticide Biosal (neem-dependent formulation) exerts anticholinesterase actions [Calotes Versicolor]. Cholinesterase concentrations in the kidney and liver are decreased by 13.60 - 18% and 39.52 - 52.61%, respectively, after exposure to Biosal [51].

### COVID-19 disinfectant: An alarm for scientist

During the early stages of the COVID-19 pandemic, public health authorities concluded that cleaning regularly touched surfaces was one of the most efficient methods of preventing the virus from spreading. As a result, China, South Korea, France, Spain, and a number of other countries disinfected their cities extensively. Virus-killing chemicals were sprayed on roads, parks, sports fields, and other open public areas by fleets of trucks, drones, and even robots. Such as Drones sprayed disinfectant into Indonesian homes from above. Hundreds of liters of bleach were thrown onto a public beach in Spanish villages by tractors. Infectious disease specialists and the World Health Organization have subsequently declared the technique hazardous and probable risk to health for people, citing respiratory distress from breathing the chemicals as an example. The World Health Organization has warned that mixing disinfectants such as bleach and ammonia can release potentially fatal gases. In January 2020, China became the first country to begin sanitizing its cities, and reports of poisoned animals flood in. In February, the Chongqing Forestry Bureau discovered disinfectant exposure had killed at least 135 animals from 17 different species in Chongqing, a large city in southwestern China. (https://www.nationalgeographic.com/animals/article/disinfectant-public-cities-pandemic-urban-wildlife-cvd[ZN1]). Reptiles are an integral part of an ecosystem, and harming them could cause a significant disruption in the ecosystem.

### Other potential threats

### UVB (Ultraviolet B) radiation

The contaminant in the atmosphere reduces the thickness of the ozone layer, allowing more UV-B radiation to enter the planet. UV-B levels have risen by an approximately 5-10% from 1979, particularly at higher altitudes. On the other hand, amphibians are similar to reptiles in that they are less resistant to UV-B radiation due to their bare skin and shell-less eggs **Figure 2**. The eggs of reptiles are rarely exposed to UV-B radiation, so they are unlikely to be endangered at this time [11]. Scientists are worried about the consequences of increasing UV-B levels and ozone depletion. UV-ability B's to communicate with toxins, the atmosphere (e.g., drought), and disease in dynamic ways is of particular concern.

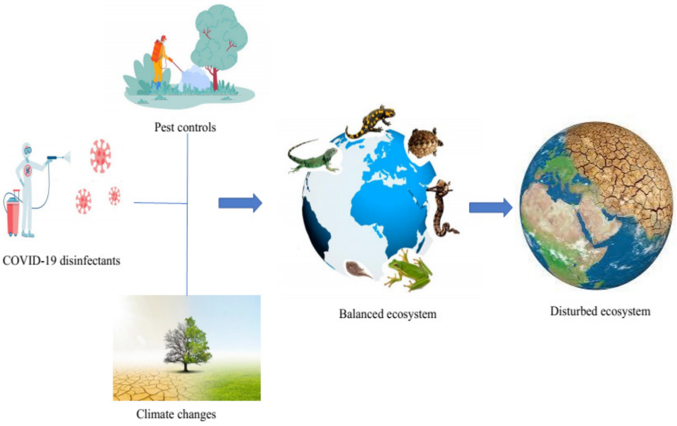


**Figure 1:** Illustration of chemicals and climate changes effects on reptiles and ecosystem.

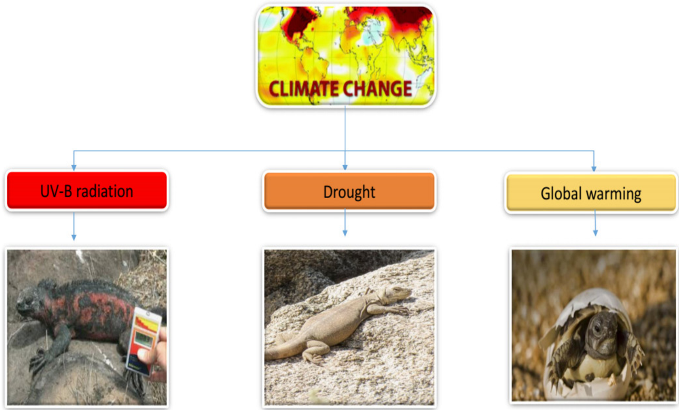


**Figure 2:** Illustration of climate changes effects on reptiles.

**Table 1:** Chemicals effects on the different life stages of reptiles.

| Stage of life | Measures | Expected impacts on persistence of population | Toxicological susceptibilities | Route of Exposure | Possible exposure medium |
|---|---|---|---|---|---|
| Egg | Mortality,<br>Time to hatch,<br>Hatching success,<br>Weight at hatching,<br>Sex ratio in exceptions | High for short-lived species and low for long living species | Unknown | Dermal Maternal acquisition | Maybe high but due to data limitation its unknown Probably low |
| Juvenile | Mortality,<br>Development,<br>Behaviors,<br>Lesions,<br>Metabolic rate | High | Possibly more vulner-able than adults but unknown in compari-son to eggs | Oral,<br>Dermal,<br>Respiratory | Orally; high from food and water Dermal; high from soil, plants or stone wall at fields edges and low from water Respira-tory; Maybe low Overspray: high |
| Adult | Mortality,<br>Development,<br>Behaviors,<br>Lesions,<br>Metabolic rate | High | Maybe less vulnerable than juveniles | Oral,<br>Dermal,<br>Respiratory | Orally; high from food and water Dermal; high from soil, plants or stone wall at fields edges and low from water Respira-tory; Maybe low Overspray: High |

**Table 2:** Chemicals effects on the different life stages of amphibians.

| Stage of life | Measures | Expected impacts on persistence of population | Toxicological susceptibilities | Route of Exposure | Possible exposure medium |
|---|---|---|---|---|---|
| Embryonic stage | Mortality,<br>Malformation,<br>Development duration | Impact is low on the species which lay more eggs and probably high in less eggs laying midwife toads | low | Dermal and mater-nal acquisition | Dermal exposure is high Maternal transfer is low |
| Hatchling larvae | Mortality, Development,<br>Malformation,<br>Development duration,<br>Behavior | Impact is low on the species which lay more eggs and probably high in less eggs laying midwife toads | High | Dermal and oral | High from water, food and sediment |
| Larvae | Mortality,<br>Development,<br>Malformation,<br>Development duration,<br>Behavior | Impact is low on the species which lay more eggs and probably high in less eggs laying midwife toads | High and especially effects the endocrine system | Oral,<br>Dermal,<br>Respiratory | High from sediment, water or food and Low from air |
| Metamorphosis stage | Duration and Success rate | Medium-low | High and especially effects the endocrine system | Dermal,<br>Respiratory | High from sediment, water or food and Low from air |
| Juvenile | Mortality, Growth,<br>Behaviors, Lesions,<br>Sex ratio exceptional in some cases | High | Unknown | Oral,<br>Dermal,<br>Respiratory | Water, soil, food, plants Air, and overspray |
| Adult | Mortality,<br>Reproduction,<br>Behaviors,<br>Lesions | High | Unknown | Oral,<br>Dermal,<br>Respiratory | Water, soil, food, plants Air, and overspray |

### Drought

Fluctuations in the timing and amount of precipitation are dangerous to reptiles and amphibians. Drought is to blame for the frog population decline. Also, drought can affect amphibians by interacting with other survival and reproduction factors like disease, UV-B radiation, and contaminant exposure. Drought is a common occurrence, but it happens so quickly that animals may adapt [52]. According to reports, the drought is projected to worsen to a 66-90% severity in the future [53]. On the other hand, desert reptiles are severely harmed by drought because there is little or no free water for them and their prey. Another problem with drought is desiccation, harvesting, and drinking water, contributing to reptile death. Dehydration of reptiles' body fluids is also possible since certain reptiles, snakes, have coils to store water. Some reptiles exhibit this behavior. This is particularly significant in the desert, where rainwater does not always collect [54]. Long-term drought in the Sonoran Desert caused diamond-backed rattlesnakes (Crotalus atrox) to harvest and drink rainwater, according to [54].

### Climate change

Climate change is raising the temperature, which may affect some reptiles and amphibians. As evidence, the freshwater turtle's sex increases, early maturity, and increased juvenile growth rates have been noticed [55]. Because of their temperature-dependent sex determination, crocodilians and some turtles may be the most affected. This changing sex ratio can affect population dynamics and persistence. Climate change may affect the hibernation times of reptiles and amphibians. The lack of a prolonged hibernation period may lead to starvation or gonadal development changes over the winter. Desiccation could occur if summer temperatures rise too high, making burrows unusable. Illegal herpetofauna collection in the Southwest may affect some populations. Illegal collection for the pet trade is the most severe threat to twin-spotted rattlesnake (Crotalus price) populations in the United States at the moment [56]. This species is found only in four disjunction mountain ranges in southeastern Arizona. Collecting reptiles can also result in habitat loss, negatively affecting ecosystems [57]. Collectors knock apart and overturn rocks to reveal snakes in their hiding places; this typically results in permanent damage to the cracks and crevices that function as shelters in the rock outcrops.

## Conclusion

Chemicals have the most significant impact on reptiles. On the other hand, the reptile toxicity data is severely lacking and needed to be more investigated. Different chemicals can reduce productivity and fertility in many species, posing a severe threat to reptiles, amphibians, and the marine environment. Alternative chemical efficacy to reduce the impact on the reptilian population needs further study. Furthermore, studies must consider the advantages of both agricultural and conservation cultures at the same time to make realistic and responsible decisions about the management and protection of biodiversity within ecosystems. Scientists from both groups should share their findings to make practical and well-informed decisions on preserving and conserving biodiversity in agricultural landscapes.

In addition, the current global scenario of a COVID-19 pandemic has triggered the use of chemical disinfectants to stop the virus from spreading. The majority of disinfectant ingredients are sodium hypochlorite, chlorine, and bleach, both highly toxic to terrestrial and aquatic life. Toxicants can move through the food web if they are introduced into an ecosystem. The mucous membranes of the respiratory and digestive tracts may be irritated or corroded by this substance. Exposure can be fatal in severe cases.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Credit authorship contribution statement

Daniya Ualiyeva: Conceptualized the article. Daniya Ualiyeva and Zafran Khan: Wrote original draft, review and edit the manuscript

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