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Harm Hides Where Measurement Ends

Why no clear evidence is not the same as no harm, and how measuring the tail would settle the pesticide paradox

VIJAY RAMPRASAD RAO, PHD · TAILENDERS ANALYTICS

FOR REGULATORS, PUBLIC-HEALTH AGENCIES, FOOD AND AGRICULTURE COMPANIES, FARMWORKER AND FARMER ORGANISATIONS, JOURNALISTS AND SCHOLARS

ABSTRACT

Are pesticides harming us? If they are, why can the evidence not say so clearly? Most people are certain of the harm; regulators in the United States, the European Union and the WHO/FAO system keep concluding that typical exposures are safe. This working paper argues that both are right about different people. At the dietary exposures most people carry, residues sit far below reference doses and the largest cohorts find little or no excess risk. At the tail of the exposure distribution (applicators and hired sprayers, women who mix concentrate, children exposed in the womb, carriers of slow-metabolising genotypes, and people in crisis with a lethal bottle within reach) harm is real, often large, and systematically under-measured. 'No clear evidence' is what four filters produce when they average that tail into a population mean: studies that would see chronic, mixture and occupational harm are not done; every common error in the studies that are done pulls results toward no effect (in the Agricultural Health Study's own validation data, a true tripling of risk appears as 1.1 to 1.9); regulators decide on data the registrant generates, some of it never disclosed; and where independent evidence emerged, doubt was manufactured. The filters are thickest where exposure is highest: the United States measures bodies, food and water nationally, India measures food and deaths, Uganda measures none of the three, and none of the three measures farmworkers at national scale. Where measurement was built, harm was found; where the most toxic products were restricted, lives were saved, with 19,769 fewer suicides in Sri Lanka over the decade after its 1995 to 1998 bans and no measurable loss of yield. No clear evidence is not the same as no harm. It is a statement about where we have chosen not to look.

KEYWORDS

pesticides; evidence; regulation; undone science; measurement error; farmworkers; tail-end; glyphosate; paraquat; chlorpyrifos; suicide; India; United States; Uganda; Tailwinds

COMPANION PAGE

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Argument

Are pesticides harming us? If they are, why can the evidence not say so clearly? These are the two questions people ask, and the formal answer, that there is no clear evidence of harm at typical exposures, satisfies almost no one. It should not. The answer is accurate about the plate and wrong about the tail.

The paradox is genuine because both sides stand on evidence. Glyphosate sits in IARC's Group 2A as probably carcinogenic to humans (Guyton et al. 2015). Paraquat is associated with Parkinson's disease in occupational users at odds of about 2.5 (Tanner et al. 2011). Pesticides are among the leading means of suicide in the world (Mew et al. 2017). Yet regulators conclude that typical exposures are safe, residue monitoring finds almost every food sample within legal limits, and the largest cohort of exposed applicators found no significant cancer excess for glyphosate at any site (Andreotti et al. 2018).

This paper makes three claims. First, 'clear evidence' is the output of an evidence system, and that system is built to miss harm at the tail: four filters, structural, methodological, institutional and strategic, each push findings toward no effect. Second, the filters are thickest exactly where exposure is highest, so the evidence gap sits where the burden sits. Third, the paradox dissolves into two claims that are both true: at typical dietary exposure harm is small or undetectable with current tools, and at the tail it is real, large and under-measured. Where measurement was built, harm was found. Where restriction was tried, lives were saved.

1

Four filters turn real harm into 'no clear evidence'

Each filter would produce some false reassurance on its own. Stacked, they make a strong one. None requires a conspiracy, and the first three would operate even if every firm behaved impeccably.

FILTER	WHAT IT DOES	ANCHOR FIGURE	DIRECTION
Structural	The studies that would detect chronic, low-dose, mixture and occupational harm are not funded or designed	Sub-Saharan Africa: 38% of 391 pesticide studies examined people	Absence of study read as absence of harm
Methodological	Exposure error, single biomarkers, healthy workers, latency, mixtures, averaging over susceptible groups	A true relative risk of 3.0 observed as 1.1 to 1.9	Toward no effect
Institutional	Registrant data, secrecy, non-disclosure, removal by consent	Registrant studies 99% negative; published studies 70% positive	Toward the registrant's reading
Strategic	Ghostwriting and demands for unattainable certainty	A glyphosate safety review retracted after 25 years	Doubt sustained where evidence emerged

Structural: the studies that would find chronic harm are not done. Frickel and colleagues name this undone science: research left unfunded, incomplete or ignored that civil society identifies as worth doing (Frickel et al. 2010). Standard guideline tests dose animals near toxic levels and do not test latency; risk is assessed one chemical at a time, although combinations each below its own no-effect level can act together (Kortenkamp et al. 2007). Human studies are thinnest where exposure is highest: of 391 pesticide studies in 37 sub-Saharan African countries from 2006 to 2021, only 38 percent examined people, and few followed them over time or measured biomarkers (Fuhrimann et al. 2022). For most pesticides in most places, 'no clear evidence' literally means no study.

Methodological: every common error pulls toward the null. Random error in measuring exposure weakens estimated effects. The Agricultural Health Study measured how much: using its own validation data, a true relative risk of 3.0 appears as 1.1 to 1.9, and a true 2.0 never appears above 1.4. The authors concluded that 'false negative findings might be common' (Blair et al. 2011). A single urine sample for a pesticide that clears in hours ranks children poorly: day-to-day variation within a child is 2 to 11 times the variation between children (Bradman et al. 2013; Attfield et al. 2014), and one sample can shrink an effect estimate by 40 to 80 percent (Perrier et al. 2016). Farmers are healthier than the general population, which hides what pesticides take from them: applicators in the Agricultural Health Study died at about half the general rate (Waggoner et al. 2011). Harm often arrives late: daughters whose mothers carried high levels of DDT during pregnancy had 3.7 times the odds of breast cancer, a finding that took 54 years of follow-up to see (Cohn et al. 2015).

Institutional: the registrant writes the record the regulator reads. For glyphosate genotoxicity, the US EPA relied mostly on registrant studies, 99 percent of them negative, while IARC relied mostly on published studies, 70 percent of them positive (Benbrook 2019). Of 35 developmental neurotoxicity studies submitted to the EPA that had corresponding EU dossiers, 9 were not disclosed to EU authorities (Mie and Rudén 2023), and raw industry data for chlorpyrifos showed brain changes at every dose tested that the study summary did not report (Mie et al. 2018). In the United States, removal in practice requires the registrant's consent: the EPA has all but stopped using non-voluntary

cancellation, and the country approves 72 agricultural pesticides banned or being phased out in the European Union, which accounted for 26.9 percent of US agricultural pesticide use in 2016 (Donley 2019). Continued registration is therefore weak evidence of safety.

Strategic: doubt was manufactured where evidence emerged. Michaels named the product-defence industry (Michaels and Jones 2005); Freudenburg and colleagues named the demand for unattainable certainty before action (Freudenburg et al. 2008). The clearest pesticide case is a glyphosate safety review published in 2000 and cited hundreds of times, retracted in late 2025 for undisclosed authorship by Monsanto employees (Williams, Kroes and Munro 2000, retracted; Kaurov and Oreskes 2025). The retraction is contested, and it concerns how the evidence base was built, not whether glyphosate causes cancer. What it shows is that a document authored by the party with most at stake sat in the safety literature for 25 years.

2

The evidence gap sits where the burden sits

The four filters are thickest where exposure is highest. The systems that turn illness into data (registries, workers' compensation, toxicology laboratories, biomonitoring and accurate use statistics) are concentrated where exposure is lower.

	BODIES	FOOD	WATER	POISONING DEATHS	FARMWORKERS
United States	National biomonitoring	National monitoring	National monitoring	Not reviewed	Not designed for at national scale
India	No national programme found	National residue monitoring	Site studies	National, by method; not by occupation	Not measured nationally
Uganda	Site studies	No national system found	None found	Hospital studies	Not measured nationally

Where someone built an instrument, it found what had not been counted. Community surveys across six Central American countries implied that 98 percent of pesticide poisonings went unreported, and that 76 percent of them were work-related (Murray et al. 2002). A season-long diary study in Andhra Pradesh cotton villages recorded poisoning signs in 83.6 percent of exposure events; in the most serious episodes, no one sought medical care, and women's mixing and refilling were as hazardous as spraying (Mancini et al. 2005). In five Kampala hospitals, 91.2 percent of pesticide poisoning diagnoses rested on the patient's history alone (Ssemugabo et al. 2017). In US states with surveillance, poisoning rates among farmworkers ran an order of magnitude above other workers, and women farmworkers were poisoned at almost twice the rate of men (Calvert et al. 2008).

India's official record shows the gap in its structure. The National Crime Records Bureau counts suicides by insecticide (25,770 in 2023, 15.0 percent of all suicides; National Crime Records Bureau 2025) but does not record method against occupation, so the deaths of farmers and hired sprayers by pesticide cannot be read from the official series. Absence of evidence in these settings is weak evidence of absence, because each missing instrument removes precisely the high-exposure cases.

3

The best case for small risk, and what it concedes

The opposing resolution deserves its full weight, because much of it is correct. Dietary intakes sit far below reference doses: for the residues most often found on the 'Dirty Dozen' fruits and vegetables, all 120 exposure estimates fell well below chronic reference doses, and three-quarters were under 0.01 percent of them (Winter and Katz 2011). The largest organic-diet cohort, 623,080 women followed for 9.3 years, found no lower overall cancer risk among those who usually or always ate organic food (relative risk 1.03; Bradbury et al. 2014). The most heavily exposed cohort found no significant cancer excess for glyphosate (Andreotti et al. 2018). And risk-perception research shows that lay judgement tracks dread and unfamiliarity more than dose, so intuition would run hot whether or not harm exists (Saleh, Bearth and Siegrist 2019).

The concessions are as large as the case. Pesticide self-poisoning kills about 110,000 to 168,000 people a year, 14 to 20 percent of suicides worldwide (Mew et al. 2017). Restricting the most lethal products saves lives without loss of yield: Sri Lanka's bans of the most toxic pesticides in 1995 and 1998 were followed by 19,769 fewer suicides over the next decade (Gunnell et al. 2007), with no measurable fall in productivity (Manuweera et al. 2008). Regulators themselves revoked or let lapse specific molecules, such as chlorpyrifos, on neurodevelopmental grounds. A meta-analysis restricted to the highest-exposure groups found a non-Hodgkin lymphoma relative risk of 1.41 for glyphosate (Zhang et al. 2019), which even defenders read as an occupational signal. And Sri Lanka's 2021 collapse, often cited against restriction, was mainly a fertiliser story: no supply of organic inputs could replace the nitrogen withdrawn (Drechsel et al. 2025).

4

Two claims, both true

At typical dietary exposure, harm is small or undetectable with current tools. This does not prove zero effect: mixtures, non-monotonic dose responses and very small relative risks remain open. But a person eating conventionally grown food is not, on present evidence, taking a large risk, and the intuition that every residue is a poison overstates it.

At the tail, harm is real, large and systematically under-measured. Children of mothers in the highest fifth of prenatal organophosphate exposure in a California farmworker cohort scored 7.0 IQ points lower than those in the lowest fifth (Bouchard et al. 2011). Carriers of a slow-metabolising PON1 variant exposed to organophosphates had more than twice the odds of Parkinson's disease, and more than five times among those diagnosed at 60 or younger (Manthripragada et al. 2010). These subgroup estimates are individually imprecise and should be read as replicated and suggestive, not settled. What is settled is the pattern.

INSTRUMENT BUILT	WHAT IT FOUND
Community surveys, Central America	98% of poisonings unreported; 76% work-related
Season-long diaries, Indian cotton villages	Poisoning signs in 83.6% of exposures; no care sought for the most serious
Clinically confirmed cases nested in the Agricultural Health Study	Paraquat and Parkinson's, odds 2.5, where self-report showed nothing
Archived pregnancy blood, 54-year follow-up	In-utero DDT and daughters' breast cancer, odds 3.7
Farmworker birth cohort with repeated measures	7 IQ points between highest and lowest exposure fifths
Raw registrant data, reanalysed	Brain changes at every chlorpyrifos dose, missing from summaries
State surveillance, California and other US states	Farmworker poisoning an order of magnitude above other workers

How a tripled risk disappears. The following arithmetic is illustrative, not a published estimate. Suppose one person in ten carries an exposure or genotype that triples the risk of a disease, and the other nine carry no excess. Averaged across all ten, the relative risk is 1.2. Exposure error of the kind the Agricultural Health Study measured then shrinks that 1.2 to about 1.08, a signal that needs roughly 225 times the sample required to see the tripling in the susceptible tenth directly. A real tripling of risk becomes an invisible 8 percent excess, and the published finding reads 'no clear evidence of harm'. This is the argument of *The tail inside the average* (Ramprasad 2026) applied to toxicology: an average is a statement about nobody in particular, and the people it misrepresents most are the people at the tail.

5

What would settle it

The methods literature points to designs that each answer one filter: repeated or pooled biomarkers with a calibration substudy; exposure built from use records and maps rather than recall; nested studies with clinically confirmed outcomes; archived samples from pregnancy and childhood followed for decades; susceptible groups specified before analysis; statistics built for mixtures; and natural experiments around bans, which so far have been applied to suicide but not to chronic outcomes such as Parkinson's disease or children's IQ. Long-term cohorts in high-exposure settings in South Asia and sub-Saharan Africa are largely missing, though that is where the contrasts are widest.

Three steps follow for the institutions that govern pesticides. First, report harm as a distribution with a named tail, not as a population average, and label every blank cell as a measurement gap, not an absence of harm. Second, hold each law to its own words. The US federal pesticide law weighs 'unreasonable adverse effects on the environment' against benefits; India's Insecticides Act, 1968 exists 'to prevent risk to human beings or animals'; each names a people its records cannot see, because no occupation-by-method poisoning series exists in India and no national biomonitoring is designed for migrant and seasonal farmworkers in the United States. Third, measure the tail directly: confidential, sampled verification of exposure among sprayers and their families, reported only in aggregate, would do for pesticide burden what Sri Lanka's bans did for pesticide deaths. It would make the harm countable.

What would overturn this argument is stated in advance: a well-measured, repeated-biomarker cohort of high-exposure applicators and their children, in a high-use setting, that finds no excess in neurological, developmental or cancer outcomes; or ban-based natural experiments showing no change in chronic outcomes after the removal of the most hazardous products.

Confidentiality, privacy and data sharing

This paper synthesises published studies, official statistics and public records. It uses no data on identifiable persons. When Tailenders Analytics measures exposure for a client, it follows the Tailenders Privacy and Confidentiality Policy and the Tail-End Protocol: consent in the respondent's language, identifiers held apart from responses, results reported only in aggregate, and findings that travel toward the people measured, never against them.

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Limits

This is a synthesis, not a new study, and its sources vary in quality. Several subgroup findings rest on small numbers. The worked illustration depends on stated assumptions (a rare outcome, equal baseline risks, non-differential error) and is a demonstration of mechanism, not an estimate. Suicide-reduction evidence comes from ecological designs, and part of it may be offset by substitution of other methods. Some regulatory statuses change quickly; those stated here are as of 15 October 2026. The widely quoted estimate of 385 million unintentional poisonings a year is not used: the paper it came from was retracted in 2024, and no peer-reviewed estimate has replaced it.

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