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# Risk Behaviors During Pesticide Application: An Observational Study Among Cotton Farmers in Côte d'Ivoire

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**Abstract**

*Risk behaviors during pesticide application remain insufficiently documented through direct observation in African cotton-farming settings. In the sub-prefecture of Toumoukoro (northern Côte d'Ivoire), cotton production involves 19,562 registered producers who routinely handle organophosphates and pyrethroids. Most available studies rely on self-reported data, which introduces a social desirability bias that overestimates protective behaviors and underestimates actual risk practices. This study aimed to describe and quantify risk behaviors observed during pesticide application, to test their association with three individual determinants — received training, educational level, and duration of exposure — and to compare observed results with self-reported data to document the declarative-behavioral gap. A non-participant observational study was conducted with a purposive sub-sample of 68 cotton producers (22% of a quantitative survey of N = 315) across 13 villages. Each session covered the full application cycle (3 to 5 hours), coded in real time on a standardized eight-section grid. Fisher's exact tests, relative risks (RR), and phi coefficients were used, triangulated with questionnaire data. Results showed that 73.5% of producers mixed pesticides with bare hands, 100% did not wash after application, and 0% wore boots or full-body protective clothing. Training received by 87% of producers produced no measurable behavioral effect ($p = 1.000$ for each PPE item; RR = 0.92 to 1.00). The only statistically significant determinant was exposure duration: 100% of producers exposed for ≥ 4 hours wore no gloves (RR = 1.78, $p < 0.001$). Risk behaviors are near-universal, homogeneous, and driven by structural determinants — economic barriers to PPE access and community norms of indifference — which training alone cannot correct. Simultaneous interventions targeting PPE economic accessibility and community-level normative change are essential.*

**Keywords:** *Cotton Farming, Côte d'Ivoire, Direct Observation, Occupational Health, Pesticides, Personal Protective Equipment, Risk Behaviors.*

## Introduction

Cotton farming in Côte d'Ivoire occupies a central position in the national agricultural economy, particularly in the northern regions where it represents the primary cash crop for smallholder households [1]. The country ranks among the leading cotton producers in West Africa, with over 132,000 registered growers cultivating approximately 444,870 hectares [2]. In the sub-prefecture of Toumoukoro (Ouangolodougou department, Tchologo region), the cotton sector involves 19,562 registered producers almost all of whom use WHO Class II organophosphates and pyrethroids for crop protection [2]. These molecules — including profenofos, chlorpyrifos, and cypermethrin — are

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neurotoxic compounds whose repeated dermal, respiratory, and oral absorption during application constitutes a well-documented occupational health risk [2, 23]. Acute effects include acetylcholinesterase inhibition, bronchospasm, and cholinergic syndrome; chronic effects encompass neurobehavioral disorders, reproductive toxicity, and carcinogenesis [11, 24].

Despite the documented toxicological profile of these substances, behavioral practices during field application remain insufficiently characterized through direct observation in Ivorian and broader West African cotton-farming settings. Most available African studies on pesticide exposure rely on self-reported data collected through structured questionnaires [3, 4, 6, 7, 25]. This approach, while operationally efficient, is structurally limited by social desirability bias — a systematic distortion whereby respondents adjust their declarations toward what they perceive as normatively expected, typically overestimating protective behaviors and underestimating risk practices [19, 26]. The magnitude of this bias has rarely been quantified through concurrent direct observation in the same study population, leaving the true extent of behavioral risk poorly understood and program evaluations potentially misleading [5, 27].

Non-participant direct observation, conducted in the natural work environment over the full duration of pesticide application sessions, addresses this methodological limitation [35]. Unlike self-report data, behavioral observation captures practices as they actually unfold, independently of producers' awareness or stated intentions [5, 14]. This approach is recommended by the international public health literature for characterizing occupational exposure in agricultural settings where literacy, linguistic barriers, and social pressure may compromise the reliability of declarations [11, 15, 28]. The WHO has repeatedly emphasized that direct field assessment is essential for evidence-based occupational pesticide risk management in low- and middle-income countries [8, 29].

In sub-Saharan Africa, the structural determinants of pesticide risk exposure among smallholder farmers have been extensively discussed [38]. Studies in Benin [3], Malawi [4], Ethiopia [5], Burkina Faso [6], and Côte d'Ivoire [7, 12] converge on several common findings: the vast majority of farmers handle pesticides without adequate personal protective equipment (PPE) [39]; the cost of equipment is consistently identified as the dominant access barrier [8, 31]; and training programs, while widespread, produce no measurable effect on field protective behaviors [3, 6, 32]. [3] reported that 85% of cotton farmers in Benin exceeded recommended pesticide doses without wearing protection, a pattern strikingly similar to what was anticipated in Toumoukoro. [7] documented that cotton farmers in Côte d'Ivoire showed high symptom prevalence despite awareness of pesticide risks, pointing to the insufficiency of knowledge-based interventions alone. Similarly, [8] found in Burkina Faso that 91% of cotton producers never wore gloves during application despite a majority having received safety training. In a systematic review covering 42 African studies, [9] confirmed that PPE non-use rates above 80% are characteristic of smallholder cotton production across the continent, irrespective of training coverage.

The health consequences of these behavioral patterns are well-documented. Pesticide intoxications are responsible for an estimated 385 million cases of acute poisoning globally each year, with 99% occurring in low- and middle-income countries [10]. In West Africa, [11] documented acute intoxication symptoms — including nausea, dizziness, skin irritation, and respiratory distress — in cotton farmers following pesticide application, while [12] demonstrated epidemiological associations between organophosphate exposure and non-Hodgkin lymphoma, brain cancer, and adverse reproductive outcomes. The burden of chronic exposure is further amplified by the absence of post-application decontamination practices [13] and the co-occurrence of tobacco smoking during spraying [2, 16], which combines bronchopulmonary and cholinergic toxicity pathways synergistically.

The theoretical framework of this study mobilizes two complementary models. the theory of social representations [14] explains how community-level beliefs — such as the perception that pesticides are ‘dangerous but necessary’ — neutralize individual preventive intentions by embedding risk within a culturally legitimized narrative of agricultural productivity. the theory of planned behavior [15] further elucidates how the gap between intention and action arises when structural constraints (economic inaccessibility of PPE, absence of community protective norms) override individual motivation. Together, these frameworks predict that risk behaviors will be independent of cognitive variables such as training and educational level, and primarily driven by structural and normative determinants — a hypothesis this study is designed to test through direct observation.

This study is part of a broader mixed-methods doctoral research design combining a structured questionnaire administered to a representative sample of 315 producers and direct non-participant observation of a purposive sub-sample of 68 producers. Its specific objectives are: (1) to describe and quantify risk behaviors observed during pesticide application; (2) to test the association between these behaviors and three individual determinants — received training, educational level, and duration of exposure; and (3) to compare observed results with self-reported questionnaire data to document and quantify the declarative-behavioral gap. The study contributes to a growing body of evidence demonstrating that observational methods are indispensable for capturing the true extent of occupational pesticide exposure in agricultural settings where self-report data are structurally unreliable [5, 11, 14, 27].

## Materials and Methods

### Study Setting and Population

The study was conducted in July and August 2024 in the sub-prefecture of Toumoukoro, an intensive cotton-producing zone in northern Côte d’Ivoire, comprising 13 villages with a total population of 44,372 inhabitants distributed across 4,959 households. The sub-prefecture borders Mali and Burkina Faso, making it a transboundary zone exposed to informal circulation of unregistered pesticides [13, 33]. The target population consisted of active cotton producers registered in the village cotton producer groups (GVC), estimated at 19,562 individuals [2].

### Methodological Approach

Direct observation was applied to a purposive sub-sample of 68 producers drawn from the quantitative survey sample of 315, representing 21.6% of that total. Sub-sample constitution followed two complementary criteria: geographic representativeness (proportional distribution across all 13 villages) and data saturation, defined as the point beyond which new observation sessions yielded no analytically novel behavioral information [16]. Producers were selected independently of their training status or educational level, to avoid selection bias.

### Observation Protocol

Each observation session covered the full pesticide application cycle, from insecticide mixture preparation through empty container disposal and product storage, lasting three to five hours per session. The observer adopted a strictly non-participant stance to minimize the Hawthorne effect [17]. The extended duration of sessions facilitated the attenuation of this effect by allowing producers to revert to their habitual behaviors. Behaviors were coded in real time on a standardized eight-section grid covering: personal protective equipment worn, preparation procedures, spraying techniques, post-application hygiene, empty container management, storage conditions, environmental risks, and a behavioral summary.

### Variables and Statistical Analyses

Three categories of determinants were tested: (a) specific pesticide training received (yes/no, self-reported); (b) educational level (none, primary, secondary); (c) duration of exposure during the observed session (short < 4h vs. long ≥ 4h). Observed behaviors were analyzed using Fisher's exact tests for contingency tables, with calculation of relative risks (RR). The phi coefficient was used to measure effect size for binary associations. 95% confidence intervals were calculated using the Wilson method. The significance threshold was set at $p < 0.05$.

### Ethical Considerations

Informed consent was obtained from each participant prior to observation. Participant anonymity is guaranteed through individual coding. The necessary administrative authorizations were obtained from the Sub-Prefecture of Toumoukoro and the relevant local authorities. All procedures were conducted in accordance with the Declaration of Helsinki. No personal identifying data were retained in the research database.

## Results

### Characteristics of the Observed Sub-Sample

The sub-sample is exclusively male (100%), consistent with the gender structure of cotton farming in the region [11], with a mean age of 40.5 ± 14.2 years (median: 39.5; Q1 = 29.5; Q3 = 49.5). 72% of producers have no formal education (Table 1). 87% received specific pesticide training provided by Ivoire Coton. Exposure duration during observed sessions exceeded four hours for 53% of producers, constituting the maximum-risk group.

**Table 1.** Socio-demographic and Exposure Characteristics of Observed Producers n = 68

| Variable | N | Value / % | Analytical note |
|---|---|---|---|
| Mean age | 68 | 40.5 ± 14.2 years | Q1=29.5 Median=39.5 Q3=49.5 |
| Male sex | 68 | 100.0% | Exclusively male |
| No formal education | 49 | 72.0% | Majority without formal schooling |
| Primary education | 14 | 21.0% | — |
| Secondary education | 5 | 7.0% | — |
| Specific pesticide training (yes) | 59 | 87.0% | Central paradox of the study |
| Exposure duration ≥ 4h | 36 | 53.0% | Maximum-risk group |
| Exposure duration 3–4h | 21 | 31.0% | — |
| Exposure duration 2–3h | 9 | 13.0% | — |
| Exposure duration 1–2h | 2 | 3.0% | — |
| Geographic distribution | 68 | 13 villages | Multi-site representativeness |
| *95% CI: Wilson method. Binomial test vs $H_0$ = 50%.* | | | |

## Observed Personal Protective Equipment Use

The respiratory mask was the only PPE item worn by a majority of producers (77.9%, n = 53). Gloves were observed in only 20.6% of producers (n = 14), and protective goggles in 32.4% (n = 22). No producer wore boots or full-body protective clothing (0%, n = 0 in both cases). This finding, consistent across all 13 villages and all producer profiles, reflects a structural barrier rather than a knowledge or motivation deficit [8, 31]. The Training × PPE cross-tabulation is presented in Table 2. For all five equipment items tested, Fisher's exact tests return p = 1.000, with RR values ranging from 0.92 to 1.00, indicating that training produces no measurable differential effect on PPE use.

**Table 2.** Observed Personal Protective Equipment Use n = 68 and Training × PPE Cross-Tabulation

| PPE observed | N worn | % | p-value (Fisher) | Interpretation |
|---|---|---|---|---|
| Respiratory mask | 53 | 77.9% | 1.000 ns | Local practical norm, independent of training |
| Protective goggles | 22 | 32.4% | 1.000 ns | RR trained/untrained = 0.97 |
| Gloves | 14 | 20.6% | 1.000 ns | Skin protection absent in 4/5 producers |
| Boots / closed footwear | 0 | 0.0% | — | Total absence — structural barrier |
| Full-body protective clothing | 0 | 0.0% | — | Total absence — structural barrier |
| *All Fisher's exact tests return p = 1.000 ns (trained n=59, untrained n=9). RR = 0.92 to 1.00 for each PPE item. ns = not significant.* | | | | |

## Risk Behaviors Observed During Application

### Mixture Preparation

73.5% of observed producers (n = 50) mixed the pesticide directly with their bare hands, making this the most frequent risk behavior documented in the study. Label reading before preparation was performed by only 20.6% of producers (n = 14), independent of educational level (Table 4). This finding is consistent with results from Côte d'Ivoire [4, 7] and Benin [3], where manual pesticide mixing without protection was the dominant practice.

### Application and During-Exposure Behaviors

58.8% of producers smoked during spraying (n = 40). Between 37.5% and 44.4% consumed food or beverages during application depending on exposure duration. Between 34.4% and 38.9% directed the sprayer toward their own body during turns. These behaviors amplify oral and dermal absorption pathways simultaneously [11, 17].

### Post-Application Hygiene

100% of observed producers (n = 68) did not wash their bodies after spraying, without a single documented exception. In exposures lasting ≥ 4 hours, where dermal pesticide loading is at its maximum, the absence of decontamination extends and amplifies residual cutaneous absorption [17, 37].

### Empty Container Management

42.6% of producers burned empty containers on site and 36.8% abandoned them in the field. No producer returned containers to an organized collection point. The phi correlation between burning and abandonment was positive and significant (phi = 0.268, p < 0.05), indicating co-occurrence of these two environmentally risky practices among the same individuals, consistent with findings from West African cotton contexts [6, 13, 33].

## Determinants of Risk Behaviors

### Received Training: Total Dissociation from Observed Behaviors

Despite 87% of producers being trained, the Training × risk behaviors cross-tabulation revealed no significant difference (Fisher p = 1.000 for each PPE item). The RR trained/untrained for bare-hands mixing was 0.99, for glove-wearing 0.92, and for goggles 0.97. These data empirically document a social desirability bias in questionnaire self-reports, where trained producers declared wearing PPE at a rate of 55.1% compared to 38.5% for untrained producers (OR = 1.96, p = 0.005).

### Educational Level: No Gradient on Protective Behaviors

Table 4 presents practices by educational level. None of the five tested practices showed a significant difference across the three groups (p ∈ [0.870; 1.000]). The most counter-intuitive finding is the rate of bare-hands mixing: 73% among non-educated, 71% among primary-educated, and 80% among secondary-educated producers (p ≈ 0.900). Secondary-educated producers showed the highest rate of risk behaviors, suggesting a cognitive overconfidence effect linked to greater product familiarity [18, 32].

**Table 3.** Risk Behaviors by Duration of Pesticide Exposure — Fisher's Exact Test n = 68.

| Observed behavior | Short < 4h (n=32, 47%) | Long ≥ 4h (n=36, 53%) | p-value | RR |
|---|---|---|---|---|
| Mixing with bare hands | 68.8% (22/32) | 77.8% (28/36) | 0.400 | 1.13 |
| No gloves worn | 56.3% (18/32) | 100% (36/36) | < 0.001 *** | 1.78 |
| Smoking during spraying | 53.1% (17/32) | 63.9% (23/36) | 0.368 | 1.20 |
| Food / beverage consumption | 37.5% (12/32) | 44.4% (16/36) | 0.561 | 1.19 |
| Sprayer directed toward body | 34.4% (11/32) | 38.9% (14/36) | 0.700 | 1.13 |
| No body wash after application | 100% (32/32) | 100% (36/36) | — (no variance) | — |
| Burning of empty containers | 37.5% (12/32) | 47.2% (17/36) | 0.418 | 1.26 |
| Abandoning containers in field | 34.4% (11/32) | 38.9% (14/36) | 0.700 | 1.13 |

**** p < 0.001. RR = relative risk (long / short). Absence of variance for body washing renders the test inapplicable.*

**Table 4.** Application Practices by Educational Level — Fisher's Exact Test n = 68.

| Observed variable | None (n≈49, 72%) | Primary (n≈14, 21%) | Secondary (n≈5, 7%) | p-value |
|---|---|---|---|---|
| Label reading before preparation | 20% (~10/49) | 21% (~3/14) | 20% (~1/5) | ~1.000 |
| Mixing with bare hands | 73% (~36/49) | 71% (~10/14) | 80% (~4/5) | ~0.900 |
| Use of measuring container | 69% (~34/49) | 71% (~10/14) | 60% (~3/5) | ~0.870 |
| Gloves worn | 20% (~10/49) | 21% (~3/14) | 20% (~1/5) | ~1.000 |
| Storage in separate room | 53% (~26/49) | 50% (~7/14) | 60% (~3/5) | ~0.930 |

*No statistically significant difference (p ∈ [0.870; 1.000]) between educational groups. Estimated cell counts (~) based on reported percentages. ns = not significant.*

### Exposure Duration: The Only Statistically Significant Determinant

Table 3 contrasts the short-exposure group (< 4h, n = 32) with the long-exposure group (≥ 4h, n = 36). The only behavior reaching statistical significance was absence of gloves: 56.3% in the short group versus 100% in the long group (RR = 1.78, p < 0.001). The producers with the longest exposure — and therefore the greatest cumulative dermal absorption risk — are precisely those who wear no cutaneous protection [17, 37]. All seven remaining behaviors showed RR values consistently above 1.00 in the long-exposure group (RR = 1.13 to 1.26), none reaching significance individually due to limited sample sizes, but their perfect directional consistency constitutes an important analytical signal.

## Discussion

### Direct Observation Reveals a Large Social Desirability Bias

The dissociation between declarative and observed data constitutes the most original methodological contribution of this study. In the questionnaire phase, 55.1% of trained producers declared wearing PPE compared to 38.5% of untrained producers (OR = 1.96, p = 0.005), a difference that would suggest training produces a meaningful behavioral effect. Direct observation completely invalidates this apparent effect: Fisher p = 1.000 for each of the five PPE items tested, with RR values from 0.92 to 1.00. The discrepancy reflects the social desirability mechanism described by [18], in which trained respondents — having been explicitly instructed on protective behaviors — are more likely to report those behaviors regardless of actual practice. [19] established that this bias is particularly pronounced in surveys on safety compliance, where perceived social expectations are strong and the gap between reported and actual behavior can exceed 30 percentage points.

This finding extends and quantifies prior observations in the literature. [20] in Kinshasa documented that knowledge of pesticide risks was associated with better declared practices but not with observable field behaviors. [5] in Ethiopia found that applicators with higher knowledge scores had comparable symptom rates to less knowledgeable counterparts. [8] similarly showed in Burkina Faso that declared glove use was three times higher than observed glove use in the same population. The originality of the present study lies in its concurrent design: questionnaire and observation data were collected in the same population during the same field campaign, allowing a direct statistical quantification of the declarative-behavioral gap (OR = 1.96 declared vs. RR = 1.00 observed). This methodological contribution is consistent with the call by [21] for triangulated mixed-methods designs in occupational pesticide research.

From a public health surveillance standpoint, these results carry significant implications. Studies relying exclusively on self-reported PPE use in populations where training has been delivered will systematically overestimate the prevalence of protective behaviors. Prevalence estimates derived from such studies — frequently used to guide resource allocation and program evaluation — may therefore substantially misrepresent the actual exposure burden. [22] and the WHO Global Plan of Action on Workers' Health [23] both recommend that direct observation or biological monitoring should be incorporated as standard components of pesticide exposure assessment in cotton-farming populations.

### Risk Behaviors Are Structural, Not Cognitive

The absence of an educational gradient on protective practices (p ∈ [0.870; 1.000]) and the complete dissociation between received training and observed behaviors converge to establish a central conclusion: risk behaviors during pesticide application do not result from a knowledge deficit, but from a structural obstacle. This finding is theoretically consistent with the planned behavior model [15], which predicts that even when an individual has acquired knowledge and holds a positive attitude toward protection, behavioral control — defined here by economic access to PPE — is the binding constraint that determines actual conduct. the concept of structural self-efficacy [24] further specifies that when external barriers are perceived as insurmountable, behavioral intention — however well-formed — fails to translate into action.

The analytical distinction between cognitive and structural tasks is critical. In the questionnaire data, educational level exerts a significant dose-dependent effect on cognitive tasks such as label reading ($\chi^2 = 119.91$, $p < 0.001$; V de Cramér = 0.617) and dose compliance ($\chi^2 = 18.72$, $p < 0.001$). By contrast, for structural tasks such as PPE use, where performance depends on purchasing power rather than cognitive capacity, educational level has no measurable effect ($p = 1.000$ for gloves). This bifurcation supports the framework proposed by [25]: interventions targeting cognition will be effective for tasks that are cognitively mediated, and ineffective for tasks that are economically mediated.

The economic barrier to PPE access is empirically massive in this population. In the questionnaire phase, 89.2% of producers reported no easy access to PPE, with 90.7% citing cost as the primary reason (OR cost/unavailability = 100.4, $p < 0.001$). The observation data confirm this barrier structurally: 0% of 68 producers wore boots or full-body protective clothing across all 13 villages. These results align with consistent findings from [4] in Malawi, [26] in Côte d'Ivoire, FAO global assessments [27], and [8] in Burkina Faso, all identifying cost as the primary barrier to PPE adoption in smallholder contexts. [9] estimated in their systematic review that subsidy programs reducing PPE cost by 70% increased adoption rates by a factor of 4.2 in comparable West African settings.

The community normative dimension reinforces this structural analysis. In the questionnaire data, 87.6% of producers perceived their community as having normalized pesticide use without protection, and only 29.8% believed their community viewed PPE as useful. This normative environment — captured by this framework [14] as the social representation of pesticide risk as a 'necessary evil' — amplifies individual behavioral inertia by removing social incentives to deviate from the dominant unprotected practice. [28] demonstrated that community risk normalization creates a 'risk thermostat' effect: when a hazardous practice is perceived as universal and normative, individual perception of personal risk is paradoxically reduced, further suppressing preventive behavior.

## Exposure Duration Amplifies Risk Without Generating Protective Adaptation

The finding that 100% of producers exposed for ≥ 4 hours wore no gloves (RR = 1.78, $p < 0.001$) documents a paradox of particular public health importance: the subgroup with the highest cumulative dermal absorption risk is precisely the one with the lowest level of cutaneous protection. In pharmacotoxicological terms, the dermal dose received during a pesticide application session is the product of the surface-specific absorption rate, the skin surface area exposed, and the duration of contact [17, 37]. [13] demonstrated that dermal exposure of unprotected cotton field spray operators can reach 3.2 mg active ingredient per hour per unit body surface, accumulating to levels exceeding the acceptable operator exposure level (AOEL) for profenofos after approximately 90 minutes of unprotected spraying. In the present study, 53% of producers sprayed for four hours or more without any gloves, corresponding to cumulative exposures far beyond this threshold.

This paradox is structurally explicable: it is not that long-exposure producers are indifferent to protection — it is that the economic barrier to PPE access is uniform and absolute. A producer who cannot afford gloves will have no gloves regardless of how long they spray. This finding is consistent with results from Ethiopia [5] and Bangladesh [29], where exposure duration was similarly uncorrelated with protective behavior adoption among smallholder farmers. [30] reached an identical conclusion in a Brazilian cotton-farming context, finding that the duration-protection paradox was eliminated only when gloves were provided free of charge, confirming the structural — not motivational — nature of the barrier.

The universal absence of post-application body washing (100% across both exposure groups) deserves separate emphasis. This behavior extends the effective exposure duration beyond the application session by maintaining dermal pesticide contact for an indeterminate post-spraying period. [13] and [31] both showed that post-application dermal absorption continues for several hours after active spraying ends, depending on product formulation and ambient temperature. In the context of 53% of producers spending ≥ 4 hours applying pesticides followed by an absence of any decontamination, the cumulative dermal dose per session in this population is substantially higher than endpoint-of-application estimates suggest. This finding is particularly alarming given that 65.1% of producers in the questionnaire sample also declared regular tobacco consumption, which synergistically amplifies bronchopulmonary effects of organophosphate exposure [2, 36].

The seven remaining behaviors in Table 3 — including smoking during application (RR = 1.20), food consumption (RR = 1.19), and container burning (RR = 1.26) — all show RR > 1.00 in the long-exposure group. Their perfect directional consistency suggests that extended application sessions are contexts of heightened overall behavioral vulnerability, a pattern consistent with fatigue-related behavioral disinhibition documented in occupational health literature [24]. Future studies with larger sub-group samples should test this pattern with adequate statistical power.

### Limitations

This study has several limitations. The small size of the untrained group (n = 9) reduces statistical power of the Training × behaviors cross-tabulation, and the absence of significance cannot be distinguished from a power deficit. Proportional estimation of certain cells in educational level cross-tabulations limits precision of p-values. The Hawthorne effect, although attenuated by session duration [17], cannot be entirely excluded. The absence of objective biomonitoring prevents quantification of actual internal exposure dose [11, 29]. Finally, the study was conducted in a single sub-prefecture during one agricultural season, which may limit generalizability to other cotton zones in Côte d'Ivoire or the wider West African region.

## Conclusion

This observational study conducted among 68 cotton producers in the sub-prefecture of Toumoukoro establishes that risk behaviors during pesticide application — bare-hands mixing (73.5%), total absence of boots and full-body protective clothing (0%), universal absence of post-application body washing (100%) — are near-universal, homogeneous, and independent of received training (Fisher $p = 1.000$), educational level ($p \in [0.870; 1.000]$), and for most behaviors, exposure duration. The only statistically significant determinant is exposure duration ≥ 4 hours for glove absence (RR = 1.78, $p < 0.001$). These behaviors are driven by structural determinants — economic barriers to PPE access and community norms of indifference [9, 34] — which training alone cannot correct. Simultaneous interventions targeting PPE economic accessibility through subsidies, qualitative reform of training programs toward practical behavioral transfer, and community-level normative transformation are essential to achieve a durable and measurable reduction in pesticide exposure among this population [8, 29, 34].

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## Ethical Approval

This study was conducted in strict accordance with the ethical principles of the Declaration of Helsinki. Informed and voluntary consent was obtained from all participants prior to inclusion, with freedom to withdraw at any time without consequence. Individual anonymization was ensured through coded identifiers. Administrative authorization was granted by the Sub-Prefecture of Toumoukoro. All relevant institutional and community-level authorizations were obtained.

## Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request, subject to applicable data protection regulations and institutional supervision conditions.

## Author Contributions

- **Adama Coulibaly:** Conceptualization, methodology design, field data collection, formal analysis, writing — original draft, writing — review and editing.
- **Binate Nouho:** Supervision, methodology validation, writing — review and editing, project administration.

All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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