Toxic Uncertainties and Epistemic Emergence: Understanding Pesticides and Health in Lao PDR

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Agrichemicals and other toxicants are now ubiquitous in both human bodies and the environment, yet public debate and scientific practice on their effects are still mired in uncertainty. Recent research in the history of science, feminist science, and technology studies has advanced ways of thinking about ignorance and uncertainty. Combined with key insights from political ecology, specifically the ontological continuity of bodies and environments and the uneven production of both knowledge and exposure, I suggest a conceptual intervention. I propose epistemic emergence—a way of thinking about the relations between forms of often situated, partial, and imperfect evidence that could be greater than the sum of their parts—as a way of working with uncertainty. Epistemic emergence pairs conventional scientific data with lay methods, takes into account the complex ecology in which exposures occur, considers how exposure interacts with social lives, and asks what forms of knowledge might make harm articulate enough for action (Liboiron 2015) in a particular context. Using a case study of community-based biomonitoring in upland Laos where pesticide use was near zero fifteen years ago and today risky levels of biomarkers for insecticide appear in children, I discuss what epistemic emergence might look like in practice. *Key Words: pesticides, political ecology of health, science and technology studies, uncertainty.*

The presumption that bodies could be isolated from environments—that they are ontologically separable things—was a founding assumption of environmental health science (Nash 2008). Given the ubiquity of agrichemicals and other toxicants, this separation needs to be reexamined. Geographers have recently begun to break down the ontological and conceptual barrier between bodies and environments (Guthman and Mansfield 2013), challenging the link between behavior and exposure (Mansfield 2012; Galt 2013) and demonstrating the uneven distribution of the ability to mitigate environmental toxic risks (Barraza et al. 2011; Galt 2013). At nearly every scale and in every part of the world, chemicals and bodies are materially entangled (Agard-Jones 2013) in ways that are very difficult to standardize, detect, manage, and predict. The current scientific debates on pesticide—most notably in lawsuits over Roundup—echo almost exactly the terms of debate set over lead arsenate in the 1940s (see Whorton 1975). Getting past those stale debates requires evaluating the epistemological biases and the ontological premise on which we evaluate harm and finding new ways of working with the radical uncertainties that such a premise might present.

Recent work in the history of science, feminist science, and technology studies has much to say on this particular impasse. The toxic effects of agrichemicals are largely imperceptible (Murphy 2006), especially in the places where the majority of the worlds' pesticide users live and work. Understanding bodies and environments as ontologically continuous, I argue, requires that we think about agrichemicals as agnogenic (Proctor and Schiebinger 2008). Between the confounding variables that muddle cause and effect, because of the potential for the impacts of agrichemicals to interact with other health factors, and because of the way in which they interact with social lives in unpredictable ways, agrichemicals interact with people and environments in such a way as to create ignorance (Stone 2014). Combined with key insights from political ecology, specifically the ontological continuity of bodies and environments and the uneven production of both knowledge and exposure, I suggest a conceptual intervention for political ecologies of health and exposure where uncertainty is high and resources are scarce. I propose *epistemic emergence* as way of thinking about the relations between forms of often situated, partial, and imperfect evidence that could be greater than the sum of their parts. Paired with more

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conventional methods, epistemic emergence offers us a way of working with uncertainty or, to paraphrase Liboiron (2015), make complex forms of harm articulate enough for action.

I begin with a discussion of the uneven geography of environmental health science and the ways in which agrichemicals produce ignorance. I then present an ethnography of a community-based biomonitoring project in northern Laos in which local activists and government officials faced trying to make the impact of insecticide exposures visible. Then I return to the idea of epistemic emergence from multiple, partial knowledges.

Thinking Beyond Body–Environment Dualisms

Geographers are increasingly looking at health as a complex nature–society issue (Mansfield 2012; Sultana 2012). Political ecologies of health offer key insights about how health is situated within political, economic, and environmental systems that are deeply unequal, as well on the material consequences of the various ways in which health is discursively and scientifically understood (King 2010). Emerging work in environment–health geographies goes further to fundamentally rethink the assumed boundary between bodies and environments, with the body's permeability as a key theme (Senanayake and King 2019). Efforts to open the "black box" of the body treat bodies as mutable, biological, and constituted through interactions with the environment (Guthman and Mansfield 2013, 486). This more ecological approach highlights how porous bodies are to the chemicals, hormones, microbes, stressors, and resources of the environment and, in return, how the body responds to the environment in iterative ways (Guthman and Mansfield 2013; Jackson and Neely 2015). This approach sees bodies as inherently situated and unevenly produced (Guthman and Mansfield 2013). Such a conceptual model is particularly applicable to pesticides and toxics, because experiences of toxicity can differ based on history of prior exposure, other health conditions like poor nutrition and kidney disease, and environmental conditions like soil type and groundwater resources (Nash 2004). Work on toxics in other contexts shows how exposure itself is the result of a complex ecology. Symptoms might manifest in different ways in different bodies at different times; such variability highlights the need to look at emergent properties in complex body–environment ecologies (Murphy 2006). New work on epigenetic effects of certain agrichemicals makes it extremely difficult to prove a relationship between a particular site of exposure and the onset of illness; such illness might not manifest for a generation and could be altered by other events over a life course (Romero et al. 2017). New work in chemical geographies recognizes that such a reality defies the fundamental assumptions of spatial epidemiology (Romero et al. 2017) and thus requires new methodical approaches. One way in which political ecologies of health have dealt with such issues is to rely on partial and situated accounts (Jackson and Neely 2015)—methods that do not count in standard regulatory science. Much like approaches pioneered in popular epidemiology and civic science, such an approach can expand the terrain of what kinds of knowledge count and provide an organizing framework for more expert knowledge (Brown 1992; Kroll-Smith and Floyd 2000; Ottinger and Cohen 2011; Wylie, Shapiro, and Liboiron 2017). When bodies and environments are seen as mutually constituted, however, an array of knowledge beyond questions of chemical hazard becomes relevant to the question of impact, from how (agro)-chemicals act on social lives, race, gender, resources, and opportunity (Agard-Jones 2013; Luna 2018).

Such an understanding introduces a significant additional degree of uncertainty into environment–health geography (Senanayake and King 2019). I suggest that one way of working with these uncertainties is to be clear about the epistemic and ontological limits of current approaches, relying on multiple situated knowledges, and taking seriously the impetus toward pursuing explanation at the scale of emergent properties (Murphy 2006; Senanayake and King 2019). Such an approach can help avoid the "data treadmill" (Shapiro, Zakariya, and Roberts 2017, 583) and orient toward questions of what kind of knowledge, and for who might spur action. Drawing on recent work in the history of science and science and technology studies, I illustrate the epistemic limits of current approaches to documenting pesticide impacts in the Global South. I also suggest that thinking past body–environment dualisms requires understanding the way in which agrichemicals and other toxicants produce ignorance. Such a project can offer a different theoretical and practical toolkit to articulate what counts as harm.

The Uneven Production of Knowledge and Exposure

In 2018, 28 percent of global employment was in agriculture (World Bank 2019). Whereas in the United States, the European Union, and other economically advantaged regions, the proportion of people employed in agriculture has been falling for over a century, in South Asia, East Asia, and sub-Saharan Africa, the number of people working in agriculture has actually grown since the 1960s (World Bank 2008). These places are also some of the fastest growing pesticide markets. Pesticide use is increasing worldwide almost twice as fast as food production, but it is expanding the fastest in middle-income countries (Schreinemachers and Tipraqsa 2012). Although data are thin in low-income countries where agricultural commercialization is expanding, there is ample case study evidence that pesticide use is rapidly increasing among low-income smallholders—for example, in Kenya, Bolivia, Ethiopia, Mali, China, and India (Haggblade et al. 2017; Bickel 2018; Ottiger 2018). Simply put, more people than ever are exposed to agrichemicals, largely in environments with minimal monitoring, regulation, and health surveillance.

Drawing on feminist science studies, we can think of the uncertainties surrounding such everyday exposures as what Murphy (2006) called a domain of imperceptibility. By this she meant the absence of scientific knowledge created by the epistemological limits of a disciplinary approach and the often purposely created imperceptibility designed to make the impacts of—and responsibility for—chemical harms uncertain (Murphy 2006). This imperceptibility is profoundly geographically uneven. Aside from the efforts of industry to sow doubt and the deprioritized nature of much environmental health research, there are serious epistemic limits to the current approach in low-resource environments. For example, poisoning cases are the most straightforward effects of agrichemicals to recognize and document, yet the phenomenon is woefully undercounted. To illustrate, a project to improve the needlessly bureaucratic system of health surveillance in the Western Cape of South Africa increased reported pesticide poisoning rates tenfold; 86 percent of cases were occupational exposure (London and Bailie 2001). Another survey of 32,245 agricultural workers in Central America indicated that pesticide poisoning was previously underreported in the region's health surveillance systems by 98 percent, amounting to 400,000 poisonings a year (Murray et al. 2002). Contrast this figure with the official United Nations (UN) global estimate of 200,000 annual poisoning cases (UN Special Rapporteur on the Right to Food 2017).

Even the good data are epistemologically limited; they count only the immediate, acute reactions that require medical attention to the point where there would be a report or interaction with a clinic, which in low-resource rural areas is not guaranteed to be available. In much of the Global South, pesticide use is largely informal (see, e.g., Barraza et al. 2011; Galt 2014; Shattuck 2019). Protective equipment can be impractical for hot, humid, or steep landscapes; too expensive; not provided by plantation owners; and not properly maintained. Its use can be constrained by social norms or the ecological conditions of farming far from wells, tanks, and hygiene facilities (Murray et al. 2002; UN Special Rapporteur on the Right to Food 2017). The gap between farmers' knowledge of pesticide hazards and strict adherence to best pesticide handling practices is "an extremely robust finding about real-world situations from behavioral and social scientists" (Galt 2013, 345), meaning that low-level acute poisoning, unreported accidents, and low-level chronic exposures are almost certainly a fact of life in the majority of places where pesticides are used, to largely uncertain effect.

Then there is the question of which bodies "count"' (Guthman and Brown 2016). It is worth noting the obvious: Agricultural workers and small-scale farmers are socially marginalized globally. Phenomena that predominantly affect marginalized communities, like pesticide drift, are little studied (Harrison 2006). Efforts to make impacts of pesticide visible share a history with farm worker organizing (Nash 2004). Migrant agricultural workers the world over are disproportionately exposed and yet are rarely included in epidemiological or biomonitoring studies; cancers and other health issues can take ten to twenty years to show up, and tracking down migrant workers to monitor health impacts has "rarely been possible" in epidemiology (Alavanja 2009, 305), especially because migrant workers often have precarious citizenship and job status. For biomonitoring, scientists need lab equipment, knowledgeable people to run it, supplies to run tests, and universities, governments, and companies that can support them to do so. To paraphrase Latour (1987), hard facts are expensive.

Long-term prospective cohort studies tracking pesticide users, the gold standard in epidemiology, are costly and, if long term, require political, institutional, and population stability over as much as a decade or more to complete. Relatively fewer longitudinal studies of children, like those in the Unites States that exposed the impacts of organophosphates on brain development (Gunier et al. 2017), have taken place in the Global South. The studies that do exist, however, indicate that exposures and health outcomes for agricultural workers might be more serious than they are in better surveilled countries like the United States. A pilot study of fifty female agricultural workers in Thailand, for example, found that average concentrations of urinary metabolites of organophosphate insecticides were twice the comparable figure from a study of farm workers in California's Salinas Valley and almost three times higher than in the general U.S. population (Ryan et al. 2012). Higher rates of exposure were associated with lower birth weight and adverse birth outcomes (Naksen et al. 2015). The expanded SAWASDEE study, funded largely by the U.S. National Institutes of Health (NIH), follows 300 mothers and their children for three years after birth at a cost of $563,957 (NIH 2018). A similar cohort study of 350 mothers is ongoing in South Africa (Naidoo et al. 2016), as is another looking at reproductive and neurobehavioral health effects due to pesticide exposure among 1,000 adolescents in the Western Cape (Chetty-Mhlanga et al. 2018). In short, studies of the relationship between pesticides and bodily health exist all over the world (Wesseling et al. 1997; UN Special Rapporteur on the Right to Food 2017). The problem is that the knowledge that exists concerns populations least likely to count politically, is often partial, and is often insufficient to overcome uncertainty in the traditional regulatory frame. This imperceptibility has a politics: In waiting for certainty, one abdicates liability and responsibility for any resulting human health and ecological harm.

Ignorance and Agnogenesis

The debate on agrichemical safety is at a discursive, political, and empirical impasse.[1] Although there is certainly strong evidence that chemical companies have worked to hide or "manufacture doubt" about the true toxicological impact of their products (Markowitz and Rosner 2002; Oreskes and Conway 2010; Lerner 2017), such purposeful malfeasance is not necessary to produce uncertainty about the toxic entanglements of bodies and agrichemicals. Uncertainty about what constitutes harm and adequate evidence for it is not difficult to come by—it is a product of the science itself, a product of how agrichemicals alter both bodies and environments.

In August 2018, a former groundskeeper slowly dying at the age of forty-six from non-Hodgkins lymphoma was awarded a $289 million judgment against the makers of glyphosate. The plaintiffs presented key evidence based on laboratory studies of mice. The attorneys for the company called up evidence from a long-term cohort study of 90,000 farm workers that found no evidence of increased cancer risk.[2] The company's attorneys raised doubts that damage found in mice and rats was a good stand-in for humans. Amy Cornell, president of the Agribusiness Council of Indiana, stood by glyphosate in the press, saying it "is one of the world's most studied chemicals" (in Bienkowski 2018). Cornell's claim might very well be true but does not exonerate glyphosate by itself. In fact, the debate over the Roundup trials (which at the time of writing include more than 13,400 filings in U.S. courts) is an echo of the past. The first debate over commercial pesticides in the United States was over lead arsenate. There, too, a cohort study found no impact on orchardists using the product—even in a follow-up thirty years later (Nelson et al. 1973; Whorton 1975). U.S. Food and Drug Administration officials at the time argued that the only way to see damage was in animal trials; the industry argued that rats and guinea pigs were not a perfect analogue for people (Whorton 1975). Of course, lead arsenate is now unquestionably associated with skin and lung cancers and adverse neurological effects (National Library of Medicine n.d.). The time lag between exposure and effect is so well established for toxics writ large that some impacts can only be seen through "slow observation" (Davies 2018, 1537).

The disciplinary roots of regulatory environmental health science lie in both industrial hygiene and public health sanitation (Nash 2008). The idea that both bodies and environments absorbed industrial chemicals was not, in itself, a problem; how much they absorbed was (Nash 2008). Quantifying this absorption in a bounded space (like the factory) to predict a threshold beyond which an effect could be traced to a single, measurable cause—for example, lung disease and dust—became the standard (Nash 2008). The other pillar of historical toxicology was based in public health sanitation approaches deeply influenced by germ theory. These early reformers emphasized bodily purity and believed that disease could be localized in particular pathogens from which the body could be isolated. This, according to Nash (2008, 655), "cultivated an unrealistic public expectation that environments are—or at least should be—external to health." Chemicals came to be assessed on a molecule-by-molecule basis, not because that is necessarily how they work in the world but because of the "molecular bureaucracy" with which we came to understand them (Hepler-Smith 2019). The field of risk assessment developed to center on thresholds of exposure to individual molecules with traceable, predictable causes and effects—on the technical risk assessment of certain objects—not the multigenerational impacts, environments, and social relations they alter. The legacy is such that regulatory science has robust, necessary, and ultimately narrow standards against which evidence is evaluated.

Agrichemicals are agnogenic (Proctor and Schiebinger 2008; Stone 2014) by nature: Materially the way they work in the world produces uncertainty. The latency between suspicion and scientific consensus about a chemical's effect is just one form of this agnogenic nature. Agrichemicals and their products come into contact with people and ecologies and socialities in so many ways that each interaction, each product, creates a whole field of things about which we know nothing. To paraphrase anthropologist Stone (2014), this is not necessarily dangerous: The danger of any technology lies in the context in which it is used.

Latour (2009) argued that social scientists must move "from certainty about the production of risk-free objects (with their clear separation between things and people) to uncertainty about the relations whose unintended consequences threaten to disrupt all orderings, all plans, all impacts" (25). Taking this seriously asks researchers to focus on the relations those objects disrupt (for better or worse). This goes beyond the common focus on how agrichemicals are used and whether they are used according to safety instructions. Agrichemicals themselves are a sort of a social agent. They allow plantations to thrive where it was previously impossible to grow industrial crops and thus consolidate the ownership of land (Murray 1994). They can allow small farmers to get a grip on the cash economy (Castellanos-Navarrete and Jansen 2018). They might save labor and make education more possible for children, especially girls (Admassie and Bedi 2003; Edmond 2017). They can grow debt as well as cotton (Gray and Dowd-Uribe 2013). Men might have more access to chemical inputs, increasing intrahousehold power differences (Peterman, Behrman, and Quisumbing 2014). Agrichemicals can improve the social status of low-caste young men (Aga 2019). Agrichemicals might change conceptions of sexuality and masculinity to great consequence (Agard-Jones 2013). They are imbricated in ideas of whiteness and blackness, modernity and race (Luna 2018).

The imbrications of agrichemicals, economies, and socialities alter the fundamental social determinants of health. The way in which agrichemicals disrupt social relations can thus have every bit as powerful an impact on bodies as their long-term toxicological profiles. These social impacts are not cleanly predictable; they can be transformative in ways that belie easy normative judgments. This larger definition of chemicals' agency is a more empirically faithful way to pose the questions "How do agrichemicals affect public health?" or "What happens when agrichemicals act on bodies and their environments?"

The agnogenic nature of agrichemicals and the history of uncertainty around their effects point to an epistemological and ontological impasse—a choke point in both how we know and how we imagine agrichemicals and bodily entanglements. Latour gave an apt metaphor to imagine the epistemic limits of science: "Scientific facts are like trains, they do not work off their rails," he wrote. "You can extend the rails and connect them but you cannot drive a locomotive through a field" (Latour 1992, as cited in Carolan 2008). This metaphor can be expanded to think about whole disciplines; those, too, work on epistemic "rails" (Carolan 2008). Although the fields of toxicology and epidemiology traverse important ground, they do not capture the whole field of relations that determine the health effects of agrichemicals. As long as the debate remains on those rails, essential though they might be, the evidence will likely continue to be debated on the same necessary but insufficient terms.

Framing the debate on agrichemical safety on the narrow disciplinary tracks on which they currently travel writes out all of the relations that are situated or can be only partially grasped (Haraway 1988). Data gathered by less expensive methods or by non-researchers, data that are nonstandardized, particular to a place, qualitative, partial, or situated, are often seen as not objective enough for inclusion in regulatory processes. Such types of data are often purposefully kept out by regulators and regulatory scientists (along with industry) from environmental decision making because they rely on "things that cannot be counted but for which most people matter just as much as the things that can be unproblematically added and subtracted" (Carolan 2008, 735-726).

What is valid or visible to the state—and thus actionable—is an essential, but partial, take on the whole field of available evidence. It is not that the impacts of rapidly increasing pesticide use are impossible to assess; it is that these impacts are unlikely to be evaluated in ways that meet the high scientific standard required of a modern managerial or juridical approach to risk assessment, and even if they did, they are unlikely on their own to force political action because of whose bodies they affect.

As scholars of health social movements have long pointed out, the kinds of science taken on by citizen science projects, nongovernmental organizations (NGOs), and other laypeople can make impacts visible and bodies count in ways that often precede formal, more scientifically acceptable university or government efforts (Brown 2007; Iles 2007; Hess 2009). NGOs in the United States and Europe already produce scientific and technical inputs in combination with evidence of everyday exposures and, in some cases, helped political actors to interpret the science differently from most regulatory scientists (Iles 2007). Public epidemiology and civic science have long combined lay and expert methods of toxicological assessment, often using lay methods to organize and justify attention and resources from experts with methods more legible to the state (Brown 1992; Fortun and Fortun 2005; Wylie, Shapiro, and Liboiron 2017). The resources to move up from or connect lay and expert methods as in the model of popular epidemiology are more likely to represent the global regulatory exception rather than the rule, however. Depending on the context, the audience for such data might or might not be state regulators. Who will be the most effective actor, what might be a successful organizing strategy, who needs to be informed, and how cannot be assumed. Even where formal studies are connected to civic science, political struggles often get stuck in a tug of war over what data are acceptable, creating a "data treadmill" that can stymie action (Shapiro, Zakariya, and Roberts 2017).

The issue, to paraphrase Liboiron's work on microplastic pollution, is decidedly not a lack of correlative evidence for some sort of health effects given the exposures that are occurring. The problem is that the available evidence, the evidence that is practically quantifiable, does not provide a clear, scientifically decisive picture of what effects are produced under what conditions, in which bodies at which time, and whether those effects can be called harm (Liboiron 2015). The big question for an increasingly contaminated planet is how to "make emerging, amorphous forms of harm not only discernible, but *articulate enough* for action" (Liboiron 2015, 4, italics added).

I now turn to a case where local organizations attempted to do just that in the uplands of Lao PDR.

Growing Pesticide Use and Uncertainty in Lao PDR

Until fifteen years ago, Laos was one of the world's lowest per capita agrichemical users. Beginning in the early 2000s, a rapid transition to commercial agriculture was accompanied by a rapid increase in the use of agrichemicals. Data from the Lao Ministry of Agriculture show that from 2006 to 2016, pesticide imports increased 3,696 percent[3] as commercial agriculture took off. In Xieng Khouang Province, where the following case is situated, this increase translated into a local change from zero pesticide use to two to three times the standard industry-recommended herbicide application rates on average. Although widespread pesticide use there began with the arrival of commodity maize, chemical use is increasingly spreading to traditional upland rice production, on vegetables for local markets, and in the small-scale contract horticulture that followed the maize boom (Asai 2016; Rassapong et al. 2018). For these latter growers, exposure can be nontrivial. One NGO survey estimated that Lao vegetable farmers are using more pesticide per acre than other growers in the region, and exposure for those vegetable farmers is between 93 and 128 days per year (Rural Development Sole [RDS] 2016). In addition, pesticide use is largely informal. Chemical mixing is often done directly in stream beds in blue tarps strung over bamboo frames. Protective clothing is practical for the heat but insufficient to protect people; signs of low-level exposure are nearly universal and stories of accidents and acute poisoning are commonplace (Shattuck 2019).

Over thirteen months between 2016 and 2018, I joined NGO and Lao government efforts to assess and reduce risk from pesticides. This work was part of a larger project on social and environmental transformations in the Lao uplands, which included an eighty-seven-household survey of maize farmers; thirty-one semistructured interviews with government officials and NGO workers working on pesticide issues and agricultural development in the area; and semistructured interviews with twenty-seven pesticide applicators (Shattuck 2019). Using participant observation, I followed government and NGO pesticide risk reduction and extension activities and a community-based biomonitoring project conducted by a Thai environmental NGO and the Lao Ministry of Health. I also tracked the politics of the data they collected as they were presented in government meetings and development industry forums.

The data in question began with a program of RDS, a small Lao company partnered with a regional NGO called The Field Alliance and Helvetas International, a Swiss government-affiliated development organization. RDS used rapid blood cholinesterase tests in middle schools to promote awareness of pesticide safety. Over eighteen months, RDS in partnership with the Department of Agriculture and the Ministry of Health tested more than 2,200 schoolchildren, farmers, and consumers for acetylcholinesterase inhibition—a sign of organophosphate and carbamate exposure—using the inexpensive field-based test kit developed by the Thai Ministry of Health.[4]

The group would show up at a school, with Ministry of Health staff in white lab coats bearing vials and reactive test papers that would turn a particular color to be read. Students and farmers would line up in long queues and answer a series of official questions. Officials from the ministry would prick a finger of each student, sample the blood, and return a result. The test papers gave results in qualitative categories: unsafe, risky, safe, and normal.[5]

The results were enough to startle government officials. In the first round of testing, 49 percent of schoolchildren in two villages in Xieng Khouang and 58 percent in two villages on the outskirts of Vientiane Capital were in the unsafe or risky categories (RDS 2016). Between consumers, schoolchildren, and farmers, consumers—largely government officials—had the most unsafe and risky test results. The following March, the group did another round of testing in five villages that grew maize in Xieng Khouang. By March, most of the dry season vegetable production has finished and land is beginning to be prepared for maize and rice, which means that the peak season for insecticide use had passed a month or two earlier. Overall, 35 percent of participants tested at risky or unsafe levels of cholinesterase inhibition. Of the 422 primary and secondary school students tested, 33 percent has levels that were risky or unsafe. Of 494 farmers, 34 percent fell into these two categories (RDS 2016). Again, consumers were more affected than farmers; 47 percent of consumers were in the risky and unsafe categories. Given that consumers seemed to have higher levels of cholinesterase inhibition, practitioners assumed in the absence of reliable data that consuming residues on vegetables could be as much to blame as occupational exposure.

I observed while these data were presented in a half dozen Lao government meetings. In every one, when the fact that government officials tested at higher risk levels than farmers was mentioned, a murmur went around the room. In meetings of mostly white, foreign international development workers, this was the statistic that created a buzz. I received questions over e-mail and in meetings about what this means for urban children—the children of government officials and development workers; people with bodies that count to those with power.

Partially in response to concerns over the RDS data, especially regarding exposure of consumers, the provincial government set up a system to screen vegetables for pesticide residues using the widely available Gt test kit. They indicated that residues were potentially an important exposure pathway as they are in neighboring Thailand (Patarasiriwong 2017), but the test itself is a low-accuracy screening tool. An official described to me additional issues in trying to train staff to use the tests in the field:

> The test strips change colors based on how much pesticide is there. But sometimes it is very hard to tell. Often we go to the market, or to farmers' fields to do the testing, and it depends on the light what the color

> looks like. My team is discussing what the color is, what the result is, in front of the farmer, and is it difficult to be certain. Sometimes we go to the farmer to say their vegetables are contaminated and they say it is impossible because they do not spray or they do not trust the test (Interview with government official, Xiang Khouang, Laos. Interviewed November 13, 2017).

Although my (mostly foreign) colleagues loved to point to problems of corruption and "capacity" in Laos, in this case that was not the issue. The official in charge graduated from a prominent Western university and very seriously wanted to try to get enough information to solve the problem. There simply wasn't the cash or lab facilities.

There is very clearly a geographic or place-based imperceptibility here—the resources to do "good science" or even move up from or connect lay and expert methods as in the model of popular epidemiology are extremely limited in this context. Furthermore, Laos does not have a national system of health surveillance. The government is currently developing such a system, but the planned system does not have a category for reporting poisoning cases or pesticide-related accidents.

There is another issue with using cholinesterase activity as a biomarker in places like the Lao uplands. Cholinesterase inhibition can also be an indicator of or be exacerbated by anemia, malnutrition, liver disease, and hepatitis (Ramachandran et al. 2014). Low-protein diets are common in remote areas, as is micronutrient deficiency. Laos also has one of the highest rates of liver disease in the world, thanks to the prevalence of a parasite in *padek*, the locally popular raw fermented fish paste, and the prevalence of hepatitis B (Black et al. 2014). How much measured cholinesterase inhibition is enhanced by these factors is unknown (although liver disease is unlikely to affect children).

The blood tests the group was using were, like many lay methods, imperfect and less accurate than gas chromatography and other lab methods. They did not have to be perfect, however. I was told numerous times by the NGO workers involved in the project that the data were for "awareness raising." They were an "indicator" that there is a problem, one worker told me. The data are "for the farmers and their families, not the international community," another explained. The audience for these data was not primarily a government with too few resources to even stop banned products from appearing on shelves and zero political will to slow the growth of commercial agriculture. In this case, the primary audience for the data was the community itself.

We came to an impasse in the field, a sort of microcosm of the larger agnogenic nature of agrichemicals, when discussing what to tell the parents about what might happen to their children who had tested in the risky or unsafe categories, other than generally to avoid exposure. What might the long-term effects be? There was no way to know for sure.

The group did not stop trying to get more and better information. I participated in the group's other efforts to assess the impacts of pesticides, including an analysis of a limited number of urine samples with gas chromatography to corroborate the field tests and laboratory testing of soil and water from two model watersheds, as well as interviewing pesticide applicators and surveying maize farmers for my own research. At the request of two villages in which water contamination was a source of conflict between upstream and downstream villages, the group tested water and soil samples for pesticide contamination. In one predominantly maize farming community, atrazine was detected in surface waters in and downstream from the village at rates up to four times higher than World Health Organization standards for drinking water (Rassapong et al. 2018). I also surveyed maize farmers, 7 percent of whom reported having vomited after spraying herbicides (Shattuck 2019).

To try to corroborate the results of the rapid field tests, the group also took urine samples from a very small group of volunteers (twenty-one farmers, students, and government officials) to send to a university lab in Chiang Mai to test for metabolites of organophosphates and pyrethroids and glyphosate excretion. The much more costly urine samples the group had analyzed according to standard scientific procedure also indicated exposure is common. Testing urinary metabolites with liquid or gas chromatography in a lab costs \$80 to \$100 per sample in the region. The group only tested the urine for metabolites of organophosphates, not carbamates, which are anecdotally more widely used on vegetables locally. They also tested for a metabolite of pyethroids and for glyphosate excretion. Pyrethroids are commonly used on both vegetable crops and indoors to combat mosquitoes and other insects. Glyphosate is the second most commonly applied herbicide in the maize growing communities, although it is on track to replace paraquat for the top spot. Glyphosate was detected in 24 percent of the urine samples, from three farmers and two young students in farming families.

These results were startling but not out of step for the region. The combination of methods the group used followed in microscale those used in a study of 841 farmers and consumers by the Thai Department of Environmental Quality, which found that more than 85 percent exceeded the index values for cumulative dietary exposure and were potentially at risk for impacts to the nervous and endocrine systems (Patarasiriwong 2017).

Of course, the sample sizes in Laos were limited by resources, but there were other more intrinsic sources of uncertainty where the uneven production of science and the agnogenic nature of toxics interact. The levels of urinary metabolites in a single sample can be affected by a wide variety of variables—time since last exposure, diet and water consumption, age, alcohol consumption—all of which can affect body metabolism. Standards for testing urinary metabolites often require multiple spot samples with the same volunteers over a period of time to verify that the metabolites are being continually produced and to see whether levels fluctuate with changes in chemical use (Calafat 2016). Evaluating the ways in which herbicides interact with the body is even more challenging (McCally 2002). There is no readily available rapid test for herbicide exposure. Glyphosate, for example, has a limited residence time the body—meaning that a few weeks after an acute exposure event, there could be no measurable trace in the body. There is no scientific consensus on the impacts of glyphosate exposure or at what level that exposure might be harmful.[6] There is also no consistently predictable relationship between levels of herbicides, their breakdown products in urine, and health outcomes. That is, although evidence of exposure is one thing, the latency and the number of variables between exposure and the eventual health outcomes are far apart and difficult to trace without conducting expensive, large-*n* cohort studies. To produce certainty here one would need years to decades and several hundred thousand dollars for an epidemiological study—an ethically questionable endeavor in a place where seasonal hunger is a reality and poverty, not exposure, was the priority for the vast majority of farmers. Even that might not do it, given the complex mediation between agrichemicals, economic resources, social lives, and lingering toxicological uncertainty.

Several NGO workers told me that such extensive efforts to document herbicides in the body were not worth it. As one NGO worker told me,

> One of the most frustrating things to do is to find out how bad it is. I don't think I am the only one. I talked to one [toxicologist]. I talked to her on the phone a few weeks ago. I asked her about this, how to detect glyphosate. She said, "You called me again about this thing?!" I said "I don't have anybody else to consult." She said, "I am giving up too." I said "Why? You are the only one I know going after this." She said, "The more I did it, it is the same result." The result is everyone has it but nobody cares (Interview with NGO worker. Bangkok, Thailand. Interviewed June 3, 2017).

To be clear, it was not that "nobody cared" about agrichemicals. Farmers most certainly were concerned, but given the pressures of trying to make a living in a low-end global commodity chain, exposure was seen by many as a fact of life. Wealthier farmers, however, almost all paid others to spray for them. Spray crews in the part of the country where I was working were majority indigenous Khmu, newly landless or land poor in a region where landlessness was a new phenomenon, and were broadly stigmatized as lazy, drunk, and addicted. Accidents and poisonings were written off because sprayers were often seen as inherently risky people (Shattuck 2019). Impacts to their bodies were invisibilized in their own communities by the fact of their social marginalization (Shattuck 2019). Even locally, their bodies did not count.

In Xieng Khouang, it was difficult to have a conversation about pesticides without talking about the broader scale agrarian changes that had very recently reordered the relations between upland people and their environments. The area had been a center of opium production under the French. High-value timber and then nontimber forest products were logged out in the early 2000s; opium was completely banned in 2006. The maize boom followed. Maize and herbicides allowed communities to siphon value from the soil fertility left as forests were cleared in the absence of other ways to get cash. The first few years were good; some families even sent their children to college. Average household income in the better-off of my survey villages ten years later, however, amounted to about $1.28 per person per day. Most people were just holding on.

A sprayer I will call Joy exemplifies this contradiction of economic transformation, bodily exposure, and social invisibility. Joy's brother passed away young from liver disease. One day she told me this was because he worked a spray crew and was the first in the village to buy a spray pump; other days she said it was because he had a drinking problem. There was no way to know whether it was either. Joy was also one of the only women who sprayed for a living. Her hard work in a "man's occupation" earned her respect in the village, a place in the local women's union usually reserved for elites, and some crucial financial independence from an alcoholic husband. Exposure helped her create a life worth living for her kids, even if it was a life most likely altered by the chemicals she worked with every day. Murphy's (2017, 497) concept of "alterlives" is particularly apt here. Alterlives "includes being in the mess of consumption, subsistence, and side effect, being in the contradictions of existing in worlds that demand chemical exposures as the conditions for eating, drinking, breathing." Murphy talked about "resurgent life," about making it work through exposure, resisting the label of damaged, still documenting and holding to account actors for the harms of colonial and extractive regimes. Joy—smart, indomitable, fabulous karaoke singer that she is—reminded me of this. Two points are salient here. First, the impact to her body, and to her brother's body, will never be counted. As a marginalized, near-landless farmer, she does not count politically. Second, by accepting exposure as a fact of life, by using such exposure to improve her life, the bodily impact becomes even less visible but no less real than the changes in her economic fortunes. Agrichemicals might have been a positive force in her life for some years, and we can acknowledge this, we can admire her strength and resourcefulness, without letting go of the injustice of an agrarian system in which exposure is a condition for making her way through life.

The entrance of agrichemicals in Xieng Khouang has reconfigured individual health profiles like Joy's in ways that are unpredictable. Agrarian systems, like other environments, can be imagined as emergent ecologies (Murphy 2006) of land, people, agrichemicals, microorganisms (like the liver flukes that cause so much liver disease), access to nutrition, economic resources, and social lives. These factors can interact in ways that manifest differently in different bodies at different times. This points to the benefit of pursuing explanation and problem solving at the scale of emergent properties—an increasingly important concept in health geographies (Senanayake and King 2019). A faithful empirical accounting of impact here requires an approach that acknowledges the political invisibility of the affected bodies and addresses this emergent ecology of exposure as a whole.

Epistemic Emergence and the Politics of Imperceptibility

I was discussing pesticide residue data and government plans to act on them with one of the white development workers involved in the data collection. He was asking me about how they should communicate the results of the urine tests to farmers. I began to explain about the uncertainties inherent in the methods they had used. "Are we ever going to be able to conclude anything? The headline figures are obviously useful for awareness raising and stirring up interest among the donors and policymakers. But we are lucky there is nobody else. … who knows the subject well enough to realize how unreliable all this data really is." (Email communication with NGO worker, Vientiane, Laos: March 31st 2017).

Months later I reminded him about that exchange and asked how civil society is to know that a problem actually exists or how severe it is. He seemed confident that given the data collected by both NGOs and local government, given the consistent picture painted by data from multiple sources including from over the border in Thailand, and given what is visible in the field, that there was certainly evidence of a problem worth solving, even if none of that evidence could stand on its own. The government officials I discussed these data with largely agreed. The blood tests on their own were one thing. Combined with the lab analyses of urine, soil, and water samples; observations of the conditions under which pesticides are used; anecdotes about poisoning deaths that never make it into hospital records, these forms of partial knowledge point in the same direction. Then there are the data from different epistemic starting points: the broader context of agrarian change in the region, stories like Joy's, the social conditions that further invisibilized pesticide applicators, and the overall precarity of the agrarian system. These different epistemic starting points help explain why exposure is both common and locally imperceptible.

The ability to decide what kinds of knowledge count and what constitutes proof is itself a terrain of struggle. As Bourdieu (1975) explained, “The scientific field is the locus of a competitive struggle, in which the specific issue at stake is the monopoly of scientific authority” (19). Paired with data from conventional toxicology and epidemiology studies that predict neurodevelopmental impacts in children exposed to organophosphates and potential adverse birth outcomes for exposed pregnant women, the data my NGO colleagues collected in Laos pose a political question as much as a scientific one. Their combination of traditional methods, like the laboratory urine analyses, with the cheaper test kits, comparison with regional results, and qualitative data about use, exposure, poisonings, and the way in which agrichemicals interact with poverty show that those impacts are likely widespread. Even if they are not reliable enough to pin down the precise magnitude of the problem, the question is how much it matters. If the biomonitoring data on children in Laos are off significantly—say one in five children is exposed at risky levels instead of one in three—how much does that difference matter? Asking such questions points us less to scientific uncertainty and more toward political contestation.

The uneven production of scientific knowledge and the agnogenic nature of agrochemical harms mean that the kind of certainty called for by traditional regulatory science is likely to remain unattainable—especially in places like Laos. The epistemological form in which the problem is defined and argued by such actors is still rooted in the limited vision of early regulatory science when a linear cause and effect could be quantified and environments were imagined as ontologically separate from bodies. As Carolan (2008, 734) noted, “Beyond being an impossible task, the goal of more science in the name of relinquishing uncertainty is also (often) a meaningless one. For such an expectation is based upon the false belief that such debates reside in questions of pure fact, rather than realizing that their roots lie (in most cases at least) within differing value orientations.” Truly comprehensive risk assessment requires both quantitative and qualitative, both standardized and nonstandardized, both seemingly universal and obviously situated forms of data. The question then is this: Taking many forms of evidence together, how much of what kinds of evidence is enough to articulate harm to bodies that are often invisibilized?

Working with uncertainty then requires that we look at many kinds of partial, situated, and imperfect data in relation. Although this kind of triangulation is not standard in regulatory science or the governance of chemicals, different kinds of evidence can “interlock in a manner that makes the whole epistemologically greater than the sum of its parts” (Carolan 2008, 733). This epistemic emergence—using multidisciplinary work and multiple forms of knowledge in relation with established fields to create a way of knowing that is greater than the sum of its parts—could make harms perceptible enough for action. This approach could be a complement to civic science and public epidemiology approaches in that it takes into account the whole emergent ecology in which exposures occur, the nonpredictable ways in which such exposures reconfigure individual health profiles, and how exposure interacts with social lives. Most crucial, epistemic emergence does not rely on moving up from lay to expert methods necessarily, instead asking what forms of knowledge might make harm articulate enough for action in a particular context.

Epistemic emergence as a concept is grounded in the politics of social negotiation, the question of what kind of knowledge might matter to whom, and the acknowledgment of the whole ecology in which exposure becomes a condition for resurgent life. The relationship between knowledge and action is not straightforward. What knowledge (if any) can make harm to marginalized bodies count differs dramatically by context. In this case, the biomonitoring and related data were put to work in multiple ways at different scales: from community education and participatory extension efforts, to discussions with agricultural extension workers about how to transition not to safer pesticide use but to farming systems that required fewer pesticides, development industry efforts to support organics, and regional advocacy aimed at informing governments with more regulatory power and influence over the pesticide industry (in this case Thailand and Vietnam; see Jatiket et al. 2018). In some venues the value of the data was largely discursive, but given the widely recognized unevenness in available resources for toxicology and epidemiology, the data were also the best available in Laos with which to make decisions—and many government officials I interviewed took it quite seriously.

More broadly, greater reliance on epistemic emergence could be one way of articulating the diffuse forms of environmental harm that constitute much of our bodily interactions in an already contaminated world. Instead of the "germ by germ, chemical by chemical" approach of the past (Nash 2008, 557), we might think about the transformative coming together of bodies and environments and socialities that (agri)chemicals allow and what work they do, how they produce different embodiments and subjectivities, to paraphrase Agard-Jones (2013). The previous generation of regulatory science has insisted on an ontological clarity that is no longer adequate—and likely never was. I would argue that we have reached a place in the history of environmental problems where our own commonsense ontologies have been undermined—where the boundaries between bodies and chemicals and environments have blurred to the point that holding actors accountable in the traditional mode is ever less likely. The realities of life in an already contaminated world, like the ubiquity of agrichemical use, require that we rethink the relationships between bodies and ecologies, between people and nature, in nondualist, radically open ways. If we can move away from the chemical as an ontologically separate thing with its own inherent risks to include an assessment of the complex relations between chemicals, bodies, socialities, and environments, we can have a more honest discussion of risk and impact—and articulate that impact in ways that might help bring into being different relations between bodies and environment, people, and land.

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Note

1. The public debates on agrichemicals cover a tiny portion of the more than 10,000 pesticides that are still approved in the United States under "conditional registration"—pesticides for which companies promised to provide missing toxicological and environmental impact data in the 1970s, 1980s, and 1990s but never did (Iles 2018). Although these might (or might not) be adequately tested individually, they are seldom tested in terms of their "cocktail effect" (Meeker, Sathyanarayana, and Swan 2009).
2. Although the Agricultural Cohort Study has not found evidence to support a link between non-Hodgkin's lymphoma and glyphosate, other epidemiological studies have (Eriksson et al. 2008; Schinasi and Leon 2014).
3. I calculated this number based on the total pesticide use the Lao Ministry of Agriculture reported to the UN Food and Agriculture Organization (UNFAO) for 2006—4.3metric tons (FAOSTAT 2019). The 2016 figure at the time of writing had not been reported to the UNFAO. I used the figure (136.247 metric tons) given in a public presentation by the director of the Regulatory Division for the Department of Agriculture (Souvandoune 2017).
4. The group chose to focus on organophosphates and carbamates because of their ubiquity and their relative technical legibility. Carbamates and organophosphates act on the nervous system and can be detected by the activity of the enzyme cholinesterase, which carries signals across nerve endings. Common herbicides, however, have no such inexpensive way of measuring their mark on the body in low doses.
5. I was not present to observe these tests and did not conduct or directly observe any biomonitoring with human subjects or collect data in schools directly. I interviewed practitioners about the process of testing and participated in public government and community meetings where the data were discussed. Data stripped of personally identifiable information that were gathered through these awareness-raising activities were shared with me after the fact.
6. Glyphosate is currently the subject of intense scientific controversy after the International Agency for Cancer Research declared it a likely carcinogen and the State of California followed suit. The European Union and the U.S. Environmental Protection Agency have reached opposite conclusions.

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