

Organizational Silence and Chronic Solvent Exposure in Industrial Paint Shops: A Transferable Mixed-Methods Design Framework for Respiratory, Neurobehavioural, Dermal and Psycho-Organizational Assessment

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Abstract:

A documented methodological gap characterises the literature on the health of industrial paint-shop workers: most published studies measure self-reported symptoms without the concurrent measurement of exposure, of ventilation, or of the organizational mediator that governs reporting and protective behaviour. The compound consequence is that the resulting figures are publishable yet weakly interpretable, since virtually all competing explanations remain open.

This article proposes a transferable methodological framework, formulated as a protocol template addressing a genuine need of researchers working in resource-constrained settings, that measures three interacting levels concurrently: physico-chemical exposure; respiratory, neurobehavioural and dermal health outcomes; and the psycho-organizational context surrounding reporting.

The framework rests on a four-phase sequential explanatory mixed-methods architecture, reinforced by an internal unexposed comparison group, objective spirometric measurement, a reference-based engineering audit of every spray booth included, repeated measurement across two contrasting seasons within the same site, and a provisional cumulative exposure index replacing raw job tenure. The measurement toolkit comprises six modular packages, each with a lower-cost alternative and a declared short form.

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Three operational components are proposed: a report–record discordance index, advanced as an exploratory indicator of dysfunction in the reporting channel rather than a direct measure of silence; a cumulative exposure index, advanced as a provisional model intended for relative ranking rather than dose estimation; and a testable theoretical model, designated the “vicious circle of protective silence”, which posits that silence sustains the conditions of exposure and then suppresses the symptoms arising from them, thereby warranting the inclusion of silence in the occupational hazard chain as an organizational mediator rather than an attribute of the worker.

The reference design is cross-sectional in essence; it therefore supports neither definitive causal inference, nor individual diagnosis, nor the derivation of a safe exposure threshold, nor national generalisation.

Keywords: study design; occupational exposure assessment; organizational silence; cumulative exposure index; mixed methods.

1. Introduction: the methodological gap and the design question

Workers in industrial paint shops—including those who spray trailers, structural frames and vehicle bodies—constitute an occupational group chronically exposed to a complex mixture of organic solvents, volatile organic compounds (VOCs), heavy metals and isocyanate hardeners. Concern over the chronic neurological effects of exposure to organic solvents dates back to the 1970s, when scientific attention shifted from acute, reversible effects, which were already largely accepted and understood, towards the possibility of chronic and irreversible sequelae: “Concerns that exposure to organic solvents in the workplace may cause irreversible damage to the central nervous system arose during the 1970s. The acute, reversible effects of such exposure were already well-accepted and largely understood. However the new concerns focussed on the potential for chronic irreversible effects.” (Spurgeon, 2002, p. 2)

Despite the extensive literature accumulated over the ensuing decades, the available evidence does not, in its present form, provide an integrated account of the relationship between a worker’s actual exposure, the health outcomes that are reported, and the organizational context that determines the conditions of such reporting. The present article addresses industrial paint shops employing manual spray application in the Maghrebi context specifically—a work environment in which these three dimensions plausibly intersect, while the manner of integrating them within a single design remains to be specified. The following subsections analyse the literature in order to locate this shortfall precisely, before deriving from it the design question on which the proposed framework rests.

1.1 Analysis of the methodological gap

The field continues to face a methodological problem that consists less in a scarcity of data than in the limited capacity of certain designs to link exposure, outcomes and organizational context. A weight-of-evidence appraisal supports the conclusion that long-term exposure to solvent mixtures may impair neurobehavioural performance, yet the same review concedes that the overall picture remains equivocal (Spurgeon, 2002, pp. 19–20). We contend that part of this ambiguity may be attributable to the architecture of the designs employed, and particularly to the concentration of a number of epidemiological studies on functional outcomes—cognitive performance and symptoms—without a disciplined characterisation of exposure itself.

The same descriptive pattern recurs on the respiratory side of the literature. A dearth of research on the effects of solvents upon the respiratory system has been noted, together with methodological inconsistencies across several studies that have investigated this relationship (Yarrou & Rathebe, 2022, p. 1). Where more rigorous designs are available, informative signals do emerge: a recent meta-analysis reported substantially elevated odds of respiratory symptoms among

workers exposed to volatile organic compounds relative to unexposed populations—cough (OR = 2.72), dyspnoea (OR = 3.59) and wheezing (OR = 2.28)—alongside significant reductions in FEV₁ and the FEV₁/FVC ratio (Sekhar et al., 2024, p. 1).

1.2 Three named gaps that define the design problem

On the basis of the foregoing, the deficiency of the field may be condensed into three distinct gaps which together constitute the design problem that this framework was formulated to address.

1. Measuring the symptom without measuring the exposure. Symptoms are reported—cough, wheeze, neurological complaints—without any concurrent measurement of air velocity, of contaminant concentration in the worker's breathing zone, or of the efficiency of engineering controls. This widens the space of competing explanations and constrains the capacity to adjudicate any relationship between exposure level and health outcome.

2. Neglect of the drying window. Exposure is reduced to the moment of spraying alone, whereas time-resolved measurements have demonstrated that exposure during drying may exceed exposure during spraying when ventilation is weak:

“under conditions without outdoor air supply, the drying process required hours, during which the less volatile solvents passed through a concentration maximum in the gas phase, so that the exposure during drying exceeded the exposure during spraying.” (Sabic et al., 2024, p. 1)

This finding indicates that characterising exposure on the basis of the spraying phase alone may substantially underestimate total exposure within the workshop, particularly under conditions of limited ventilation.

3. Absence of the organizational mediator from the design. Organizational silence—understood as the withholding of the expression of organizational problems or concerns that a worker may well perceive—has not been incorporated into the chemical occupational hazard chain, with the attendant possibility that this omission affects the completeness of the symptom and protection data obtained in field studies (Morrison & Milliken, 2000).

Reversing the direction of the research question

The customary question—“why does the worker not protect himself?”—assigns structural responsibility to the individual. The present framework reverses this direction and asks instead: “what makes reporting inadequate protection a costly behaviour?” The explanatory focus thereby shifts from “harsh weather” and “the unaware worker” towards modifiable engineering and organizational controls. This is a declared analytical choice, not a derived finding.

1.3 The design question and the context of derivation

This article does not pose a research question tied to any particular site; it poses a general design question that may be formulated as follows: *what is the minimum set of design components that permits a reduction in the confounding of exposure effects with organizational and climatic effects in industrial paint shops using manual spray application, without claiming that these effects can be independently disentangled within a design comprising a limited number of sites?* The formulation “reduction of confounding” rather than “disentanglement” is a deliberate qualification, arising from the fact that a two-site design does not possess the statistical capacity to separate climate from organization, as Section 4 makes explicit.

The components of this instrument were derived from a review of the occupational health and organizational behaviour literatures, adapted to the characteristics of small and medium-sized paint shops employing manual spray application and variable ventilation in the Maghrebi context. The article reports no empirical data, and its parameters are derived not from any particular dataset but from published reference values. The framework may accordingly be expected to suit most

closely those workshops that share these operational characteristics—notably manual spraying, solvent mixtures and variable ventilation—whereas its suitability for automated lines, or for sectors that involve no manual spraying, requires independent adaptation and appraisal.

2. Conceptual foundation and the proposed generative model

This section is ordered so as to serve the construction of the instrument itself, proceeding from exposure, through the three outcome domains, to the dynamics of window, technique and temperature, thence to the psycho-organizational mediator, and finally to the generative model from which the entire architecture of the instrument is derived.

2.1 Exposure: a complex chemical mixture rather than a single substance

The paint worker is exposed not to an isolated substance but to a mixture, of which solvents are the principal constituent, entering the body by three routes:

“The most important component of paints is solvents. [...] Solvents enter the bodily respiratory system through inhalation, inadvertent ingestion or through dermal absorption.” (Yarroo & Rathebe, 2022, p. 1)

Volatile organic solvents have been shown to constitute more than one third of paint formulations, while the mixture extends further to encompass heavy metals, aromatic and aliphatic hydrocarbons, and silica crystals (Ghobakhloo et al., 2023, p. 1). Nor is this mixture free of documented early biological effects: DNA damage has been observed in exposed workers relative to controls (Saironi et al., 2025, p. 771), and the oxidative stress arising from the inhalation of toluene, benzene and xylene has been characterised as generating single- and double-strand breaks in DNA (Iritaş et al., 2025, p. 2). Occupational exposure as a painter was classified by the International Agency for Research on Cancer as a Group 1 human carcinogen in 1989 (Patel et al., 2024, as cited in INRS, 2025, p. 4).

2.2 The three outcome domains: respiratory, neurobehavioural and dermal

With respect to the respiratory domain, inhalational exposure is associated with the emergence of airway disease, and the effects are intensified where solvent mixtures are involved (Yarroo & Rathebe, 2022, p. 2), accompanied by the significant decrements in pulmonary function indices noted above.

With respect to the neurobehavioural domain, the sixteen-item screening questionnaire (Q16) remains the most widely used instrument, and an exposure–effect relationship has been documented for it, with relative risks rising from 2.42 to 3.41 as exposure duration increases (Chen, as cited in Spurgeon, 2002, p. 26). The instrument itself, however, is subject to a decisive diagnostic caveat, as set out in the neurobehavioural package below.

With respect to the dermal domain, contact with—and the airborne transfer of—epoxy hardeners and isocyanates produces allergic contact dermatitis, which may affect the eyelids in the absence of direct contact, a presentation described in the clinical literature as airborne contact dermatitis (Ravi & Thomas, 2018, pp. 26–28). We accordingly employ the anatomical distribution of lesions, particularly at non-contact sites, as an exploratory indicator of ventilation inadequacy rather than as a merely individual symptom.

2.3 Window, technique and temperature: heat as a behavioural mediator

Transfer efficiency is governed by the type of technique employed: it is low for the conventional spray gun, at approximately 20 to 40 per cent, and higher for the HVLP gun, averaging 65 per cent (OECD, 2004, pp. 13–14). The reference standard requires an air velocity of not less than 100 linear feet per minute across the open face of the booth (OSHA, 2012, § 1926.66(b)(5)(i)).

A postulated thermal–behavioural rule, not a demonstrated one

On the basis of field observation and climatic data, we consider it plausible that manual ventilation behaviour follows a general thermal logic: in the hot season, openings are held open and natural extraction improves irrespective of the adequacy of mechanical ventilation; in the cold season, openings are closed in order to accelerate drying and retain heat, so that vapour accumulates during the drying window. The ranking of exposure between two sites may therefore invert seasonally, which renders measurement in two contrasting seasons a condition of the design rather than an option, and obliges the user to document the state of openings at every measurement session.

2.4 The psycho-organizational mediator: silence, psychological safety and safety climate

Organizational silence is defined, in its classical literature, as the deliberate withholding of genuine expression from those with the capacity to effect change:

“the intentional withholding of any form of genuine expression about the individual’s behavioural, cognitive, and/or affective evaluations of their circumstances to persons who are perceived to be capable of effecting change or redress” (Pinder & Harlos, 2001, p. 334)

Silence in contemporary organizations has been characterised as more than a transient individual act: it constitutes a powerful collective phenomenon that shapes organizational behaviour and impedes effective change (Morrison & Milliken, 2000, p. 707). Moreover, silence is not merely the converse of voice but operates independently of it in empirical data, the correlation between the two not exceeding -0.15 , while its intensity is more strongly associated with negative affect and perceived psychological safety than is voice (Sherf et al., 2021, as cited in Lainidi et al., 2025, p. 2). Of greater methodological consequence is its substantial association with burnout:

“a moderate effect size between greater employee silence and greater burnout ($Q = .43$ [...] $k = 44$, $n = 13,633$) [...] moderate effects were observed between greater employee silence and greater emotional exhaustion ($Q = .44$).” (Lainidi et al., 2025, p. 9)

Subgroup analyses reveal a stronger effect in non-Western settings ($Q = .46$ as against $Q = .33$), which supports the legitimacy of testing the instrument across culturally divergent contexts and renders linguistic adaptation a condition of validity rather than a refinement (Lainidi et al., 2025, p. 9).

Psychological safety—defined as a shared belief that the team is a safe place for interpersonal risk-taking—constitutes the determinant that may be expected to restrain silence (Edmondson, 1999, p. 354). Workplaces lacking psychological safety have been shown to foster silence and disengagement and to generate a reluctance to report problems, thereby increasing errors, depressing morale and intensifying burnout; the same review documented a substantial positive association between a caring work climate and psychological safety ($\beta = 0.53$) and a negative association between that climate and emotional exhaustion ($\beta = -0.42$) (Ip et al., 2025, pp. 2, 10).

Safety climate completes the picture. It has been defined as a frame of reference reflecting employees’ perceptions of the relative importance of safe conduct within their occupational environment, with genuine management commitment identified as the most consistent characteristic distinguishing low-accident from high-accident companies (Zohar, 1980, pp. 96–97). Safety culture, in turn, has been described as developing through five stages—indifference, response, dependence, independence and interdependence—along which any given site may be located (Saik et al., 2025, p. 4). Work pressure is framed by the demand–control–support model, in which the most hazardous condition (iso-strain) arises from the conjunction of high demands,

low control and low social support (Johnson & Hall, as cited in Crescenzo, 2016, p. 290). Finally, risk perception itself is to be read as a judgement that exceeds mere technical estimation (Slovic, 1987, p. 285).

2.5 The proposed generative model: the “vicious circle of protective silence”

Status of the model

What follows is a testable theoretical model, not a demonstrated finding. It is a postulated pathway, formulated in the present work for the purposes of derivation and subsequent testing, which the cross-sectional reference design cannot establish. The claim advanced here is testability, not proof.

The model rests on two distinct postulated loops, and the distinction between them matters because their methodological consequences differ:

- **The protective loop (upward).** If the worker withholds a report of inadequate protection, the conditions of exposure may remain uncorrected, whereby silence becomes a factor in the persistence of the hazard rather than merely a reaction to it.
- **The measurement loop (downward).** If the worker withholds the symptoms themselves, health surveillance data may be systematically incomplete; that is, silence corrupts the monitoring instrument itself. This raises the important possibility that an “absence of cases” in official records may, in certain contexts, represent an absence of reporting rather than an absence of disease. This reading is consistent with evidence that silence constrains the flow of information and weakens organizational performance, that fear of retaliation is associated with performance ($r = .690$), and that addressing silence may prove more beneficial than merely encouraging voice (Dhaqane, 2024, pp. 28, 31; Lainidi et al., 2025, p. 17). Consistency with the literature is not, however, proof of the pathway in this particular occupational setting, which is precisely why the testing of the pathway is assigned to prospective longitudinal designs.

A deliberate terminological constraint

We deliberately refrain from describing silence as an occupational risk factor in the strict sense, since designating a variable a “risk factor” requires longitudinal or experimental evidence that a cross-sectional design cannot generate. The formulation we adopt is the following: it is proposed that organizational silence be incorporated into the occupational hazard chain as a measurable organizational mediator and a candidate risk factor, a status that longitudinal designs must examine.

3. The reference design architecture

The instrument rests on a four-phase explanatory sequential mixed-methods design, reinforced by four structural additions. Any application that substitutes a purely quantitative design for this architecture falls outside the scope of the instrument and may not be attributed to it.

Table 1. The four-phase reference design architecture

Phase	Procedure	Instrument / method	Descriptive output
–1 (optional): feasibility and access	Feasibility appraisal and securing of access	Site reconnaissance; written access agreement	Feasibility report and inventory of field obstacles
0: foundational	Reference-based environmental and engineering audit of every booth	Audit checklist (38 items) plus air-velocity measurement	Engineering compliance score for each site

1: quantitative	Cross-sectional survey of both groups, repeated across two seasons	The six packages (Section 5)	Quantitative database × two seasons
2: qualitative	Semi-structured interviews to saturation	Seven-domain interview guide	Transcripts and a double-coded coding scheme
3: integrative	Integration and return of findings to the field	Integration matrix plus feedback session	Integrative inference and qualitative validation

3.1 The four structural additions

First, dual comparison. An exposure-based comparison between exposed workers and an internal unexposed control group drawn from the same site, and a site-based comparison between contextually divergent sites. The exposure-based comparison remains the stronger inferentially, since it holds site and organization constant; the site-based comparison remains descriptive and burdened by confounding, as demonstrated below.

Second, within-site seasonal comparison. Measurement in two contrasting seasons while the organizational structure remains constant. This constitutes the principal mechanism for identifying thermal and ventilation effects, in place of comparison between two sites of differing climate.

Third, the objective measurement dimension. Spirometry together with the measurement of air velocity, temperature and humidity, thereby securing a portion of the outcome set through measurement that does not depend on worker self-report.

Fourth, the archival dimension. The juxtaposition of health surveillance records with questionnaire-based self-report in order to compute the report–record discordance index, advanced as a conditional exploratory indicator as detailed in Section 8.

4. Sites, participants, and the confounding of climate with organization

The structure of the sample is expressed in proportions and conditions rather than absolute numbers, since absolute numbers are the signature of a particular project rather than a property of the instrument.

4.1 The dual-variation condition

The instrument is applied at a minimum of two sites, designated Site A and Site B, which satisfy a dual-variation condition: documented climatic variation, evidenced by official climatic data and plausibly affecting ventilation behaviour; and organizational variation in enterprise size, in the level of engineering compliance of the spray booth (according to a three-way classification: no booth / partial / compliant), and in the presence or absence of a formal safety structure. Geographical proximity is not required, and the characteristics of each site must be documented in a standardised table published alongside the findings.

It is pertinent to note that the availability of a spray booth is itself strikingly variable in practice: between 50 and 80 per cent of automotive refinishing shops employ minimum engineering controls, and the presence of spray booths is more frequent in larger workshops (OECD, 2004, p. 14).

4.2 The structural problem: climate and organization are perfectly confounded with site

If Site A combines a given climate with a given organizational configuration, and Site B a different climate with a different configuration, then climate and organization become perfectly

confounded with site. With only two sites, the effect of climate cannot be separated from the effect of organization, because the number of higher-level units (two) does not permit it, however large the number of workers within each site. It is therefore not claimed that the design “protects inference from the confounding of climate with context”, since such a claim would exceed the design’s actual capacity.

This limitation is addressed not by softening the language but by relocating the examination of the climatic component to a different analytical level, according to the three strata set out below.

Table 2. Strategy for handling the confounding of climate with organization			
Analytical level	What varies	What is held constant	What may legitimately be inferred
Within site × season	Thermal conditions, state of openings, ventilation behaviour	Organizational structure, management, booth, and the individuals themselves	The strongest stratum: association of thermal variation with variation in exposure and symptoms
Within site × exposure	Exposure status (exposed / control)	Climate, site, organization and governance	Association of exposure with outcomes, with climate and organization held constant
Between sites	Climate and organization jointly (confounded)	Nothing of consequence	Descriptive only; causal interpretation is proscribed

Climatic variation between sites is thereby transformed from a source of inference—which the design cannot support—into a site-selection criterion that widens the range of observed thermal variation and increases the likelihood of detecting seasonal inversion. This is a legitimate function, and a modest one.

4.3 Inclusion and exclusion criteria

Table 3. Participant inclusion and exclusion criteria		
Group	Inclusion criteria	Exclusion criteria
Exposed	Performance of painting or surface-preparation tasks within the workshop for at least six months, with attendance of not less than four hours daily	Refusal to participate; administrative work without direct exposure
Internal control	Workers from the same site without direct exposure, matched on age (± 5 years), with smoking status and sex taken into account at selection	Refusal to participate; any previous employment in painting or surface preparation exceeding six months at any time

A complete enumeration of exposed workers at each site is adopted, given the customarily small size of this population, thereby maximising statistical power within the limits of the available population; the internal control group is constructed at a ratio approaching 1:1 with the exposed group. The qualitative sample is determined by the criterion of theoretical saturation with maximum variation in tenure, position, symptom severity and level of silence; the point of saturation is to be reported rather than a pre-specified target number.

5. The six packages: modular components

The measurement toolkit is configured as six modular packages, each with its own components, operational definitions, licensing status, lower-cost alternative and accompanying caveats. Modularity is constrained by an explicit rule prohibiting the extraction of inexpensive packages and the omission of costly ones, as addressed in Section 10.

Table 4. The six packages: components, licensing status and lower-cost alternative			
Package	Core component	Licensing status	Lower-cost alternative
1. Respiratory	Standardised symptom questionnaire (ATS-DLD / NOSQ type) plus spirometry	Protected instrument; source to be acknowledged	Questionnaire alone, with disclosure
2. Neurobehavioural	Sixteen-item screening instrument (Q16 type), bounded by explicit constraints	Conditional; source must be requested	No lower-cost alternative; the package is omitted in its entirety
3. Dermal	Standardised items plus a 14-site anatomical map	Items composed herein: open licence	Photographically documented visual examination
4. Psycho-organizational	Individual silence, climate of silence, psychological safety, safety climate, demand/control/support, burnout	Mixed: climate-of-silence items open; borrowed scales require source acknowledgement	A declared short form for each scale
5. Exposure assessment	Three tiers (safety-datasheet inventory → model-based estimation → field measurement)	OECD/OSHA standards plus an open composed index	Lowest tier: safety-datasheet inventory
6. Thermal-climatic	Temperature and humidity plus the state of openings at every session	Open	Simple temperature and humidity reading

5.1 The neurobehavioural package: bounded by explicit constraints

The screening instrument is presented together with a mandatory caveat printed at the head of the package, since its diagnostic validity is the subject of a published reservation:

“the number of false positives and false negatives produced by the Q16 when compared with an independent measure do not provide convincing evidence of its high sensitivity or specificity as a screening tool.” (Spurgeon, 2002, pp. 27–28)

Three constraints are accordingly imposed upon the user: first, the instrument is to be read as a screening device and not as a diagnostic one; second, the score is to be reported both continuously and dichotomously (at the threshold); and third, non-significant results are to be read as inconclusive rather than exclusionary, consistent with the observation that studies of this type can only suggest the possibility of effects, which then require further investigation (Spurgeon, 2002, pp. 51–52).

5.2 The dermal package: an exploratory distributional indicator

The package employs an anatomical map of 14 sites and computes the ratio of lesions at non-contact sites to those at contact sites. The clinical rationale for the indicator derives from the literature: certain patients who had no direct contact with the resins nevertheless presented with eyelid lesions alone, on the basis of which the authors considered airborne contact dermatitis the likely mechanism (Ravi & Thomas, 2018, p. 28).

A necessary qualification

We refrain from describing an elevated ratio as engineering evidence of ventilation inadequacy, since such a step would constitute an illegitimate inferential transition: the cited source is a clinical case series of limited size that supports the plausibility of an airborne transfer mechanism, not the validity of the ratio as an engineering indicator. The characterisation adopted is the following: an exploratory distributional indicator that may signal an airborne contribution to exposure, to be interpreted exclusively in conjunction with air-velocity measurement and the engineering compliance score.

5.3 The psycho-organizational package: an explicit separation of two measurement levels

This package measures six distinct constructs. We emphasise an important methodological separation between the measurement of silence at the individual level and the measurement of the climate of silence at the unit level: conflating the two within a single account creates the impression that they are competing instruments for one construct, whereas they are in fact two different constructs assessed at two different levels of measurement.

Table 5. Constructs of the psycho-organizational package: level of measurement, instrument status and function			
Construct	Level of measurement	Instrument status	Function within the model
Individual silence (defensive / acquiescent / prosocial)	Individual	Scale borrowed from the literature	The principal postulated mediating variable
Climate of silence	Unit / workshop	Six composed items, not yet validated	Organizational context variable
Psychological safety	Individual and unit	Edmondson type, borrowed	Postulated determinant of silence
Safety climate	Unit	Zohar dimensions, borrowed	Modifiable organizational variable
Work strain and burnout	Individual	Demand/control/support plus exhaustion, borrowed	Context variables and tertiary outcomes
Social desirability	Individual	Three composed items, open licence	Response-bias control

Safeguards for the measurement of silence

The measurement of silence is not considered valid if data are collected through the line-management hierarchy. The instrument stipulates six mandatory safeguards: (1) collection away

from management offices; (2) sealed envelopes or self-deposit; (3) no transmission of the questionnaire via the team leader; (4) an explicit assurance that employment status is unaffected by responses; (5) anonymising coding; and (6) presentation of silence findings to management in aggregate form only. In the absence of these safeguards, workers' responses may be confounded with the effect of the collection procedure itself, thereby weakening the validity of the data and potentially exposing workers to unintended risk.

5.4 A declared short form

In order to prevent administration time from exceeding one hour in a production workshop operating under deadline pressure, each package is accompanied by a short form specifying the priority items and the estimated administration time, on the condition that any coverage or precision forfeited through abbreviation is explicitly stated.

6. Exposure assessment, engineering audit, and the provisional exposure index

6.1 Three tiers of exposure assessment ordered by cost

Exposure assessment may be organised across three tiers. The lowest tier begins with an inventory of safety data sheets (SDS) and an enumeration of hazardous constituents; a recent review of such datasheets identified 61 unique CAS numbers, among them 14 potent sensitizers, two IARC Group 1 known carcinogens and seven IARC Group 2B possible carcinogens (Patel et al., 2024, as cited in INRS, 2025, p. 5). The recommended tier advances to a model-based estimation of emission by reference to standardised scenarios—for instance, a crossdraft booth with a conventional spray gun at a mean concentration of 35 mg/m³ (OECD, 2004, p. 30)—supported by the measurement of air velocity, temperature and humidity. The full tier encompasses breathing-zone air sampling and biomarkers, such as hippuric acid for toluene (Iritaş et al., 2025, p. 2), while taking into account that exposure during drying may exceed exposure during spraying (Sabir et al., 2024, p. 1).

6.2 The engineering audit checklist

The 38-item audit checklist is promoted to a separate printable appendix with documented reference criteria, and each item is furnished with a blank column headed “corresponding provision in national legislation (to be completed locally)”. Among these criteria are: an air velocity of not less than 100 linear feet per minute across the open face (OSHA, 2012, § 1926.66(b)(5)(i)); separation of the booth from other operations by not less than three feet (OSHA, 2012, § 1926.66(b)(8)); Class 1 or Class 2 air filters (McKinney Fire Department, n.d., p. 2); and a non-combustible, non-sparking floor, with dry-filter removal efficiency averaging approximately 90 per cent (OECD, 2004, p. 14).

6.3 The cumulative exposure index: a provisional model intended for ranking, not dose

This index replaces raw job tenure—a poor proxy, since it treats a year of work in a compliant workshop as equivalent to a year of work with no booth at all—with a semi-quantitative estimate that combines window, technique, engineering control and protection across the duration of exposure, according to the following formulation:

$$CEI = \sum_t [D_t \times w_{\text{window}} \times w_{\text{technique}} \times w_{\text{engineering}} \times w_{\text{protection}}]$$

where D_t denotes the duration of exposure in period t , and the w coefficients are provisional indicative weights.

Declared status of the index

This index does not estimate a true dose, nor does it yield a value possessing physical meaning. Its declared purpose is singular: the relative ranking of exposure levels among individuals

within the same study, pending calibration against direct personal measurement. Three strict constraints follow. First, its values are to be used as ranks or quartiles rather than absolute quantities. Second, its values are not to be compared across two studies with differing calibration. Third, no safe exposure threshold is to be derived from it, consistent with the fact that the literature itself does not permit an adverse effect level to be discerned (Spurgeon, 2002, p. 53).

Table 6. Index parameters, provisional indicative weights and sensitivity ranges			
Coefficient	Indicative weight	Acceptable range	Nature of the evidential support
Window (w_{window})	Spraying 1.0 / ventilated drying 0.6 / enclosed drying 1.0+	0.6–1.2	Direction supported; value indicative
Technique ($w_{\text{technique}}$)	Conventional 1.0 / HVLP 0.55	0.45–0.70	Best supported: derived from published transfer efficiencies
Engineering ($w_{\text{engineering}}$)	No booth 1.4 / partial 1.0 / compliant 0.6	0.6–1.4	Derived from the compliance score (38 items)
Protection ($w_{\text{protection}}$)	None 1.0 / intermittent 0.8 / consistent 0.4	0.4–1.0	Weakest support; see the caveat below

Specific caveat concerning the protection coefficient

Assigning personal protective equipment a fixed coefficient (0.4, for example) implies that its use reduces exposure by a stable proportion, which is not the case. Field effectiveness depends upon the type of device, the quality of facial seal, the correctness and duration of use, the nature of the substance, the type and age of the filter, and maintenance; it may collapse to near zero with a saturated filter or an ill-fitting mask. We therefore designate this coefficient an “indicative protection weight” rather than an “exposure coefficient”, oblige the user to document the type, filter and condition of the device, and require that a version of the analysis be conducted with this coefficient omitted entirely (fixed at 1.0) and its results reported alongside.

The question of mathematical form

It must be acknowledged explicitly that the choice of a multiplicative form is not inferred from the literature; it is a modelling decision that is theoretically justified and open to refutation. The theoretical justification is as follows: we consider it more plausible that these factors operate interactively rather than additively, since the presence of a compliant booth attenuates the effect of a poor technique whereas its absence compounds that effect—a multiplicative rather than an additive logic. The assumption itself nevertheless requires testing, and the user is accordingly obliged to compare three forms (multiplicative, weighted additive, and rank-based/logarithmic) and to report their results jointly rather than fixing the multiplicative form *a priori*. Should the ranking of individuals change substantively across the three forms, the index is unfit for use in those data, and this is to be reported as a methodological finding rather than a failure.

7. Linguistic and cultural adaptation

Certain instruments in this field are applied without a clearly specified pathway for their linguistic and cultural adaptation, which may result in their administration in a language other than that of the workers, or in translations whose appropriateness has not been verified. This section presents a general six-step pathway applicable to any target language, with its application to Arabic and to colloquial Arabic (Darija) offered as an illustrative case in the Algerian and Maghrebi context.

Table 7. The six-step pathway for linguistic and cultural adaptation		
#	Step	Procedure and recommended scope
1	Forward translation	Two independent translations into the target language, supervised by bilingual specialists
2	Synthesis	Reconciliation of discrepancies between the two translations in a documented unified version
3	Back-translation	Back-translation into the source language and comparison with the original to detect semantic drift
4	Expert panel and dialectal adaptation	Review of cultural equivalence and preparation of a Darija-language aid for ambiguous items
5	Preliminary cognitive testing	Pre-testing with 8–10 workers from outside the analytic sample to verify clarity of wording
6	Preliminary reliability appraisal	Re-administration to 12–15 participants at an interval of 10–14 days, with computation of internal consistency

A necessary statistical qualification

We recall that 12–15 participants are insufficient for any decisive psychometric judgement, since numbers of this magnitude yield very wide confidence intervals around reliability coefficients. We therefore characterise this step as a preliminary reliability assessment whose purpose is to detect gross defects—ambiguous items, items of inverted direction, items that participants do not comprehend—prior to wider administration. Full psychometric validation, encompassing factorial structure and reliability with acceptable confidence intervals, is deferred to a larger sample and assigned to the third stage of the validation pathway.

The user is obliged to report the results of their adaptation—preliminary reliability values, modified items, and comprehension difficulties observed—in a concise appendix upon which other users may build, thereby transforming each application into a contribution to the improvement of the instrument rather than a consumption of it. The measurement of silence and psychological safety is structurally sensitive to cultural difference, and literally translated items lacking dialectal adaptation may measure a construct other than that intended by the original. This is particularly so for silence items, which carry socially sensitive content whose acceptable expression varies across cultures, such that adaptation becomes a condition of measurement validity rather than an embellishment of it.

8. Outcome hierarchy, modelling rules, and the reporting-gap index

8.1 The mandatory outcome hierarchy

Presenting all outcomes with equal weight and then subjecting them to multiple tests—including logistic regression and nested models—is a reliable recipe for overfitting and for inflation of Type I error in a workshop whose population typically ranges between fifty and one hundred workers. We therefore impose an explicit and binding hierarchy, to be declared prior to data collection.

Table 8. The mandatory outcome hierarchy		
Rank	Outcomes	Reporting rule
Primary	(1) Prevalence of self-reported respiratory symptoms; (2) spirometric impairment	Two outcomes only, with effect size and confidence interval

Secondary	Neurobehavioural screening; dermal symptoms and the non-contact-site ratio	Not to be elevated to a principal conclusion
Mediating	Individual silence; climate of silence; psychological safety; safety climate	Correlational and descriptive; the language of causal mediation is proscribed
Exposure-related	Exposure index; compliance score; temperature and state of openings	All sensitivity versions to be reported
Tertiary / exploratory	Work strain; burnout; report–record gap	Labelled “exploratory” in every table

8.2 The pivotal hypothesis

Hypotheses are formulated as testable propositions rather than predictive assertions, the most consequential methodologically being the pivotal hypothesis: *the aggregate contextual variable (site, understood as an opaque bundle comprising climate, technique, enterprise size and management style) loses part of its explanatory effect once explicitly measured engineering and organizational variables are entered into the model.*

We situate this test precisely: it is a robustness and confounding-attenuation check, not a demonstration that “site was merely a proxy for climate”. A reduction in the site effect after adjustment admits several interpretations, among them that the entered variables have genuinely absorbed part of the content of site; that the reduction arises from multicollinearity among the variables; that it reflects a loss of statistical power as the number of parameters increases; or that it results from measurement error in the entered variables. We accordingly require that these four competing interpretations be reported explicitly whenever attenuation is reported.

8.3 The report–record discordance index (RRD)

Precise characterisation of the index

We refrain from attributing psychological meaning to an arithmetic difference: the discrepancy between self-reported symptoms and recorded cases is not a direct measure of silence. The characterisation adopted is the following: the report–record discordance index (RRD) is an exploratory operational indicator of dysfunction in the reporting and recording channel, and it is not to be interpreted in isolation as a measure of organizational silence under any circumstances.

$$\text{RRD} = (\text{proportion of symptoms reported by questionnaire}) - (\text{proportion of recorded cases})$$

This discordance may arise from at least seven causes, of which silence is only one: (1) divergence between the definition of a “symptom” in the questionnaire and that of a “medical case” in the record; (2) divergence in the time window; (3) the outright absence of a medical service; (4) deficient recording for purely administrative reasons; (5) divergence in the denominator and the unit of analysis; (6) non-attendance at medical consultation for practical reasons such as distance or loss of pay; and (7) deliberate withholding, which is the cause of interest here. Silence cannot be isolated from these causes by computation alone, and we therefore stipulate four procedural conditions for use of the index, each of which narrows the space of competing explanations:

- **Harmonisation of denominator and window.** The index is computed for the same group and the same time window, failing which it is not computed at all.
- **Harmonisation of definition.** Symptom is compared with symptom, not symptom with diagnosis.
- **Documentation of system capacity.** The existence of an occupational health service and the regularity of recording are documented as measured competing explanations rather than as unstated background.

- **Convergent testing.** The association of RRD with direct measures of silence at the unit level is reported; where no association is found, the index is interpreted as a defect in the recording system rather than as silence among the workers.

8.4 Sample size planning

Table 9. Illustrative planning table — approximate minimum per group ($\alpha = 0.05$, power = 0.80)			
Prevalence in controls \ effect size	OR = 2.0	OR = 2.7	OR = 3.5
10%	~215	~120	~78
15%	~150	~85	~55
20%	~118	~68	~44

We emphasise that this is an illustrative planning table rather than a general minimum. Its values were computed under specific assumptions that must be disclosed, namely the comparison of two independent proportions, a 1:1 group ratio, a two-sided test, no correction for multiple comparisons, no covariates and no clustering. The values change appreciably with any change in these factors. The reference effect sizes are drawn from meta-analytic estimates, such as OR = 2.72 for cough (Sekhar et al., 2024, p. 1).

8.5 Mandatory reporting rules: six prohibitions

Six prohibitions are specified, in respect of which no latitude is permitted in any application attributed to this framework:

1. Causal language is prohibited in conjunction with a cross-sectional design.
2. Designating any finding a “diagnosis” is prohibited.
3. Elevating a secondary or exploratory outcome to a principal conclusion after inspection of the results (outcome switching) is prohibited.
4. Interpreting RRD as silence without convergent testing is prohibited.
5. Reporting a p value alone is prohibited; effect size and confidence interval are required.
6. Reporting a single version of the exposure index is prohibited; the sensitivity versions and all three functional forms are to be reported.

Where the minimum sample size cannot be attained, the work is to be classified explicitly as “exploratory and descriptive” in the title and abstract rather than in a footnote, since strength derives from triangulation rather than from expansive interpretation.

9. Ethical governance and safeguards for the measurement of silence

An explicit separation: the ethics of this work and the ethics of the user

The present work involves no human participants, collects no individual-level data, and requires no ethical approval. What follows constitutes the unit of ethical governance incumbent upon every user when applying the instrument in the field.

9.1 Informed consent and the protection of participants

We stipulate voluntary participation with written informed consent, complete confidentiality with anonymising coding, and an explicit assurance that employment status is unaffected by responses. This last is a decisive methodological requirement in a study addressing organizational silence, since its absence generates silence produced by the research procedure itself and thereby corrupts the measurement. The right of withdrawal is guaranteed at any stage, without the need to state a reason and without consequence for the participant.

9.2 Protocol for the return of results and for referral

Where a participant reaches a threshold warranting evaluation—such as exceeding the threshold of the neurobehavioural screening instrument or presenting spirometric impairment—a referral pathway to the occupational physician is activated, with a strict separation maintained between anonymised research data and individual clinical referral. Communication to the participant is to be framed in language that does not create a diagnostic expectation: the appropriate formulation is “a result warranting examination” rather than “an indication of disease”.

9.3 Four constraints specific to the paradox of silence

1. The measurement of silence is under no circumstances to be collected through the line-management hierarchy.
2. Findings on silence and compliance are presented to management in aggregate form only—neither at the individual level nor at the level of a small team from which individuals could be inferred.
3. Recommendations are formulated as reference standards addressed to the system (ventilation, procedures, maintenance), and not as grievances attributed to identifiable workers.
4. The participant is safeguarded against any potential retaliatory consequence through coding, aggregation and the separation of channels.

Prohibition of use against workers: a licensing condition, not a recommendation

We expressly prohibit use of the instrument in individual performance appraisal or in disciplinary measures. An instrument that measures “worker compliance with protection” and “worker risk perception” is liable to administrative use in attributing responsibility for an engineering deficiency to the worker, which is the precise antithesis of the instrument’s purpose, since it was constructed to restore responsibility to modifiable engineering and organizational controls. This constraint is embedded in the licence text governing the open items, and not merely in the recommendations.

10. Applicability matrix and reporting standards

Table 10. Applicability matrix across three cost tiers		
Tier	Resources	What may legitimately be tested
Minimum	Questionnaires plus datasheet inventory plus visual audit	Symptom prevalence; RRD (exploratory)
Recommended	Plus spirometry, air measurement and two seasons	Plus the exposure–primary outcome relationship and the test of site-effect attenuation
Full	Plus air sampling and biomarkers	Plus the internal dose–outcome relationship and calibration of the CEI

A rule prohibiting the dismantling of packages

Tests that fall outside the declared tier of implementation are not to be attributed to this instrument. We oblige users at the minimum tier to classify their work as “exploratory and descriptive” in the title and abstract, so as to forestall a wave of studies reporting symptoms without measurement—which is precisely the deficiency the instrument was constructed to overcome. An instrument that is dismantled, such that its inexpensive packages are extracted and its costly ones discarded, becomes a reproduction of the original gap in new methodological packaging.

10.1 Four entry conditions for the scope of application

1. The presence of manual or semi-manual spray application.

2. The use of solvent mixtures and/or isocyanate hardeners.
3. Variable ventilation, or ventilation that is not mechanically controlled.
4. The existence of a reporting structure, however nominal; in its absence, computation of the RRD is devoid of meaning.

10.2 Executive integrity checklist

The instrument is unsuited to definitive causal inference, to individual diagnosis, to the derivation of a safe exposure threshold, to national generalisation, and to individual performance appraisal or disciplinary action. An application is not deemed faithful to the instrument if any of the following obtains:

- Absence of the internal control group.
- Reliance upon a single season.
- Use of job tenure in place of the exposure index.
- Transmission of the silence questionnaire via the team leader or management.
- Absence of sensitivity analysis across versions and functional forms.
- Absence of a pre-declared outcome hierarchy.
- Interpretation of RRD as silence without convergent testing.

11. Consolidated section: limits of inference

This section gathers in a single place all the reservations dispersed throughout the article. The purpose is at once editorial and methodological: reiterating caveats on every page produces a text that appears to be defending itself, whereas consolidating them explicitly in one location produces a text that is confident, that knows its limits and that refers the reader to them.

Table 11. Limits of inference, classified by source and by remedy		
Limit	Structural source	Remedy (and where it is addressed)
No causality	The design is cross-sectional in essence	A longitudinal design or cohort follow-up (Stage 4)
No diagnosis	Screening instruments of insufficient sensitivity and specificity	Not remediable within the framework; safeguarded by the package constraints
No safe threshold	The exposure index is uncalibrated	Calibration against personal measurement (Stage 2)
No separation of climate from organization	Only two sites $\Rightarrow$ perfect confounding	Relocation of identification to seasonal variation
No national generalisation	Sites selected under a variation condition	Not remediable; safeguarded by disclosure
Unvalidated indicators	CEI, RRD, the dermal ratio, the climate-of-silence items	The validation pathway in full (Section 12)
Limited statistical power	Workshop populations are small	The outcome hierarchy and the rule of parameter parsimony
Response bias	Silence is an intrinsically sensitive subject	The six safeguards plus the social desirability control

These limits do not constitute an apology for the framework; they form part of its output. The framework offers a measurement toolkit together with a precise account of what that toolkit can and cannot do, and a study that applies the toolkit and reports these limits explicitly is of greater service to the field than a study that produces figures of cleaner appearance while remaining silent about the conditions of their production. This is, in the final analysis, the substance of the argument from which we set out in the opening section.

12. Conclusion and the instrument validation pathway

12.1 What this framework offers, precisely stated

We do not claim here that the components of this framework are absent from existing instruments, since a claim of absence across an entire literature cannot be sustained without a registered systematic scoping review. The limited and refutable claim we adopt is the following: this framework proposes three operational components and a methodological configuration for which, within the limits of the review conducted for the present work, we found no counterpart combining them within a single design.

Table 12. The proposed components, their present status, and their requirements		
Component	What is claimed for it	What is required before confirmatory use
Threefold concurrency (exposure × outcomes × mediator)	The most substantial contribution: a methodological configuration addressing a documented gap	A registered scoping review, followed by at least one complete application
The vicious-circle-of-protective-silence model	The theoretical contribution: a postulated, testable pathway	Testing of the pathway in empirical data, and a longitudinal design
Cumulative exposure index (CEI)	A provisional model intended for relative ranking	Calibration against direct personal measurement
Report-record discordance index (RRD)	An auxiliary exploratory indicator of reporting-channel dysfunction	Convergent testing against direct measures of silence
The dermal distributional ratio	An auxiliary exploratory indicator of an airborne contribution	Comparison with air-velocity measurement and the compliance score

12.2 The residual value after all these constraints

Once all the foregoing qualifications are applied, the framework retains a value that is unaffected by the validation status of its indicators: it measures exposure, outcomes and the organizational mediator concurrently within the same chain. This concurrency alone suffices to transform the research question. Instead of asking what proportion of workers complain of cough, we become able to ask whether that proportion differs according to the measured engineering control, and whether its reporting differs according to the measured climate of silence. These two questions point towards an implementable intervention, unlike the first.

What this framework proposes is therefore a relocation of analytical responsibility: from silence as an attribute of the worker (“a worker who does not report”) to silence as an intelligible response to a structure that has rendered speech costly—a structure that is measurable and

therefore modifiable. This is a theoretical reading for which the framework supplies the instruments of testing; it is not a finding that the framework announces.

12.3 The validation pathway: four stages and a stage zero

This text does not pass from “proposal” to “research programme” by declaration, but by specifying, in accountable terms, precisely what prospective applications must establish.

Table 13. The validation pathway and what must be established at each stage		
Stage	What is established	What becomes permissible thereafter
Zero: scoping review	The boundaries of what is genuinely novel	A claim of originality in specific and evidenced terms
1: audit reliability	Inter-auditor reliability of the compliance score	Use of the compliance score as an input to the index
2: exposure calibration	Association of the CEI with direct personal measurement	Promotion of the CEI from a provisional model to a locally calibrated index
3: psychometric validation	Factorial structure and reliability of the composed items	Description of the items as “validated”
4: model testing	The vicious-circle pathway within a longitudinal design	Transition from a “postulated model” to a proposition concerning a risk factor

12.4 Concluding remarks

What has been presented in this work is not a field study of a particular setting, but a working template on which Algerian, Maghrebi and more broadly Arab researchers may draw when undertaking the study of industrial paint workers’ health within their own occupational environments. The foremost concern throughout has been that this template remain faithful to what the literature supports, modest in its claims, and open to criticism from those better acquainted with the conditions of any given workshop. The framework advances five operational components, among them a concurrent methodological configuration (exposure / outcomes / mediator) that constitutes its most substantial contribution; it reports no empirical data, proposes no safety thresholds, and appraises no identifiable individuals. It awaits at least one complete application before it can become the subject of genuine debate.

Three concluding observations encapsulate the spirit of this work.

First, industrial paint workers in the Maghrebi industrial context constitute a group neglected in the local literature: their symptoms are measured when they are measured at all, yet they are seldom studied in terms of their actual exposure or their organizational context. The utility of this work, if it has any, lies in opening the way to more rigorous designs that do justice to these workers by measuring the conditions of their work rather than attributing to them responsibility for circumstances they did not create.

Second, organizational silence, as the literature reads it, is not a purely individual psychological phenomenon but a rational response to an organizational structure within which the cost of speech is determined (Morrison & Milliken, 2000, p. 707; Lainidi et al., 2025, p. 9). Its incorporation into the occupational hazard chain, as a measurable organizational mediator, is accordingly a methodological correction to a design tradition that has overlooked it for decades.

Third, no definitive validity is claimed for the components of this framework, and the four-stage validation pathway is not rhetorical ornamentation but an explicit statement of what any researcher using the instrument must accomplish before employing it for confirmatory purposes. Instruments do not become calibrated by recommendation, but through cumulative application and reciprocal criticism.

An explicit invitation

This framework is offered for use, criticism, adaptation and refutation. The most useful thing a researcher can do with it is not to apply it as it stands, but to apply it and then report where it failed: which weights proved unworkable? which items did the workers fail to understand? which indicators failed to correlate with what they were supposed to correlate with? It is through such cumulative reporting alone that the instrument is transformed from one individual's proposal into shared knowledge.

In the final analysis, the argument on which this framework is founded is a simple one, lying at the heart of all genuine methodological work: that the researcher should measure what can be measured, refrain from claiming what cannot, and declare the limits of the work in its body rather than in its footnotes. If this work has any merit worth noting, it is, at the very least, that it has endeavoured to do so.

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