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# ACTION RESEARCH FOR HUMAN FACTORS IMPROVEMENT IN CHEMICAL SAFETY MANAGEMENT

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## 1. ABSTRACT

Chemical enterprises need a practical way to translate human-factors diagnoses into improvements that survive everyday production pressures. This article develops an action research framework for that purpose through a focused narrative review and conceptual synthesis of 18 scholarly and institutional sources, including a methodological correction. Sources cover action research, chemical-accident analysis, safety behaviour, process-safety governance, and intervention evaluation. The synthesis connects the four levels of the Human Factors Analysis and Classification System with a five-stage cycle of diagnosis, joint planning, action, observation, and reflection. Its analytical outputs are a mapping of human-factor problems to management actions, a two-cycle implementation design, and an indicator architecture separating critical-control performance, reporting activity, occupational injury, and process-safety events. The proposed first cycle examines procedure usability, task practice, and supervisory feedback; the second adapts the intervention in response to documented implementation barriers and observed control performance. Worker participation is specified as a decision process with recorded responses to proposals. Evaluation combines repeated observations, exposure-adjusted outcomes, qualitative explanations, and an explicit record of intervention changes. These are methodological results rather than evidence of an achieved reduction in accidents. The framework offers chemical enterprises a traceable route from diagnosis to organisational learning while preserving engineering controls, formal change management, and independent evaluation. Its effectiveness requires prospective validation in operating facilities.

**2.KEYWORDS:** Action Research; Chemical Safety Management; Human Factors; Worker Participation; Safety Training; Process Safety.

## 3.INTRODUCTION

Chemical safety management depends on whether engineered safeguards, operating procedures, and organisational decisions work together during actual production. The process safety management standard of the United States Occupational Safety and Health Administration (OSHA, n.d.) treats operating procedures, training, employee involvement, mechanical integrity, and management of change as connected responsibilities. The investigation of the BP Texas City refinery disaster likewise identified weaknesses in organisational oversight and safety management (U.S. Chemical Safety and Hazard Investigation Board [CSB], 2007). These sources support examining the conditions under which people work, rather than treating an operator's deviation as a complete explanation of an event.

Human-factors studies offer a structured diagnostic basis. Jiang et al. (2020) adapted the Human Factors Analysis and Classification System (HFACS) to analyse 42 hazardous-chemical storage accidents. Yalcin et al. (2023) examined 251 chemical accidents by operational activity. More recently, Ma and Jiang (2025) combined HFACS, association rules, and Bayesian networks using 62 storage-accident cases. Together, these studies direct attention to organisational resources, supervision, task conditions, and operator actions. Their retrospective associations can identify issues for investigation; they do not establish which prospective intervention will improve a particular plant.

The management problem is therefore how to turn diagnosis into a documented process of change. A training programme may address a knowledge gap while leaving an impractical procedure, unavailable equipment, or conflicting supervisory expectations untouched. A proposed improvement also needs revision when workers encounter conditions that its designers did not anticipate. Action research is relevant because it combines inquiry with deliberate change and learning across successive cycles (Lewin, 1946; Susman & Evered, 1978). Its usefulness depends on how participation, evidence, and decisions are organised, rather than on naming an existing improvement meeting an action research project.

This article asks how action research can connect multilevel human-factors diagnosis with feasible interventions and credible evaluation in chemical manufacturing. It develops a methodological framework through a focused narrative review. The contribution is a traceable relationship between a diagnosed control problem, the people authorised to change

it, the intervention tested, the evidence collected, and the next decision. The article provides analytical design outputs; it does not report completed plant fieldwork or observed accident reductions.

## 4.MATERIALS AND METHODS

### 4.1 Review design and source selection

A focused narrative review was used to integrate evidence across action research and chemical safety management. Targeted web searches were conducted on 18 October 2026 using combinations of action research, participatory action research, chemical safety, HFACS, safety training, supervisory practices, process safety indicators, and interrupted time series. The initial conceptual focus was the relationship between training, compliance, and supervision in operational work. Sources were located through publisher websites, institutional repositories, official regulatory publications, and reference links. This was a purposive review rather than a systematic search of all bibliographic databases.

Selection required an identifiable primary publication or official institutional document with direct relevance to at least one of five needs: action research methodology, human-factors diagnosis, behavioural intervention, process-safety governance, or evaluation. Foundational sources were retained without an arbitrary recent-year restriction. A recent participatory chemical-safety study was included to examine the closest direct application located in the targeted searches. Promotional accounts, untraceable numerical claims, and sources offering only general statements about safety culture were excluded from the synthesis. Eighteen publications were retained, comprising 17 substantive sources and one correction to an evaluation method. The references identify the complete selected set.

Publication details were checked against publisher or institutional records. Accessible full texts were examined where available; abstracts and original publication records supported narrower descriptive claims when full text was inaccessible. No effect size was extracted from inaccessible material, and results were not pooled. This approach supports conceptual integration but cannot estimate the prevalence or average effectiveness of action research in chemical manufacturing.

### 4.2 Synthesis procedure

The synthesis compared each source in terms of its setting, unit of analysis, diagnostic construct, change mechanism, evaluation approach, and limits of transfer. Action research principles supplied the inquiry structure; HFACS supplied the diagnostic levels; behavioural

research informed candidate mechanisms; and institutional publications established process-safety constraints. Guidance from the Health and Safety Executive (HSE, 2006) informed the focus on assurance over major-hazard controls. Table 1 records the connection between evidence domains and design decisions. The framework was then constructed by asking what observable evidence would justify retaining, adapting, or stopping an intervention at each stage.

A conceptual consistency check examined whether each proposed action addressed its diagnosed problem, whether a named decision role existed, whether its outcome could be distinguished from implementation activity, and whether its evaluation could detect an unfavourable result. This was an analytical check performed during framework development, not a Delphi study, expert validation exercise, or empirical test. Candidate interventions and indicators remain proposals even when they are informed by published evidence.

### 4.3 Action research criteria and safety governance

Davison et al. (2004) describe canonical action research through collaboration agreements, cyclical inquiry, theoretical grounding, change through action, and explicit learning. Baum et al. (2006) emphasise the involvement of people affected by the issue in reflection, evidence generation, and action. For a chemical enterprise, these principles imply a written research agreement defining the problem, worker involvement, management authority, access to evidence, confidentiality, and how disagreements will be recorded. Participation should influence the choice and revision of interventions.

The proposed field design uses a joint group of operators, supervisors, maintenance or process engineers, safety personnel, and a researcher. Worker representation should cover relevant shifts and employment arrangements; participation time should be recognised within work. Managers remain accountable for operational authorisation. A researcher facilitates inquiry and maintains the evidence record, while a separate reviewer examines outcome coding and claims of success. Changes affecting hazardous processes must pass the applicable technical review and management-of-change procedures. OSHA (n.d.) is used here as a governance reference for covered US processes, rather than as a claim about legal requirements in every country.

## 5. RESULTS AND DISCUSSION

### 5.1 Findings of the conceptual synthesis

The first result is an evidence-to-design structure linking six domains of literature (Table 1). The selected sources support treating human performance as part of a managed system, making employee involvement consequential, and examining the link between an intervention and operational performance. They do not collectively demonstrate that the proposed framework reduces chemical-plant accidents. The resulting design requirements are to define an observable control problem, give participants a documented role in decisions, preserve a record of intervention changes, and assess safety performance separately from reporting activity.

**Table 1. Evidence domains and their implications for framework design.**

| Evidence domain | Selected sources | Implication and evidence boundary |
|---|---|---|
| Action research methodology | Lewin (1946); Susman and Evered (1978); Davison et al. (2004); Baum et al. (2006) | Use collaborative inquiry, repeated action, and explicit learning. These sources establish methodological principles rather than chemical-plant effect estimates. |
| Human factors and chemical accidents | Reason (2000); Shappell and Wiegmann (2000); Jiang et al. (2020); Yalcin et al. (2023); Ma and Jiang (2025) | Connect operator actions to supervision and organisational conditions. Retrospective patterns guide diagnosis but do not identify intervention effects. |
| Training and supervision | Burke et al. (2006); Griffin and Neal (2000); Zohar (2002) | Observe trained task performance and supervisory practice. General workplace evidence requires validation in chemical operations. |
| Participatory chemical safety | Ribeiro and Ventura (2026) | Use local co-design as an implementation approach. An academic laboratory setting does not establish effectiveness in manufacturing plants. |
| Process-safety governance | OSHA (n.d.); HSE (2006); CSB (2007) | Retain formal accountability, control assurance, and change authorisation. Regulatory guidance is a design constraint, not an effect estimate. |
| Intervention evaluation | Lopez Bernal et al. (2017, 2021) | Predefine time-series contrasts and account for time trends. Methodological guidance does not resolve all confounding. |

Reason (2000) distinguishes a systems approach to error management from explanations centred on individual carelessness. HFACS offers a classification architecture spanning unsafe acts, their preconditions, unsafe supervision, and organisational influences (Shappell & Wiegmann, 2000). For intervention design, this means that a deviation should prompt examination of the supporting procedure, task conditions, supervisory response, and relevant resource decisions. A category label alone cannot establish causation, and a high frequency in historical reports does not prove that the same factor dominates the plant under study.

Evidence from chemical laboratories supplies a useful but bounded comparison. Ribeiro and Ventura (2026) describe participatory action research using workshops and locally adapted chemical-safety tools in Brazilian higher education laboratories. This provides a direct example of involving chemical users in improving practice. Its institutional setting differs from continuous manufacturing in scale, process coupling, hazardous inventory, and operating authority. The present framework therefore carries forward the collaborative method, while leaving manufacturing effectiveness to be established through prospective evaluation.

**5.2 Linking human-factors diagnosis to a research cycle**

Figure 1 sets out the proposed cycle. Diagnosis establishes the control problem and its context. Joint planning specifies the change, responsibilities, and evidence criteria. Action implements an authorised intervention. Observation records its delivery, use, and consequences. Reflection compares expectations with evidence and determines the next version. Table 2 connects this sequence with HFACS levels so that training is not prescribed automatically for every diagnosis.

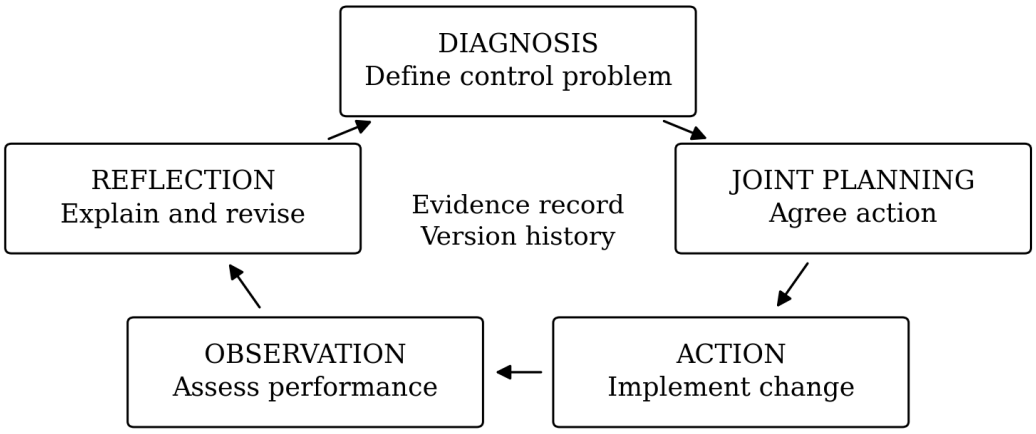



**Figure 1. Proposed action research cycle for chemical safety management.**

**Table 2. Translating HFACS diagnoses into action research decisions.**

| Diagnostic level | Candidate intervention | Evidence to examine in reflection |
|---|---|---|
| Organisational influences | Review staffing, maintenance resources, and procedure ownership with an accountable manager. | Resource decisions, unresolved constraints, recurrence of the same control failure, and reasons for rejected worker proposals. |
| Unsafe supervision | Co-design brief field checks, behaviour-specific feedback, and escalation support. | Observed feedback, consistency between shifts, responses to work pauses, and independently verified action closure. |
| Preconditions for unsafe acts | Examine workload, handovers, access to equipment, and task readiness; redesign the conditions that obstruct safe work. | Handover omissions, task interruptions, equipment availability, and workers' accounts of procedure feasibility. |
| Unsafe acts | Practise selected critical steps in a safe setting and improve task instructions through authorised procedures. | Correct performance of predefined steps, reasons for deviations, and whether relevant barriers function during work. |

Interventions are proposed examples requiring site-specific assessment.

A candidate problem could be incomplete verification during a hazardous-material transfer or omission of critical information at a shift handover. These are application examples, not findings from an observed enterprise. The joint group would first verify whether the problem occurs, which controls are affected, and whether the proposed scope is small enough to study without obscuring serious risks. Existing safeguards and formal incident responses remain in force throughout the inquiry.

For each selected problem, an intervention record should identify the relevant task and control, the supporting evidence, the proposed mechanism, accountable roles, implementation date, and measures. Its revision history should explain what changed and why. This record connects improvement decisions to the research question. A routine plan-do-check-act process can accommodate repeated improvement; an action research study additionally needs an explicit inquiry, participant involvement in interpretation, a defensible evidence trail, and an account of learning that other settings can assess.

### 5.3 First cycle of diagnosis and intervention

The first cycle should begin with a bounded operational area and a baseline period defined before interpreting intervention results. Selection should consider hazard significance, available records, operational stability, and access to relevant shifts, rather than convenience

alone. Serious hazards discovered during diagnosis require immediate operational action and must not be left unresolved to preserve a comparison period. Any such action should be documented as part of the intervention context.

Baseline inquiry would combine observations of selected tasks, interviews or small-group discussions, current procedures, training records, and relevant incident or maintenance records. Observers should use a site-specific list of critical controls derived from the plant's hazard analysis and authorised operating requirements. Two reviewers should independently code a prespecified portion of the material, reconcile disagreements, and document the coding rules and the extent of agreement. HFACS categories guide questioning; they should not force every observation into a predetermined causal explanation.

Joint planning then distinguishes knowledge problems from barriers to applying knowledge. If workers cannot identify a critical step, scenario practice and feedback may be appropriate. If workers know the step but lack equipment or time, the response must address the enabling conditions. Burke et al. (2006) provide evidence favouring engaging safety-training methods involving practice and dialogue. Their findings support considering active learning, but do not establish a plant-specific effect or justify replacing engineered safeguards with training.

The proposed action package combines task practice, review of procedure usability, and supervisory feedback only where diagnosis supports those components. Practice should take place in simulations or other authorised settings that do not introduce uncontrolled process risk. Operators can examine whether instructions match the actual sequence of work; engineers evaluate the safety implications of revisions; supervisors test whether field checks and feedback fit the work schedule. Required technical approvals precede implementation. Intervention delivery, reach across shifts, and deviations from the agreed design should be recorded.

Observation needs to distinguish attendance from transfer to work. Griffin and Neal (2000) distinguish required safety compliance from broader safety participation, making both relevant but different outcomes. Independent observation of selected critical steps can assess compliance, while records of proposals and decisions can assess participation. The cycle closes with a reflection meeting that considers quantitative patterns, worker explanations, unresolved constraints, and contradictory evidence. Its output is a written decision to retain, revise, or discontinue the intervention components, with reasons and an accountable owner.

### 5.4 Second cycle of adaptation and organisational learning

The second cycle is triggered by what the first cycle reveals. Repeating an unchanged training session would not address evidence that the original intervention failed because of equipment access, workload, or ambiguous responsibility. The joint group should select the next change from documented findings, revise the proposed mechanism where necessary, and establish a new version date. The report should distinguish planned adaptation from unplanned departures that occurred without review.

For example, improved task knowledge accompanied by unchanged critical-step performance would direct attention to transfer conditions. If observations and interviews indicate that production scheduling prevents the agreed verification, the next intervention could examine scheduling and supervisory escalation. Zohar (2002) studied an intervention targeting supervisory monitoring and reinforcement, supporting the inclusion of supervisory practice as a candidate change mechanism. Its workplace findings cannot be treated as proof of equivalent benefits for chemical process safety.

Reflection also needs to examine whether workers influence organisational decisions. Records should show which proposals were accepted, modified, rejected, or left unresolved, together with explanations. A worker should be able to challenge an impractical change or identify an unintended consequence without having a survey response or research interview used as a performance rating. An improved checklist that increases workload or shifts risk to contractors should prompt redesign even if its completion rate rises.

Successful components may be incorporated into controlled procedures, competence requirements, supervisor routines, and resource plans after verification. Expansion to another task or production unit should begin with a new assessment of hazards and operating conditions. The transferable output is an explanation of the mechanism, conditions, and evidence behind an intervention, rather than a claim that the same package will work throughout the chemical industry.

### 5.5 Measurement and evaluation design

Table 3 specifies the proposed measurement architecture. Its purpose is to avoid confusing delivery, reporting, behaviour, and operational events. HSE (2006) provides a process-safety indicator approach concerned with assurance over major-hazard controls. Building on that objective, each plant should identify a small set of measures connected to its selected critical controls and state exactly how numerators, denominators, and observation opportunities are obtained.

**Table 3. Proposed measures and rules for interpretation.**

| Measure | Operational definition | Interpretation rule |
|---|---|---|
| Critical-step adherence | Correctly completed applicable critical steps divided by applicable steps independently observed; report numerator and denominator. | Analyse by task and shift; account for repeated observations and retain serious individual failures. |
| Verified action closure | Actions verified effective by their agreed due date divided by actions due in the period. | Track overdue age and reopened actions separately; a signed closure alone is insufficient. |
| Participation in decisions | Worker proposals receiving a documented decision and explanation divided by proposals submitted. | Also examine who proposed and decided, whose proposals were adopted, and reasons for rejection. |
| Near-miss reporting | Reports per 10,000 work hours, accompanied by completeness and reporting-delay measures. | A rise can reflect greater willingness to report; examine control failures and reporting conditions together. |
| Occupational injury | Separately classified injury counts and rates using a stable case definition and an explicitly stated hours denominator. | Do not infer process-safety performance from personal injury rates. |
| Process-safety events | Separate counts by stable release and severity criteria; report relevant operating hours or task exposure where defensible. | Retain severity categories. Do not merge releases, injuries, and reports into a single score. |

The preferred primary measure is performance of the critical control implicated in the chosen problem. Observations should sample relevant tasks and shifts using a stable protocol, with trained observers who are not solely responsible for delivering the intervention. The analysis should report observation coverage and account for repeated steps within tasks and repeated tasks within work groups. A zero denominator means that no rate can be calculated; it does not represent perfect performance. Aggregate adherence should not conceal a single serious failure in a high-consequence step.

Near-miss reports require particular care. Reporting can increase when employees become more willing to disclose problems, even if underlying control performance improves. Interpretation should therefore combine report frequency with content quality, delay, independent observations, and evidence of actual control failures. The CSB (2007) recommendations include reporting without retaliation and tracking corrective-action closure. In the proposed design, reporting measures are indicators of visibility and learning as well as possible risk signals, and are not assigned an automatic favourable or unfavourable direction.

Occupational injuries and process-safety events should remain separate. Each needs a stable definition, relevant exposure information, and a consistent severity classification across cycles. A single event should not be counted several times merely because it involved an operator, a supervisor, and a maintenance team. Events with both injury and release consequences can appear in distinct domain-specific summaries, with their linkage made explicit. No combined human-error score is proposed, and a short period without a major accident cannot establish prevention of rare catastrophic events.

Where sufficient repeated observations exist, evaluation can use an interrupted time series with a prespecified intervention date, underlying trend, and expected form of change. The approach should follow the corrected specification described by Lopez Bernal et al. (2017, 2021). Counts may require a count-data model with an appropriate exposure offset; proportions require their underlying denominators. Autocorrelation, seasonality, shutdowns, product mix, staffing changes, and parallel safety initiatives need consideration. Distinct intervention versions should be marked rather than analysed as one unchanging exposure.

A comparable production unit, when available, can strengthen interpretation by showing whether similar changes occurred elsewhere. Its suitability depends on comparable hazards, operations, measurement, and baseline trends; contamination between units should be documented. Required series length and sampling intensity must be assessed against event frequency, clustering, and expected effects before fieldwork. A simple before-and-after difference can be reported descriptively when data are sparse, but cannot isolate the intervention from concurrent changes. Essential safeguards must never be withheld to create a comparison.

Qualitative evidence should explain both improvement and failure. Interviews, observation notes, and decision records can be coded for procedure feasibility, supervision, resource constraints, willingness to report, and unexpected effects. A joint evidence display should link each measured change with its timing, implementation record, participant explanation, and plausible rival explanation. Disagreement between data sources should remain visible. For example, better self-reported compliance with unchanged independent observations would weaken a behavioural improvement claim and justify further inquiry.

### 5.6 Theoretical and practical implications

The framework extends the practical use of HFACS by connecting diagnostic categories to authorised changes and repeated evaluation. It preserves a systems interpretation of human performance: learning to perform a task is useful only when the procedure, work conditions,

and supervisory response allow that performance. Training, compliance, and supervision remain central, while worker participation supplies a way to discover and revise barriers that a predetermined training model might overlook.

Action research also changes the unit of learning. An enterprise needs to know whether a particular control problem became less frequent, how the intervention was used, and why it succeeded or failed under specified conditions. A causal account becomes more credible when the predicted mechanism, observed behaviour, timing, and operational evidence agree and plausible alternatives are examined. Participation improves access to explanations but does not itself establish causation. Likewise, agreement among managers and workers is valuable for implementation while remaining open to challenge by independent evidence.

For practitioners, the immediate output is a manageable inquiry around a real task, with clear decision rights and a limited set of meaningful measures. Small enterprises may use a simplified record combining the diagnosed problem, agreed change, responsible person, evidence, and next decision. More complex facilities may require specialist support for observation design, event classification, and repeated-measures analysis. In both cases, the method complements process-hazard analysis and engineering assurance; the research cycle has no authority to relax operating safeguards.

### 5.7 Limitations and research agenda

The evidence base was selected purposively and is subject to search, language, and accessibility bias. The review did not conduct duplicate systematic screening or a formal risk-of-bias assessment, and some descriptive claims rely on abstracts or publication records. Its synthesis spans different sectors and includes methodological, regulatory, and empirical sources that cannot be combined as equivalent tests of effectiveness. The participatory chemical-safety example concerns laboratories, and the reviewed accident analyses concern retrospective cases. Direct support for the complete manufacturing framework is therefore limited.

The proposed framework has not been validated by plant implementation, expert consensus, or new participant data. It cannot establish which intervention component is effective or how long improvements persist. Researcher involvement and management power may influence participation, observation, and reporting. Future studies should publish the research agreement, baseline definitions, intervention versions, missing-data decisions, and negative as well as favourable findings. Replication across operating tasks and enterprises, followed

by stronger comparative designs where feasible, is needed before making general claims about accident reduction.

## 6. CONCLUSION

Action research offers a structured way to investigate why diagnosed human-factor problems persist and to revise safety interventions with the people who perform and authorise the work. The framework developed here connects HFACS levels with collaborative diagnosis, joint planning, authorised action, observation, and reflection. Its methodological contribution is a traceable relationship between a control problem, an intervention, the evidence used to assess it, and the next management decision. Separate treatment of reporting activity, critical-control performance, occupational injury, and process-safety events protects the interpretation of improvement. Prospective field studies are required to determine whether this approach produces sustained changes in chemical manufacturing.

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Data availability. No new participant or enterprise data were generated or analysed. The published sources supporting the conceptual synthesis are listed in the references.

Ethics. This article analyses published material and does not report human-participant fieldwork. Any subsequent study involving workers or identifiable operational records requires the applicable institutional review, enterprise authorisation, data protections, and informed-consent procedures before recruitment or collection.

Use of generative artificial intelligence. ChatGPT (OpenAI) assisted with literature discovery, drafting, language editing, and document preparation. Bibliographic details were checked against publisher and institutional records. The named authors are responsible for the submitted text and its claims.

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