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ORIGINAL ARTICLE

Making sense of snakebite: the place of biological toxins in social scientific analyses of toxicity

George Kirkham[1]

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Abstract

Through an ethnographic study of snakebite governance in Kerala, India, this article argues that social scientific theories of toxicity elucidate the biosocial dimensions of snakebite envenomation (SBE). SBE is a medical emergency engendered by the toxins in a venomous snakebite. By drawing upon work from the social sciences and humanities that conceives of the material and semiotic dimensions of biological toxins (such as venom and poison) and synthetic toxicants (such as industrial contaminants) in an integrated frame of toxicity, this article demonstrates how these theories clarify the structural drivers, indeterminacies, and multispecies health impacts that characterise SBE's manifestation as a public health issue in Kerala. It thus asserts the value of integrating insights drawn from analyses of toxicity across biological and synthetic molecules, responding to recent influential reviews that omit biological toxins from this frame due to their supposed natural genesis and constrained circulation and harms. This article consequently argues that scholars should avoid reproducing rigid taxonomic distinctions between 'natural' toxins and 'synthetic' toxicants, as insights drawn from across classes of molecules and mobilised within a unified heuristic of toxicity elucidate the structural conditions and localised experiences of toxin and toxicant exposure.

Keywords Snakebite envenomation · Toxicity · Multispecies health · More-than-human · Antivenom · Global health

This manuscript is comprised of original material that is not under review elsewhere. The study on which this research is based has been subject to ethical review with the University of Oxford's Central University Research Ethics Committee, ethics code: SOGE1A2021-035.

✉ George Kirkham
george.kirkham@sjc.ox.ac.uk

1 School of Geography and the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

Introduction

A growing body of social scientific literature has developed the lens of 'toxicity' to account for the affects, experiences, and modes of political action emergent within environments of contaminant exposure. These ethnographic accounts argue that toxicity is irreducible to the harms of "wayward particles behaving badly" (Liboiron et al. 2018, p. 333), instead emphasising "the observation that "toxicity" often functions as a proxy for a range of cultural, economic, or infrastructural instabilities" (Shapiro et al. 2017, p. 581). This research agenda (much of which responds to queer, feminist, and decolonial concerns) supplements epidemiological accounts that enumerate toxic harms with "ethical, technical, and aesthetic" efforts to 'make sense' of toxicity, pointing to ways by which toxic socio-ecological arrangements could be done otherwise to live better in a polluted world (Nading 2020, p. 209; Balayannis and Garnett 2020).

In 2017, a somewhat distinctive instance of human-toxin entanglement rose to prominence in global health arenas. Snakebite envenomation (SBE), a medical emergency engendered by the diverse toxins in the bites of venomous snakes, was recognised by the World Health Organisation (WHO) as a Category A 'Neglected Tropical Disease' (NTD) (Chippaux 2017). SBE kills an estimated 100,000 people annually, typically in poor, rural populations of the Majority World. Because of the complexity of producing antivenom therapies and inability of affected populations to pay for these therapeutics, SBE treatments are understood to not offer sustainable profit to pharmaceutical manufacturers, thus engendering 'market failures' in antivenom access (Chippaux 2017). To remedy this issue, SBE's NTD designation was promulgated alongside the WHO's 2019 *Snakebite Envenomation Strategy for Prevention Control,* a policy programme aimed at directing international research and funding towards the objectives of "empower[ing] and engag[ing] communities" to prevent and treat SBE, alongside innovating antivenoms, strengthening health systems, and facilitating partnerships to improve access to therapeutics (WHO 2019, p. xi).

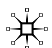
In comparison to analyses of industrial toxicants, relatively less social scientific work has interrogated the 'toxic worlds' (Nading 2020) engendered by biological toxins such as venom, poison, and microbial molecular excretions. Scanter work still has considered how a unified social scientific framework of toxicity containing insights from biological toxins and synthetic toxicants may elucidate the complexities and contingencies of the contemporary public health response to SBE. In response to this lacuna, this article proposes toxicity as a social scientific framework for conceiving of the biosocial dimensions of SBE while also reorienting recent influential analyses of toxicity that have omitted biological toxins from this analytical frame due to their supposed natural genesis and constrained circulation and harms (Liboiron et al. 2018). To do this, it surfaces prior work in the humanities and social sciences that explores the interconnected impacts of biological and synthetic toxic substances in shaping health and environmental governance, scientific authority, and lived experience, while remaining attendant to the situated relational contexts of specific chemical exposures.

To demonstrate how toxicity may be mobilised conceptually to capture snakebite's relational dynamics, this paper draws on fieldwork conducted with forest officials, snake rescuers, medical professionals, laypeople, and policy actors engaged in the Kerala Forest Department's snakebite awareness, prevention, and treatment programme in Kerala, India: an ambitious programme that aims to achieve zero SBE mortalities by 2030. To begin, I review recent conceptual work in the social sciences concerning toxicity. I demonstrate how influential work concerning toxicity has typically been applied to synthetic toxicants at the expense of biological toxins despite extant literature that deals with toxins and toxicants within a holistic frame. I thus demonstrate how this literature may reorient toxicant-focussed approaches to maintain a critical awareness of where analyses of toxicity may be usefully mobilised and expanded across classes of molecules.

Following this conceptual discussion, I move to the empirical section of this article. First, I provide background on SBE in Kerala and the Kerala Forest Department's snakebite prevention and treatment initiatives alongside outlining this article's methodology. I then demonstrate how an analytical frame of toxicity serves to clarify how actors engaged in snakebite governance in Kerala conceive of SBE as enacted by structural vulnerabilities, the indeterminacy of snake and venom identification, and human–snake relations which distribute harms and cultivate social relations across species lines. Through this analysis, I argue for the heuristic value of an integrated frame of toxicity while remaining vigilant of the contingencies of the specific toxic entanglement in question, demonstrating how SBE necessitates an analysis of encounter to supplement well-established accounts of toxic exposure. I end the article with a call for further research that asks how the risks of snakebite, and toxin-induced toxicity more broadly, are engendered and how these conditions may be reworked and negotiated.

Toxicology, toxinology, and snakebite

Within snakebite research and policy, investigations are traditionally conducted as part of the disciplinary subfield of toxinology (Ruiz de Castañeda et al. 2022). Toxinology is differentiated from the broader field of toxicology through its sole focus on toxins, that is, "specific, characterizable, poisonous chemicals, often proteins, with specific biological properties, including immunogenicity, produced by microbes, higher plants, or animals" (The National Library of Medicine's Medical Subject Headings, cited in: Wexler et al. 2015, p. 68). These include poisons (toxins that are ingested or acquired through dermal contact) and venoms (toxins administered through a delivery system, such as a fang or sting) (Zhang 2015). In the field of toxicology more broadly, "a toxicant is any chemical, of natural or synthetic origin, capable of causing a deleterious effect on a living organism" (Cope et al. 2004, p. 65). Consequently, toxins are toxicants but not all toxicants are toxins. Due to this semantic distinction, the term toxicant is popularly used to refer to only substances produced through industrial processes, such as pesticides or industrial contaminants, while venoms and other toxic substances excreted from cells are referred to as toxins (Cope et al. 2004; Liboiron 2017).

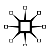


In contrast to expansive social scientific definitions that view toxicity as engendered by diverse cultural, economic, and infrastructural relations, the classical toxinological measure of toxicity is the LD50: a measure taken of the lethal dose of a toxin that on average kills 50% of test animals through a standardised route of administration (Wexler et al. 2015). Toxinological studies of snake venom from diverse geographies have contributed to improved understanding of venom composition and ophidian biology (Gutiérrez et al. 2009), bioprospecting of pharmaceutically active molecules (Orozco-Mera et al. 2024), and the refinement of antivenom therapies (Laxme et al. 2019).

Nevertheless, despite the sizeable contribution of toxinology in addressing SBE's public health burden, leading toxinologists and global health practitioners, Gutiérrez and colleagues (2023, p. 1), note that "SBE is a complex problem, and many aspects of this disease remain poorly investigated". Considering SBE's NTD designation, the authors call for multidisciplinary investigations and additional conceptual resources to conceive of how SBE's complex, biosocial dimensions render it harmful, and how these may be addressed (Gutiérrez et al. 2023). In support of this project of conceptualising the field of relations that condition SBE's emergence, I argue that social scientific theories of toxicity aid in apprehending this pathology's structural drivers, indeterminacies, and human–snake entanglements. Snakebite is a disease that 'doesn't fit' conventional medical and scientific imaginaries (Nading 2016), arising not from an overabundance of infectious pathogens, it is nevertheless 'spread' through exposure to the zootoxins secreted by an animal 'vector'. The associated risk of death and long-term disability from this exposure is mediated pre-bite through the risk of an envenomation event, and post-bite through infrastructural affordances such as transport links and medical facilities that enable rapid antivenom treatment to prevent onset of sequelae (Gutiérrez 2020). As a 'disease that doesn't fit' (Nading 2016), snakebite thus complicates standard medical categorisation, necessitating alternative ways to conceive of the disease's multiple, complex drivers and distinctive manifestations that supplement toxinological studies of the action of venom.

Toxins and toxicants in a social scientific frame

Recent work at the intersection of environmental justice, political ecology, feminist science studies, and anthropology has developed theories of toxicity to account for the inequitable distributions of non-communicable diseases in our "permanently polluted world" (Liboiron et al. 2018, p. 332). These accounts typically focus on the flows of large volumes of synthetic toxicants: industrially produced molecules that circulate through environments, constituting latent 'body burdens' of toxic exposure that engender chronic harm (Yusoff 2018; Lora-Wainwright 2021). Social scientific theories of toxicity capture how the circulations of industrial toxicants are enabled and constrained by relations between bodies, materials, environments, and capital (Liboiron et al. 2018, p. 333). These relational complexes are understood to enact pervasive yet uneven 'riskscapes' of toxicant exposure that engender inequitable distributions of disease (Morello and Shenassa 2006; Lora-Wainwright 2021).

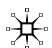


This conception of toxicity allows for considerable analytical plasticity, moving beyond 'damage-centred' accounts of toxic exposure (Theriault and Kang 2021) to enable insight into the violence of pervasive yet uneven toxic geographies (Nixon 2011) alongside the forms of political action and agency that arise from these entanglements (Tironi 2018; Kirksey 2020; Liboiron 2021). This analytical flexibility is paired with close empirical attention to "the situated biologies and ecologies of particular bodies and places" to describe the sensorial and affective registers and corporeal impacts of living with toxicants (Nading 2020, p. 210; Shapiro 2015). Such accounts have focussed on the uncertainties of sensing indeterminate toxic exposures, and the resultant 'complexity of denunciation' in addressing toxic geographies (Fiske 2018).

This work thus enables a means of thinking through toxicity as not solely an innate property of particular molecules, but something that is relationally engendered at both the scale of the experiential encounter and within widespread patterns of structural forces: "micro-toxicities [are] indexical of their macro-toxicities", as intimate exposures with toxicants are seen as 'crystallisations' of legacies of racial capitalism (Shapiro et al. 2017, p. 578). Toxicity thus provides a lens for understanding how toxic geographies are both experienced and engendered. Ethnographic accounts with an eye to both these lived and structural dimensions of toxicity have sought to testify to the injustice of injurious exposure meted out across racialised and class lines, while contending with the reality that a 'politics of purity' of permanent toxicant clean-up and quarantine is likely impossible (Murphy 2017; Liboiron et al. 2018).

Social scientific work on toxicity has emphasised the need to both repudiate the operations of the capitalist and colonial systems that render the world ever more intoxicated, while also recognising the need to find ways of living better with our polluted present (Bond 2021). In this frame, lives lived with toxic exposure should not be reduced to the damages wrought by exposure, as everyday practices exceed experiences of toxicity while 'intimate activisms' renegotiate toxic relations to reduce harms and render contaminated life more liveable (Tironi 2018; Lora-Wainwright 2021; Ippolito 2022). Meanwhile, work aimed at interrogating the more-than-human dimensions of toxicant exposure has begun to analyse how toxicity impacts life across multispecies lines (Kirksey 2020; Chao et al. 2022).

Nevertheless, as social scientific attention continues to build around toxicity, work that considers how this literature may be applied as a unified frame to consider the toxic worldings of both synthetic toxicants and biological toxins has gone overlooked. For example, in their recent review articles of social scientific analyses of toxicity, Nading (2020) and Packer (2021) make little mention of biological toxins such as venoms and poisons. Additionally, in their influential review of the concept of toxicity and related modes of political action, Liboiron et al. (2018, p. 334) suggest that a lens of toxicity is not applicable to biological toxins due to the perception that they "circulate locally" and "occur in minute qualities". Liboiron (2017, p. n.p.) has further cautioned against the category mistake of referring to toxicants, which "exist at massive scales and are tied up with everyday economic, industrial, and regulatory systems", as toxins, whose tonnage, longevity, and modes of harm are distinct, meaning they can be "dealt with via antidotes, building up of immunity, or



avoidance". Due to this distinction, Liboiron (2017, p. n.p.) suggests that referring to toxicants as toxins "naturalize[s] and depoliticise[s] industrially produced chemicals and their politics".

While an attentiveness to the specific material properties and politics of a given chemical is critical to ethnographic exploration of the situated impacts and experiences of toxic geographies, I contend that such distinctions should not disqualify toxins, including snake venom, from compatibility with a lens of toxicity. Although neither Nading (2020), Packer (2021), nor Liboiron and colleagues (2018) include biological toxins in their reviews of the concept of toxicity, much existing work in the humanities and social sciences has productively integrated analysis of biological and synthetic toxicants. For example, historical studies have shown how early experimentation with toxic and non-toxic doses of animal and plant toxins contributed to the formation of toxicology as a site of disciplinary expertise (Schickore 2018), alongside the development of contemporary threshold theories of acceptable exposure to environmental pollutants (Hayes and Gilbert 2009; Arnold 2016). Additionally, Fiske (2018) productively troubles the boundary between toxin and toxicant through an exploration of the material and semiotic transformations of oil in the Ecuadorian Amazon, while Schrader (2010) and Trinkaus (2017) demonstrate how the non-localizability, experimental indeterminacy, and widespread harms of *Pfiesteria piscicida*, a microorganism whose secreted toxins are implicated in mass fish deaths, are constitutive of ecological toxicity. Likewise, work has interrogated how the proliferation of animals with toxic capacities, including jellyfish (Rothe 2020), scorpions (Ávila and Ernstson 2019), and lionfish (Moore 2019), is akin to other abundant toxic markers of anthropogenic disturbance, such as industrial pollution, that signal the contemporary 'Anthropocene' condition.

Most relevant to this article is Arnold's (2016) historical study of India's 'poison cultures' from 1830 to 1950. Arnold (2016, pp. 10–11) proposes toxicity as an "overarching concept" demonstrating how the formation of colonial toxicological institutions constitutes a "toxic continuum" connecting early efforts to curb public anxieties concerning the risk of individual poisonings from substances such as arsenic or plant-derived poisons to the later problematisation of industrial pollution, food contamination, and use of toxic substances in pest control. Toxicology combined expertise concerning both biological toxins and synthetic toxicants, facilitating the projection of colonial scientific and moral authority in diverse domains including medicine, criminology, and sanitation. Thus, Arnold (2016, p. 1) proposes an integrated frame of toxicity to account for how the "incontestable materiality" and "semantic use" of biological toxins and industrial toxicants together shaped ecologies, governance, scientific expertise, and public anxiety in India. Although Arnold (2016) dedicates only a short section of one chapter to the issue of colonial snakebite governance, his study nevertheless effectively demonstrates how insights generated from the study of both biological and synthetic toxins may be integrated into a lens of toxicity to specify the biosocial dimensions of toxic exposure.

By building upon the above perspectives, I argue that, unlike Liboiron and colleagues (2018) suggest, conceptual insights from studies concerning both 'biological' and 'industrial' molecules aid in illuminating the relational dimensions of diverse toxic worldings, provided social scientists remain aware of the empirical

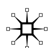
specificities of situated manifestations of toxicity (be they 'biological' or 'synthetic'). To demonstrate this, I apply this unified frame of toxicity to the case of SBE's contemporary governance in Kerala, India, where the analytic of toxicity clarifies the structural relations that drive snakebite, snakebite's indeterminacy in identification and diagnosis, and the distribution of SBE-related risk across multispecies bodies. This article thus contributes to the above literature considering toxins and toxicants in an integrated frame, demonstrating how this concept may be mobilised to provide a more holistic view of SBE's contemporary manifestation as a public health challenge in India and elsewhere.

Snakebite in Kerala

The Kerala state government has recently begun an ambitious public health programme to reduce human SBE mortality to zero, thus representing an illuminating case of engaged snakebite governance of this 'neglected' pathology. Kerala's tropical climate makes it a suitable habitat for 104 species of snake, of which 35 are venomous (Suchithra et al. 2008). This includes all of India's 'Big Four' snakes (the four species understood to be responsible for most medically important snakebites): spectacled cobra (*Naja naja*), common krait (*Bungarus caeruleus*), Russell's viper (*Daboia russelii*), and saw-scaled viper (*Echis carinatus*) (Laxme et al. 2019). Kerala is also home to the king cobra (*Ophiophagus hannah*) and hump-nosed viper (*Hypnale hypnale*), two less-common but medically noteworthy species (Suchithra et al. 2008).

Snakebite not only poses a risk of death but may also engender long-term sequelae due to limb loss, tissue damage, and mental conditions including trauma (Bhaumik et al. 2020). In India, it is estimated that only 20–30% of SBE victims in rural areas access treatment, thus generating a limited epidemiological picture (Majumder et al. 2014). In 2024 in Kerala, 30 snakebite deaths were reported state-wide through public hospitals (Bharat 2025). Available epidemiological analyses of snakebite cases in Kerala are conducted at the level of individual hospitals, with one representative study from Government Medical College, Kozhikode, identifying 1500 snakebite cases between January 2012 and October 2016 (Kumar et al. 2018). Epidemiological trends generally suggest that most bites happen to adult men working in agricultural settings, although domestic bites in urban and rural environments are not uncommon (Chandrakumar et al. 2016). Due to recognition of the acute long-term impacts of SBE sequelae in Kerala, a community-based cross-sectional study is currently ongoing to estimate the disease's socio-economic and disability-related impacts (Menon et al. 2021).

In Kerala, it is common for a snake to enter a person's home or workplace, necessitating removal. Prior to 2017, snake translocation from human spaces in Kerala was conducted in an unofficial capacity. Individual 'snake rescuers' performed translocations for a small fee. Following several high-profile injuries to amateur rescuers, the Kerala Forest Department engaged in a concerted effort to address SBE in the state by launching public awareness initiatives, training a cohort of licensed snake rescuers, and enacting a set of snake translocation regulations. These regulations



specify that snake rescuers must obtain a licence from the Kerala Forest Department which is awarded on the condition that they use a standardised rescue technique (Kirkham 2023).

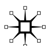
Methodology

This article draws on materials generated through one month of participant observation in Kerala with forest officials, policymakers, snake rescuers, herpetologists, and medical doctors. This involved witnessing and participating in snake rescue activities alongside participant observation of actors working in Kollam Forest Department Headquarters; Walayar State Forest Training Institute where rescuers are taught techniques for snake capture and release; a Forest Department snakebite awareness event in Thiruvananthapuram; Amrita Hospital in Kochi; and Kannur district and Kottayam district where I attended snake translocations with local rescuers. This was supplemented with 17 interviews with third sector and state policymakers, state employees (forest officials and medical professionals), volunteer snake rescuers, and snakebite affected community members. Application of the theoretical resource of toxicity to the materials generated through this fieldwork elucidated the structural, indeterminate, and multispecies dimensions of SBE.

Structural vulnerability

In India, snakebite is disproportionately experienced by poor, rural populations, with bites typically occurring on agricultural plantations (Suraweera et al. 2020). This, coupled with poor labour conditions and limited access to antivenom, means cases of death and disability by envenomation arise frequently in rural 'hotspots' (Brown and Kelly 2014; Suraweera et al. 2020). While snakebite's recent classification in public health literature as a 'disease of poverty' points to a growing recognition of how its inequitable burden is produced through uneven structural conditions (Fry 2018), recent work focussed on the political ecological dimensions of the disease has more explicitly emphasised how ongoing legacies of colonial tropical medicine, extraction, and plantation agriculture have amplified SBE's burden in the Global South (Arias-Rodríguez and Gutiérrez 2020; Gutiérrez 2020; Bhaumik 2021).

In contrast to this structural view of SBE's drivers, Liboiron and colleagues (2018, p. 334) suggest that toxicants form a taxonomic break from toxins since they "are engendered by specific systems, including industrialization, economic growth and capitalism". This, they argue, is why substances such as lead and arsenic, whose genesis ostensibly occurs 'naturally' underground and thus may be considered 'toxins', are better understood as toxicants as it is human industrial processes that engender their wide spatial distribution, chronicity, and injurious effects. As Liboiron (2017, p. n.p.) writes, "The large-scale mercury poisoning in Minamata, Japan, or Grassy Narrows, Canada are impossible for naturally occurring toxins". However, while the circulation of venom is certainly distinct from that of a synthetic toxicant such as mercury, suggesting that the large scale



of snakebite's burden is not produced through structural relations fails to situate snakebite within the specific systems that drive risky human–snake cohabitation and acute envenomation prognosis.

The role of uneven structural conditions in conditioning snakebite vulnerabilities and harms was recognised by my interlocutors in India, as the Kerala Forest Department's Snakebite Lead explained:

> "Poorer people are affected more. Often the houses will have some holes, they are made of mud and not cemented, so the snake will enter the house for shelter, it can remain there for two, three days… People also get bitten around the house when working in darkness. We have problems with power cuts, some people have problems with electricity. Working in darkness means people don't see the snakes when they reach into a cupboard, then they are bitten." (04/06/22)

As this quote highlights, the chance of risky cohabitation between snakes and humans is understood to be greatly influenced by socio-economic status, with factors such as poor housing quality and uneven provision of utilities contributing to bite risk. Medical officials also emphasised that snakebite may be best seen as an agricultural occupational hazard due to the large number of envenomed patients arriving from agricultural workplaces. Thus, intersecting political ecological relations, such as labour conditions and landscape use, condition bite vulnerability.

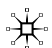
Structural relations were also understood to contribute to the outcomes of individual snakebite events, as an SBE clinician explained:

> "If a cobra bites, sometimes you only have 30 minutes to get to a hospital. That's why rural places, where the roads are not so good, the facilities may be much worse, with no hospitals near or anti-venom, that's why people there are injured more, or die." (16/06/22)

Just as the risks posed by minerals are conditioned by specific infrastructures of capitalist expansion and extraction, so too are toxic relations between human and snakes made more or less acute by the infrastructural arrangements in which human–snake entanglement arises and post-bite mobility is facilitated or constrained.

Thus, while there are always differences in the circulations, temporalities, and modes of harm of any two given toxicants, likewise, the distinctive properties of venoms and their relational contexts also lead to specific toxic worldings (Chen 2012; Nading 2020). These worldings are similarly implicated in specific systems of "industrialization, economic growth and capitalism" (Liboiron et al. 2018, p. 334), as the example of snakebite's amplification in agricultural workplaces and rural abodes demonstrates.

Nevertheless, Liboiron (2017) usefully articulates how, while toxicants enact harm through wide-scale accumulation in and disruption of corporeal systems over time, toxins such as venom engender more immediate damage and disruption to the body following a distinctive envenomation event. Such a distinction is



important but must be nuanced through consideration of the wide-scale incidence and lasting impacts of SBE upon affected communities.

Snakes are found all over Kerala and often occupy the same spaces as humans. Several Forest Officials described snakes as "urban wildlife", emphasising their successful adaptation to the built environment where they "find all kinds of holes to make their homes" (02/06/22). Wherever humans and snakes make their homes together, snakebite is understood to be a risk. Thus, the widespread entanglement of human and snake geographies in Kerala results in snakebite being understood as a persistent condition, not dissimilar to the pervasive riskscapes of toxicant exposure. Furthermore, a lens of toxicity illuminates the enduring legacies of envenomation, as recent research shows that snakebite incidents engender post-traumatic stress and long-term disability, with devastating social and economic consequences for affected individuals (Kasturiratne et al. 2021).

Consequently, by situating snakebite within toxicity, I channel Arnold's (2016) "continuum" of toxic substances, nuancing the binary distinction of toxin (natural genesis, small-scale) vs. toxicant (anthropogenic genesis, wide-scale) proposed by Liboiron and colleagues (2018). In doing so, I emphasise how the lens of toxicity positions snakebite in broader relational complexes of macro-toxicities, such as poor labour conditions, infrastructural provision, and treatment availability, opening opportunities for social scientists to investigate how these conditions arise and may be reworked to render life with snakes and other non-human entities with toxic capacities less harmful.

Ophidian indeterminacy

Recent work on the issue of SBE has emphasised the need to better understand the subjective experiences of those encountering snakes, seeking treatment, and recovering from envenomation (Ruiz de Castañeda et al. 2022). Meanwhile, ethnographic studies of contamination have utilised the lens of toxicity to explore the sensorial perceptions (Shapiro 2015; Stein and Luna 2021); physical and psychological manifestations (Singer 2011; Chen 2012); temporalities (Davies 2018); and contestations over what counts as evidence of toxicant exposure (Wylie 2018). Of these accounts of the experiential and epistemic dimensions of toxicant exposure, the challenges of sensing invisible and indeterminate molecules (Shapiro 2015), and the evidentiary regimes and politics that emerge through these processes (Brown and Gibbs 2007) are understood as significant challenges in making visible, denouncing, and managing toxicity (Fiske 2018).

Similarly, the risk of SBE can be difficult to observe. Uncertainty surrounding questions such as "Is that a snake I saw?" and "Is this snake venomous?" emerged as a notable characteristic of snakebite in Kerala. This was evident in the challenge of snake identification, as a herpetologist working with the Kerala Forest Department explained:

> You cannot identify snakes in the bird manner. Birds sit in a certain position. There is not so much variation in their poses, their angles. But snakes,

> literally every second it is changing its body shape. It is moving through the environment. So, depending on the situation you may only see the tip of the tail, a little of the scalation... Often, the snake is in a dark area, and you might not be sure if the snake is there. (20/06/22)

Serpentine morphology, movement, and behaviour make it difficult to determine if a snake is venomous or non-venomous, or if the animal is present at all. As a Forest Official explained, this uncertainty is made more acute as indeterminate snake identification can be a matter of life and death:

> Identification of snakes is very confusing, even an expert can be wrong. A combination of features is required to correctly identify a snake. You can't use one feature – there are similarities in colours, patterns, size... If a rescuer incorrectly identifies a snake and handles it carelessly, it can be very dangerous. (02/06/22)

Misidentification was seen by both forest officials and Kerala residents to be constitutive of snakebite. Numerous interlocutors remarked that bites arise when people do not see snakes coiled in dark areas such as cupboards or shoes. The cryptic behaviour of snakes and the indeterminacy of their presence/absence was seen as a considerable challenge in addressing snakebite.

Even in the event of a bite, uncertainty looms large. Forest officials explained the misconception that venomous bites always implant "two fang marks" is not always true; "this may not be so, because the snake may only have one fang, or there will be an impression only" (02/06/22). This can lead individuals to fail to seek treatment, as irregular wounds can make them presume the bite was 'dry' (absent of venom). This indeterminacy extends to snakebite treatment. A snakebite doctor at Amrita Medical Hospital explained that due to the risk of an anaphylactic allergic reaction to the horse antibodies used in antivenom, treatment is ideally only administered when there is certainty that a bite was inflicted by a venomous snake. If the snake responsible for the bite is not brought to the hospital, or a photo is not produced, clinicians who are less experienced in identifying the early signs of envenomation may wait to administer antivenom, increasing the risk of a fatal prognosis or sequelae. Snakebite is thus marked by uncertainty in both prevention and treatment, as the indeterminate identity of a bite's source poses challenges to administering appropriate antivenom.

These accounts reflect the "fundamental indeterminacies" of toxicity's "beings and doings" (Schrader 2010, p. 277). Put simply, toxicity can be done even in situations where the presence of toxins is not entirely clear. For example, Schrader (2010) demonstrates how the dinoflagellates *Pfiesteria piscicida* produce toxins only in certain experimental settings, highlighting how the organism is multiply enacted as (non-)toxic in differing environments. Likewise, Schickore (2017) reveals how scientific disagreement over the action of snake venom in animal models was fuelled by the staggering diversity of venom compositions. The case of SBE in Kerala shows how the indeterminacy of toxins is constituted through the slippery behaviour of snakes, inter-species similarities, assumptions of venomousness, and the variable knowledge practices of participants in the field and

clinical settings. Thus, indeterminate toxicity characterises snakebite, even in the absence/presence of venom, posing a significant challenge to the management of SBE as a public health issue in the region.

Multispecies health

Forest Department officials did not understand SBE's health impacts to be solely distributed within human populations. Risk of livestock envenomation was commonly cited as a key issue, while, as a snake rescuer explained, snakes themselves are impacted by their toxic entanglement with humans:

> Many people fear snakes. They often don't understand whether they are venomous. They often feel afraid when they find one [a snake], even if it isn't venomous, many people will kill it to be sure. (02/06/22)

Forest Officials described the persecution of snakes as a significant conservation issue, particularly due to snakes' important ecological role as a keystone species in controlling rodent populations.

Relatedly, work springing from recent accounts of 'multispecies justice' has emphasised how vulnerability to toxicity is shared across species lines (Chao et al. 2022). An additional strand of this literature has considered the possibilities for collective life in post-industrial landscapes, drawing attention to how chemicals mediate social relations to generate 'chemosocial collectives'—multispecies assemblages whose relationships and forms of life are moulded through exposure (Kirksey 2020). These studies both consider the collective health impacts of chronic chemical exposures (Phillips 2014), alongside the ethical commitments and intimate forms of multispecies care engendered and attenuated by toxic encounters (Turnbull 2020).

In an effort to address collective multispecies health impacts, the Kerala state has embarked on an extensive public engagement project to encourage tolerance of snakes, alongside significant expansion of snake rescue infrastructure in the region. During public engagement, Forest Officials present impressive snake imagery, descriptions of snake natural history, and information about the widespread availability of snakebite rescue services for residents of Kerala. According to the Forest Department's SBE lead, the intention of these activities is to cultivate a "motivation for conservation" (04/06/22), so that people do not attempt to kill snakes in moments of encounter, as this puts both human and ophidian interlocutors at risk. Ultimately, the ambition for this programme is to generate a broad acceptance of snakes across Kerala society; a state of coexistence where non-venomous species are no longer seen as a threat and thus do not necessitate removal from human-occupied spaces, while venomous species are "left in peace" (04/06/22) by members of the public until a trained rescuer arrives for translocation duties. While Forest Officials acknowledged that translocation still entails risk of harm to snakes, this was seen as preferable to the likelihood of lethal removal if a snake rescuer did not intervene. Although many members of the public I spoke to explained that they continued to fear snakes, they also expressed their gratitude for the expanded rescue infrastructure, which meant they no longer had to deal with snakes themselves in the lethal

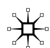
manner. Thus, while distributing harms across species lines, the toxic entanglements between humans and snakes are understood to be open to renegotiation in efforts to generate less harmful human–snake relations in snakebite geographies.

Nevertheless, while this account demonstrates how human–snake relations may be reconfigured to form alternative chemosocialities, it does differ somewhat from accounts of industrial toxicants. These studies typically focus on ongoing exposure to synthetic toxicants, and the modes of being, systemic oppressions, and diseases that emerge from these temporalities of 'chronicity and continuity' (Tironi 2018, p. 443). As demonstrated prior, while these dynamics are present in the case of biological toxins, there is also a clearer moment of encounter and an envenomation event when a bite or sting occurs. In the case of toxins then, we may supplement an analytic of toxic *exposure* with one of *encounter*.

Encounters are "events of relation" that are "affective, emotive, and sensuous", provoking unpredictable responses in interlocutors (Wilson 2017, pp. 464–465). Analyses of animal encounters in the context of human–wildlife conflict have demonstrated how these moments of relation are "defined by risk and uncertainty" (Wilson 2019, p.35), where humans and animal pose an (unequal) corporeal risk to one another (Collard 2012; Barua 2014). This is not to argue that forms of human–non-human relation are absent in prior accounts of toxicity (see: Kirksey 2020). However, as the Kerala Forest Department's efforts to encourage tolerance of snakes demonstrate, analyses of biological toxins require an attentiveness to how moments of toxic multispecies encounter emerge, and how the governance of these moments of sudden, risky relationality may either amplify risks to interlocutors or contribute to the generation of chemosocial coexistence between humans and non-human animals with toxic capacities. To focus solely on the harms that snakes pose to humans is reductive:a lens of chemosocial encounter captures how the health of snakes themselves comes to matter in SBE management, and how localised disease governance measures open opportunities for humans and snakes to live together in more mutually accommodating configurations. Thus, while theories of toxicity may provide a useful heuristic for guiding enquiry, the need to supplement analyses of exposure with a lens of encounter, which more adequately accounts for the multispecies relationalities and rapid temporalities present within snakebite situations , demonstrates the importance of social scientists maintaining a critical awareness of the situated impacts of particular toxic substances in specific geographies.

Conclusion

Toxicity offers a route to a more expansive understanding of SBE's biosocial dimensions, including its structural drivers, indeterminacy, and multispecies human–snake relations. In the case of snakebite, supplementing analyses of toxic *exposure* with notions of toxic *encounter* demonstrates that while theories of toxicity provide a useful heuristic for analysing diverse toxic worldings, it is critical to remain aware of the situated empirical realities of a toxic molecule. While this observation may appear obvious, for theories of toxicity to deliver on their stated attentiveness to the



relational enactment of toxic worlds, they should not fall back on hard distinctions between classes of molecule. Such exclusions imply that snakebite possesses a certain naturalness or inevitability, contributing to a depoliticisation of the histories and systems that have brought into being unsafe agricultural environments, poor housing, and uneven infrastructural provision of medical resources.

Nevertheless, this article offers a modest view of how a group of public health and forest officials in a specific geography conceive of the problem space of SBE. Additional research that "asks the questions before the question" (Shapiro et al. 2017, p. 586) of how the risks of snakebite, and toxin-induced toxicity more broadly, are engendered, experienced, and negotiated to render conditions of human–snake co-existence less toxic is necessary. Further research utilising this lens may look to: how snakebite governance initiatives from different geographies are responding to SBE and how they are received by at-risk populations; how the disease is experienced as an occupational hazard by agricultural workers; how cultural practices and attitudes towards snakes render human–snake encounters more or less toxic; how the more-than-human political economy of antivenom production, procurement, and provision is shaping the disease's chronicity; and how the long-term economic and social impacts of snakebite, such as death of a family member, loss of limb, or post-traumatic stress, are experienced. Additionally, issues such as the booming number of *Tityus serrulatus* scorpions in Brazil and increasing jellyfish blooms in the Mediterranean and elsewhere may benefit from the approach outlined in this article (Rothe 2020; Guerra-Duarte et al. 2023). For these future directions, a lens of toxicity provides one means of attending to both the situated macro- and micro-toxicities bound up in encounters with non-human entities with toxic capacities.

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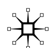

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George Kirkham is Grand Union Scholar at the University of Oxford's School of Geography and the Environment. His doctoral research draws on more-than-human geography, political ecology, and medical anthropology to study the global governance of snakebite envenomation and the making of neglected tropical diseases.