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Assessing occupational hazards in the charcoal industry: a systematic review of exposure measurements, health outcomes and control measures

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Yoerdy Agusmal Saputra¹, Yuanita Windusari¹

¹Universitas Sriwijaya



Yoerdy Agusmal Saputra

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Abstract

Background: The charcoal industry employs large numbers of workers globally, particularly in low- and middle-income countries, and combines multiple physical, chemical, and thermal workplace hazards. Evidence about exposure levels, health outcomes, and effective control measures is fragmented across small field studies, program reports, and a limited epidemiological literature. A systematic synthesis is needed to clarify real-world risks and identify evidence gaps to inform occupational surveillance and prevention.

Objective: To systematically identify, appraise, and synthesize published and grey-literature evidence on occupational hazards in the charcoal industry, specifically: (1) which exposures occur and the magnitudes reported; (2) which health outcomes are associated with charcoal work; and (3) what workplace controls or interventions have been described and evaluated.

Methods: We will conduct comprehensive searches of MEDLINE/PubMed, Scopus, ProQuest, SpringerLink, Google Scholar, and Web of Science for studies published from 1 January 2000 to 9 November 2025 in English or Indonesian. Search strategies will combine controlled vocabulary (MeSH/EMTREE where available) and free-text terms for charcoal, occupational exposure, and relevant hazards/outcomes; reference lists and citation tracking will supplement database searches. Eligible studies include observational epidemiology (cross-sectional, cohort, case-control), exposure assessment studies, intervention/evaluation reports, relevant case reports/series, and qualitative studies; laboratory or animal studies without workplace data will be excluded.

Records will be de-duplicated and screened in two stages by two independent reviewers; data extraction will be performed using a piloted form by two reviewers. Risk of bias will be assessed with design-appropriate tools (Newcastle–Ottawa/ROBINS-I, AXIS/JBI adaptations, RoB2 where applicable) plus a structured checklist for exposure-assessment quality. Data synthesis will be primarily narrative; where ≥ 2 studies report comparable quantitative outcomes (e.g., mean PM_{2.5}, pooled effect estimates), random-effects meta-analysis will be considered. Heterogeneity will be assessed via I^2 and Cochran's Q; publication bias will be assessed where appropriate. Planned subgroup and sensitivity analyses include region, worker subgroup, exposure metric (personal vs. area), study design, and informal vs. formal production. Certainty of evidence will be appraised using GRADE (adapted for observational evidence).

Dissemination: Results will be reported following PRISMA, submitted for peer review, and shared with occupational health stakeholders and NGOs active in biomass and rural industries.

Guidelines

Study designs: Observational epidemiology (cross-sectional, cohort, case–control), exposure assessment studies, case reports/series (if informative), intervention/evaluation studies, and qualitative studies providing contextual information. Experimental laboratory studies not directly assessing occupational conditions will be excluded unless they evaluate exposure–health relationships directly relevant to workplace exposures.

Language and date limits: Studies published in English or Indonesian between 2000-01-01 and 2025-11-09 (search may be extended on request).

Searches and sources: Systematic searches will be conducted in MEDLINE/PubMed, Scopus, ProQuest, SpringerLink, Google Scholar, and Web of Science. Reference lists of included studies and citation-tracking of key papers will be performed. Search strategies will combine controlled vocabulary (MeSH/EMTREE) and free-text terms for charcoal, occupational exposure and relevant hazards/outcomes. All search strings and dates will be recorded.

Screening and selection: Records will be de-duplicated and screened in two stages (title/abstract, then full text) by two independent reviewers. Discrepancies will be resolved by discussion or third-party adjudication. Reasons for exclusion at full text will be recorded.

Data extraction: A piloted extraction form will capture: study identifiers, country/setting, population characteristics (age, sex, worker type), study design, sample size, exposure assessment methods and results (sampling method, metric, concentrations), outcome definitions and measures, effect estimates (with CIs), control measures/PPE details, confounders considered, and authors' conclusions. Two reviewers will extract data independently; disagreements resolved by consensus.

Risk of bias/quality assessment: Appropriate tools will be used by study design: Newcastle–Ottawa Scale or ROBINS-I for cohort/case–control/non-randomised studies, AXIS or adapted JBI checklist for cross-sectional and prevalence/exposure studies, Cochrane RoB2 for any randomized evaluations, and a structured checklist for exposure-assessment methodological quality (sampling strategy, instrument calibration, personal vs area sampling, duration). Two reviewers will assess risk of bias independently.

Data synthesis: A narrative synthesis will describe exposures, methods and outcomes across studies. Where ≥ 2 studies report comparable quantitative outcomes (e.g., mean PM_{2.5} concentrations or pooled effect estimates for a specific health outcome), meta-analysis will be considered using a random-effects model. Statistical heterogeneity will be assessed with I^2 and Cochran's Q. If meta-analysis is not appropriate, results will be tabulated and synthesised narratively. Publication bias will be examined with funnel plots and Egger's test where ≥ 10 studies are combined.

Planned subgroup and sensitivity analyses: Where data allow: subgroup analyses by region/country income level, worker subgroup (kiln operator, transport, packing), study design, exposure metric (personal vs area sampling), and by informal vs formal production. Sensitivity analyses will exclude studies at high risk of bias.



Assessment of evidence certainty: The GRADE approach (or an adapted GRADE for observational evidence) will be used to rate the certainty of evidence for primary outcomes.

Reporting and dissemination: Findings will be reported according to PRISMA guidelines, including a flow diagram, summary tables of exposures and outcomes, risk-of-bias assessments, and gaps/recommendations. Results will be submitted for peer-reviewed publication and shared with occupational health stakeholders and NGOs working in biomass/charcoal sectors.

Secondary objectives

- 1 To estimate typical exposure concentrations (e.g., PM2.5/PM10, respirable dust, carbon monoxide, PAHs, VOCs, heat) reported in charcoal production, processing and related activities.
- 2 To summarise the range, frequency and estimated effect sizes for health outcomes linked to charcoal work (respiratory disease and symptoms, lung function, burns and injuries, musculoskeletal disorders, dermatologic conditions, biomarkers of exposure, acute carbon monoxide poisoning and any reported cancer associations).
- 3 To describe methods used for exposure assessment and outcome ascertainment and evaluate common methodological strengths and limitations.
- 4 To identify and summarise reported workplace controls, PPE use, training or interventions and any evidence of their effectiveness.
- 5 To map geographic, demographic and methodological gaps and provide recommendations for research, surveillance and occupational health practice.

Outcomes

- 6 Measured exposure metrics (air concentrations, personal sampling, biomarkers), health outcomes (respiratory symptoms/diagnoses, spirometry, injuries/burns, musculoskeletal complaints, dermatological effects, biomarkers, cancers, mortality, mental health outcomes), and measures of control/PPE effectiveness.

Study designs

- 7 Observational epidemiology (cross-sectional, cohort, case-control), exposure assessment studies, case reports/series (if informative), intervention/evaluation studies, and qualitative studies providing contextual information. Experimental laboratory studies not directly assessing occupational conditions will be excluded unless they evaluate exposure-health relationships directly relevant to workplace exposures.

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Risk of bias/quality assessment

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Reporting and dissemination

- 16 Findings will be reported according to PRISMA guidelines, including a flow diagram, summary tables of exposures and outcomes, risk-of-bias assessments, and gaps/recommendations. Results will be submitted for peer-reviewed publication and shared with occupational health stakeholders and NGOs working in biomass/charcoal sectors.