Improving Work Conditions in the Bangladesh Brick Sector

Pre-Analysis Plan

March 30, 2026

This document outlines the analysis plan for the cluster randomized controlled trial of an integrated ZZK2.0 refresher training and work conditions improvements for brick kiln owners and workers, for the “Improving Work Conditions in the Bangladesh Brick Sector: A Cluster Randomized Controlled Trial” project. The document provides a pre-specified methodology and plan for analyzing the results of the experiment.

1 Study Overview

Millions of people living in poverty in Bangladesh are threatened by accelerating climate change and worsening air quality. The brick kiln sector in Bangladesh poses two major threats. It is a major contributor to air pollution, while also subjecting workers to unsafe and exploitative labor conditions (Das et al., 2017). Its $\sim$7,000 brick kilns produce 27 billion bricks each year, generating 11% of the country’s particulate matter, 22% of black carbon, and 17% of total annual CO_2 emissions (Eil et al., 2020). In major cities in Bangladesh during the wintertime when air quality is worse, brick kilns contribute 30 to 58% of the small particulate matter (PM 2.5) (Eil et al., 2020). Exposure to air pollutants contributes to morbidity, mortality, childhood pneumonia and adverse birth and cognitive outcomes (Landrigan et al., 2018). Despite the promotion of zigzag kilns (ZZK) since 2013, most conversions have been implemented poorly (Eil et al., 2020; Alam and Barman, 2019).

Our randomized controlled trial (RCT) with 276 kilns in Khulna Division during the 2022–2023 season introduced Zigzag 2.0 (ZZK 2.0), a package of technical training and operational support for kiln owners and managers (Brooks et al., 2025). Adoption of the two most critical practices, improved brick stacking and more frequent coal feeding, resulted in 24% less coal use per 100,000 bricks produced and reductions of 21% in both CO_2 and PM2.5 emissions (Brooks et al., 2025). Importantly, Zigzag 2.0 also delivered economic wins to owners in the form of reduced spending on coal and greater production of the highest quality bricks. Owners perceived these improvements, which increased sustained uptake—in fact, one year later nearly 99% of kilns which had adopted Zigzag 2.0 continued to follow the practices. At the request of the Ministry of Environment, Forest and Climate Change, this intervention has now been scaled to 500+ kilns nationwide in 2024–2025.

In contrast, the conditions faced by kiln workers remain understudied and under-addressed. Workers, often low-income seasonal migrants, are routinely exposed to unsafe, coercive, and exploitative conditions (Miller et al., 2024). In our recent survey, about 70% reported lacking basic personal protective equipment (PPE), such as gloves, boots, or masks (Miller et al., 2024). This exposes them to frequent burns, head injuries, eye irritation, and chronic respiratory illness from smoke inhalation (Sanjel et al., 2016).

Work conditions compound these risks. Shifts typically last 12–16 hours, often near coal-fired chambers burning above 800°C (Maithel et al., 2017). Kilns rarely provide shaded rest areas, safe drinking water, or heat breaks, creating conditions ripe for dehydration, heat exhaustion, and long-term cardiovascular and renal disease (Flouris et al., 2024). Many workers and their families also live onsite at kilns in inadequate housing that lacks basic sanitation and privacy, further compounding health risks and exposure to hazardous conditions.

The labor system itself is marked by coercion. Many workers in our Khulna Division sample entered through debt-bondage contracts, leaving them unable to exit even when wages are withheld or benefits denied—practices reported by over 10% of workers (Miller et al., 2024). Moreover, child labor is pervasive—reported in more than 70% of kilns in our previous study—with families often migrating together and children contributing to manual tasks under hazardous conditions (Miller et al., 2024). The informal nature of the industry prevents effective labor regulation, and the absence of formal contracts (reported by 71% of workers) strips them of any legal protections (Das et al., 2017). This combination of physical hazards, economic coercion, and social vulnerability represents a critical human rights and public health issue.

Our past ZZK 2.0 energy-efficiency intervention brought measurable reductions in emissions and fuel use (Brooks et al., 2025), yet work conditions remain hazardous. In other settings, occupational health interventions in South Asia have focused on PPE distribution or training but without rigorous evaluation in coercive labor settings (Shoaib et al., 2024). Improving work conditions for this vulnerable population requires filling key knowledge gaps. For example, it is unknown whether low-cost workplace interventions such as shaded rest areas, hydration access, or PPE can actually improve worker health and well-being. Second, brick kilns operate through complex management hierarchies—with owners often distant from daily operations while managers and sardars (labor contractors and supervisors) control recruitment, payment, and work conditions. There is limited evidence on whether and how interventions can work through these management structures to significantly reduce coercive labor conditions, or whether owners and their managers can be motivated to make improvements that reduce labor exploitation (Miller et al., 2024). Third, we lack evidence on whether integrating worker protections into profitable improvements to kiln operation (Zigzag 2.0) can create synergistic benefits for both worker well-being and productivity, which is particularly relevant in a context with limited enforcement of labor regulations.

This study builds directly on the success of Zigzag 2.0, enhancing it with a new package of worker-centered interventions ("Zigzag 2.0+") that target work conditions and labor exploitation. Specifically, the new package integrates worker protection measures—including personal protective equipment (PPE) provision, workplace and living condition improvements, and wage payment monitoring—into the existing Zigzag 2.0 technical training and operational support framework. We hypothesize that combining worker welfare improvements with a profitable business model can take advantage of owners' economic incentives to generate meaningful improvements in labor conditions. By implementing this intervention as a randomized controlled trial, we aim to generate causal evidence on whether simple, low-cost workplace improvements can protect workers and enhance well-being, without undermining kiln productivity.

Our cluster randomized controlled trial has the following objectives:

1. Measure use and availability of essential PPE and impacts on self-reported workplace injuries.

2. Measure uptake of different workplace improvements and the quality of work and living conditions.

3. Measure impacts on wage withholding and timeliness of pay.

4. Measure impacts on labor trafficking, child labor.

2 Research Design

2.1 Sampling and Randomization

We used our database of past study kilns to create a list of 215 kilns which had already adopted ZZK2.0 in Jashore, Jhenaidah and Shatkhira districts of Khulna Division (selected due to the high number of adopters). Field teams approached these kilns, secured their consent to participate in the trial, and conducted a baseline survey. From the list of the adopted zigzag kilns, we stratified the kilns into five strata, based on prior project enrollment groups: pilot, RCT-control, RCT-technical arm, RCT-incentive information arm, and scaling.[1]

Within each stratum, we aimed to assign approximately 60% of kilns to the treatment group and 40% to the control group. For the four strata with consistent baseline data (all except the "scaling" arm), we used a re-randomization procedure to ensure balance on a broad set of pre-specified covariates, including kiln owner characteristics, kiln structural features, and past production metrics. Specifically, we repeatedly generated random assignments until we found one for which the absolute value of the Welch t-statistic for the difference in means between the treatment and control groups was less than 1.2 for every covariate. For the 'scaling' stratum, where covariate data was unavailable, we conducted a simple (unrestricted) randomization (Li and Ding, 2020).

This procedure resulted in an initial sample of 127 kilns assigned to the treatment group and 88 kilns to the control group. During baseline data collection, we then subsequently observed an approximate 20% non-operation rate among these kilns. Given available budget and implementation capacity, we therefore expanded our sample by identifying 36 additional operating kilns in close-by districts. This sixth "expansion" stratum included kilns which had adopted ZZK2.0 both through our previous programs, or independently had done so. Because baseline covariate data were not available for most expansion kilns, we assigned them to treatment and control groups using simple (unrestricted) randomization with the same 60/40 target allocation. The final targeted sample includes 251 kilns: 103 kilns assigned to the control group, and 148 kilns to the treatment group, a strategy that maximizes statistical power accounting for imperfect uptake among the treatment group, yielding a sample size of 103*5=515 workers in the control group and 148*5=740 workers in the treatment group.

[1]These strata are determined based on our research's group prior work in the Khulna Division of Bangladesh and reflect the different timing and nature of the ZZK2.0 delivery. Pilot refers to kilns that were included in the pilot study of ZZK 2.0 conducted in Jashore district among 30 kilns in the 2021-2022 brick firing season (Brooks et al., 2024). RCT kilns were enrolled in the randomized controlled trial of ZZK 2.0 conducted across 6 districts of Khulna Division during the 2022-2023 brick firing season Brooks et al. (2025). We created separate strata for kilns that were assigned to the control arm, technical-only arm, and incentive information arm, to reflect the different information and training provided on ZZK 2.0 as well as regarding work conditions. Scaling kilns are those that received technical training on ZZK2.0 during the 2023-2024 brick firing season during our team's ramp up on ZZK2.0 across Khulna and Dhaka Divisions, at the request of the Bangladesh Government.

2.2 Intervention

Owners of kilns in the intervention arm receive an integrated ZZK 2.0+ intervention which includes: (1) a training session combining a Zigzag 2.0 technical refresher with worker condition improvement (WCI) orientation, (2) individualized action planning meetings to develop kiln-specific implementation plans, and (3) ongoing field support throughout the brick production season. The WCI package is designed to enhance occupational safety, improve payment practices, and improve living conditions for kiln workers. The intervention will be delivered through a 4-hour integrated training session in November-December 2025, after baseline data has been collected. These trainings will be delivered at central kiln locations with 15-20 kilns per session. These initial group sessions will be followed by monthly site visits (60-90 minutes each) including: observation of PPE use, facility conditions; payment verification form collection; troubleshooting conversations, quarterly review meetings (2 hours) with clusters of owners to share progress, challenges and adaptive solutions, phone support available between visits for urgent technical and implementation issues.

Relationship to companion PAP and bundled intervention description. This trial evaluates a single, integrated ZZK 2.0+ package delivered as a bundled, multi-component intervention. We pre-specify two related PAPs for the same experiment: this PAP focuses on work conditions and labor outcomes, while a companion PAP focuses on heat-stress outcomes. Both PAPs describe the full intervention package, but each emphasizes the components most directly relevant to its primary outcomes. In this work-conditions PAP, we emphasize PPE provision, wage-payment monitoring, and workplace/living-condition improvements, while noting that heat-mitigation measures were also delivered as part of the package.

Intervention Components (Specified using the TIDieR framework)

Component 1: Personal Protective Equipment (PPE) and Occupational Safety

What (materials):

- Improved wooden shoes (khoroms) for the firemen
- Dust masks (cloth or disposable) for coal crushers, loaders, unloaders and molders
- Protective gloves for coal handlers, brick loaders and unloaders
- Local protective headwear (Bida) for unloaders
- Caps and towels (gamcha) for heat/dust protection for all workers
- First aid kits containing: bandages, antiseptic, pain relievers, burn ointment, oral rehydration salts (ORS)

What (procedures):

- Owners procure PPE supplies before season starts based on worker counts
- PPE distributed to workers at the beginning of the season or upon arrival
- First aid kits placed in accessible central locations (e.g., manager's office, rest areas)

- ORS sachets made available during hot months (March-May)

Who provides: Kiln owners purchase and distribute; field staff provide procurement guidelines and supplier contacts

Dose/intensity: One complete PPE set per worker at season start; replacement items available as needed; first aid supplies replenished monthly

Component 2: Wage Payment Monitoring System

What (materials):

- Standardized weekly wage tracking forms documenting: worker names, job categories, agreed wages, amounts paid, dates, payment method, signatures

What (procedures):

- Managers/owners complete forms weekly
- Forms submitted to field staff during monthly visits
- Owners conduct at least monthly direct check-ins with workers of different groups (separate from sardars) about payment satisfaction
- Any reported discrepancies documented and followed up within one week

Who provides: Field staff train managers on form completion; managers implement weekly; field staff collect and review

Dose/intensity: Weekly form completion throughout 6-month season (8 to 10 forms per kiln); monthly owner-worker engagement sessions

Component 3: Workplace and Living Condition Improvements

What (materials):

- Toilet cleaning supplies: Harpic or similar cleaning agent, brushes, soap bars
- Handwashing stations: soap bars or soapy water containers placed near toilets and work areas
- Drinking water: clean water sources positioned near resting areas
- Infrastructure improvements (where feasible): temporary shaded rest areas with mats; ventilation improvements to worker housing (windows, vents); fans in rest areas (if possible)

What (procedures):

- Cleaning supplies provided at start of season and replenished monthly
- Designated cleaning responsibilities assigned (either hired cleaner or rotation among workers)
- Weekly checks by managers to ensure supplies are available and facilities functional

Who provides: Owners procure and provide supplies; field staff provide facility improvement guidance and cost estimates

Dose/intensity: Continuous availability of cleaning/hygiene supplies throughout season; infrastructure improvements implemented within first 2 months

Component 4: Heat Mitigation Strategies

What (materials/procedures):

- Shaded rest areas near high-heat work zones (molding, firing areas)
- Clean drinking water stations positioned within 50 meters of all work areas
- ORS sachets provided for free and consumption encouraged during hot months (March-May)
- Work breaks: encourage at least 15-minute rest breaks every 2-3 hours during peak heat (11am-3pm)

Who provides: Owners establish infrastructure; managers enforce break policies; field staff provide heat safety orientation materials

Dose/intensity: Continuous access to shade and water; daily ORS availability in hot months; break policies communicated at season start and reinforced monthly

Component 5: Child Labor Awareness and pathway to prevention (Supplementary Component)

Note: This is a supplementary component of our intervention which we are piloting in this project. We do not anticipate that child labor can change much during a single season because our preliminary qualitative work suggests that the most effective way to reduce child labor is to discourage parents from bringing their children to kilns for a brick season (and once present, children are unlikely to be sent home). However, we include this component as part of our intervention to better establish awareness about child labor, and while unlikely, secondary changes to reduce child labor within a single brick season remain possible.

What (materials):

- Parental and owner/sardar awareness materials explaining risks of child labor and legal prohibitions
- Encourage owners and sardars to include in their contract templates a clause: "No workers under age 18 shall be employed"- This was acceptable and aligned with owners motivations to meaningfully address child labor at the onset
- Get commitment to include NID card verification protocol and photocopy collection forms from next season

What (procedures):

- Owners and managers will be sensitized about national child labor laws and their role in it
- Owners encouraged to include age verification clause in all sardar contracts before next season
- Sardars instructed to collect NID photocopies from all workers at recruitment for next season
- Sardars receive orientation on child labor laws and importance/awareness regarding child labor reduction (30-minute session)
- Awareness sessions/conversations with parents of children under 18 years at the kilns to encourage continuation of education and discourage involvement in income-generating activities.

Who provides: Field staff will sensitize sardars; owners enforce contract terms; managers verify documentation

Dose/intensity: One-time contract updates for the next season; at least one parental awareness conversation per family with children present

2.3 Data Collection

We developed the following quantitative data collection tools:

1. worker survey (baseline and endline)
2. kiln observation checklist
3. manager survey (endline)

Baseline survey (November-December 2025)
Prior to the start of the intervention, we will administer a comprehensive baseline survey across all study kilns. At each kiln, five adult workers will be randomly selected across the main job categories at brick kilns: firemen, molders, coal crusher, loaders, and unloaders, yielding a study population of approximately 1200 workers. Eligible participants include adult kiln workers (aged 18 and above) who have been employed for at least two weeks during the production cycle across primary job categories (molding, loading, stacking, and firing). Exclusions apply to those unable to provide informed consent or those in supervisory/non-production roles. The survey will capture detailed worker information, including demographics, employment status, and occupational exposures. Specific modules will measure access to PPE, payment practices, availability of rest and sanitation facilities, and self-reported health and well-being. A kiln observation form will be filled to capture baseline conditions of the kiln including living conditions and timely payment mechanisms used by managers. Baseline data was ultimately collected from a sample of 199 kilns (118 in treatment and 81 in control) and 1000 workers.

Ongoing monitoring (November 2025–April 2026)
Monitoring will occur throughout the kiln production season. Quantitative monitoring in intervention kilns will include regular audits of PPE availability and use, verification of wage payment records, inspections of sanitation and rest facilities, and short worker surveys on occupational safety, health, and well-being. Data from these monitoring activities will be used to adapt and refine the intervention in real time, ensuring responsiveness to local challenges.

Endline survey (projected April 2026 -May 2026)
Towards the end of the kiln season, we will collect an endline survey using instruments parallel to the baseline. This will allow for the measurement of uptake, changes in PPE availability and use, wage payment practices, access to rest and sanitation facilities, proportion of child labor, and worker health outcomes. Additional modules will capture worker satisfaction, well-being, and productivity indicators, as well as owner perceptions of costs and benefits associated with the intervention. A kiln observation form will be filled to capture endline conditions of the kiln including living conditions and timely payment mechanisms used by managers. We intend to collect measurements from the same workers, to create pre/post intervention paired measurements, but in the event the same worker cannot be found or refuses to participate in endline measurements, we will collect endline measurements from a replacement worker, if possible in the same category.

For outcomes measured both through worker surveys, manager survey, and through enumerator observation, we will characterize the extent and direction of any discrepancies and discuss implications for interpreting worker-reported outcomes that lack enumerator validation.
Purposive qualitative assessment
To understand implementation experiences, barriers to adoption, and mechanisms of change, we will conduct in-depth interviews with stakeholders from purposively selected kilns representing varied implementation contexts. Selection will stratify kilns based on intervention adherence levels (high, moderate, low) as observed during monitoring visits, allowing us to identify facilitators and obstacles to successful implementation across different contexts. A team of trained qualitative researchers will conduct semi-structured interviews with approximately 10-15 firemen, 10-15 brick loaders. 10-15 workers from other job categories, up to 15 managers and 20 owners.

Qualitative objectives: These interviews will explore: (1) perceived usefulness and feasibility of each intervention component; (2) contextual factors that enabled or were barriers to implementation; (3) unintended consequences or spillover effects; (4) recommendations for adaptation in future scale-up; and (5) mechanisms through which the intervention may have affected (or failed to affect) worker health, safety, and economic outcomes.

3 Outcomes and Power Calculations

As described above, five adult workers were randomly selected across the main job categories at brick kilns: firemen, molders, coal crusher, loaders, and unloaders, yielding a study population of approximately 1,000 workers from the 199 enrolled kilns. The sample will be split by gender with an approximate ratio of 1-to-9, based on our previous survey experience (random sampling of workers resulted in a sample of 10% women). We have estimates of intracluster correlation (ICC) for each of our primary outcomes computed from previous survey results, which we have incorporated in the calculations detailed below. The cluster randomized study has three primary outcomes, each measured at the worker level, clustered at the kiln level:

1. **Personal Protective Equipment (PPE):** We use principal components analysis (PCA) to calculate a continuous PPE index for each worker, using a set of 9 indicators taking a value of 1 if a given worker reports access to a given PPE item (cooling towels, gloves, helmets, head coverings, boots, goggles, masks, first aid support, oral rehydration salt (ORS)), and zero otherwise. Our

study is powered at 80% to observe a minimum difference of 0.30 in PPE index, using a two sided test and computed using previous season data (standardized effect size of 0.26), with an ICC of 0.25.

2. **Workplace conditions:** We use principal components analysis (PCA) to calculate a continuous index reflecting the quality of working conditions each worker reports. Components include sanitation conditions, access to rest areas, cooling sheds, and amenities in living quarters. Our study is powered at 80% to observe a minimum difference of 0.46 in a working conditions index computed using previous season data (standardized effect size of 0.29), using a two sided test and accounting for a high level of within cluster correlation (ICC = 0.39).

3. **Timeliness of wages:** For each kiln, timeliness of wages is measured using the share of workers reporting on-time payment during the preceding 3 months of work (or since the beginning of the season, if shorter than 3 months). Although available data for the timeliness of wages is limited, we use wage reporting from a previous study of sample kilns to estimate a minimum detectable effect size of 7.3 percentage points in the probability of timely pay (a standardized effect size of 0.23 relative to baseline) using a two sided test, given a relatively high ICC of 0.32.

Secondary Outcomes:

1. **Labor trafficking indicators:** Conditions contributing to labor trafficking are measured using a standardized set of indicators developed by the United States Department of State Trafficking in Persons Office. The standard tool consists of 39 total indicators (4 extremely strong indicators, 14 strong indicators, and 21 medium indicators) for conditions related to labor trafficking determination. Our survey focuses on a subset of 17 of these indicators deemed culturally appropriate and relevant to the intervention as assessed through previous qualitative research. Our primary outcome is then computed as a continuous measure of the total number of indicators experienced (weighting medium indicators at 0.66). Previous surveys collecting similar data show that our study is powered to detect changes of 0.32 trafficking indicators (a standardized effect size of 0.28) using a two sided test with 80% power at a 5% confidence level, and accounting for a relatively high intra-cluster correlation coefficient of 0.36. Additionally, we will use these indicators to construct a dichotomous outcome measuring whether or not each individual worker is trafficked or not trafficked according to the classification scheme in Okech et al. (2025), as well as a dichotomous measure of whether or not any worker at a kiln was classified as trafficked. We will use both the worker-level measure and the kiln-level measure as study outcomes.

2. **Child labor:** Child labor will be measured through three complementary outcomes: (1) worker-reported observations of children (under 18 years) engaged in brick kiln work activities during the current season, (2) worker- stated intentions to bring children to work at the kiln should they return the following season, and (3) manager-reported intentions to include age verification of contracted workers, and clauses to deter workers bringing children (<18 years) to work. While we do not expect measurable changes in current-season child labor prevalence due to the timing and nature of migration patterns (as noted in Component 4), these measures will allow us to assess whether the awareness component influences future labor recruitment practices and worker attitudes toward child labor.

3. **Self-reported injuries:** Workplace injuries will be measured using an index formed using principal components analysis (PCA) of worker injury incidents occurring in the past 2 weeks, categorized by type (serious injuries, fractures or muscle injury, burns, respiratory problems, vision or hearing problems, psychological problems, or changes in menstrual cycles). The 2-week recall period balances accuracy of reporting with sufficient observation time to capture injury events. Our sample size provides 80% power to detect a reduction of approximately .34 in the injuries index (a standardized effect size of about .22), based on injury reports in a previous survey of the same brick manufacturing sites, and a low intra-cluster correlation of about 0.13 computed from the same survey. We will also construct a binary indicator of whether a worker experienced any of the reported injuries. Sensitivity analysis will be conducted to explore effects on binary outcomes capturing whether each type of injury was experienced during the preceding 2 weeks.

4 Empirical Strategy

To evaluate the causal impact of the integrated the Zigzag2.0+ intervention, we will estimate intention-to-treat (ITT) specifications for the primary and secondary outcomes using ordinary least squares (OLS) regression of the following form

$$Y_{ik} = \beta_0 + \beta_1 T_k (+\beta_2 Y_{ik,t-1}) + \mathbf{X}'_{ik}\boldsymbol{\beta} + \delta_s + \epsilon_{ik} \tag{1}$$

where Y_{ik} is an outcome of interest for worker i at kiln k, T_k is a binary indicator for assignment to the treatment arm, $\mathbf{X}_{ik}$ is a vector of covariates[2] selected through post-double LASSO (Belloni et al., 2013), and δ_s are randomization strata fixed effects for stratum s. The term $Y_{ik,t-1}$ represents the baseline value of the outcome for worker i at kiln k. Our data collection plan is to re-interview the same workers at endline who were surveyed at baseline, which would allow for the inclusion of this lagged outcome variable. However, we anticipate that re-surveying the same workers at endline may be challenging, and it is hard to quantify how successful we will be in tracking individuals. The feasibility of including $Y_{ik,t-1}$ will therefore depend on the rate of successful re-interviews. Consequently, we pre-specify the following analytical approaches. Subject to the re-interview rate, specification (2) is expected to provide the most statistical power, followed by specification (1).

1. *Full cross-sectional analysis*: If the rate of successful re-interviews is low, our primary specification will be a cross-sectional analysis of all endline workers, which omits the $Y_{ik,t-1}$ term. This approach maximizes the sample size.

2. *Panel data analysis*: For the subsample of workers for whom we have both baseline and endline data, we will estimate the full specification including the $Y_{ik,t-1}$ term. This approach controls for individual-level heterogeneity and is expected to generate the most precise estimates by reducing residual variance, as long as the rate of successful re-interviews is high.

The coefficient β_1 captures the causal effect of assignment to the intervention on each outcome (relative to assignment to the control arm). The covariate vector $\mathbf{X}_{ik}$ is selected using the post-double LASSO procedure, which runs LASSO separately for the outcome and treatment variables

[2]Potential covariates will be derived from the baseline survey and include worker demographics, type of work they perform at the kiln, outside work options, regular work during the non-brick season, migration to kilns, prior knowledge and experience on kilns, and self-reported health and well-being.

to identify covariates that predict either, then includes the union of selected covariates in the final specification to improve precision while guarding against overfitting. Because workers are nested within kilns, we will calculate heteroscedasticity-robust standard errors adjusted for clustering at the kiln-level for all specifications. For hypothesis testing, p-values will be calculated both based on the heteroscedasticity-robust standard errors from the regression and using randomization inference (RI) to honor the experimental design. We will conduct permutations by re-randomizing treatment assignment holding the number of treated and control units constant within each original stratum-wave cell. The final p-value will be derived from the distribution of the estimated coefficient β_1 across all feasible permutations.

Because workers in different jobs face different conditions at brick kilns, we will explore heterogeneity in the treatment effects by job category, and other characteristics such as prior kiln experience and sex.
To account for multiple hypothesis testing across our three primary outcomes, we will report adjusted p-values following the procedure outlined by Anderson (2008) and using the Benjamini et al. (2006) sharpened two-stage procedure.

Because we do not anticipate perfect compliance with the intervention but it is of policy relevance to understand impacts among adopters, we will also estimate the local average treatment effect (LATE) using randomized assignment to the intervention arm as an instrument for adoption. Based on pilot experience, we will define kiln-level adoption using the kiln observation and the manager survey administered at endline. The checklist yields four domain scores: (i) PPE provision/availability and use, (ii) wage payment monitoring, (iii) sanitation and living conditions, and (iv) heat mitigation infrastructure and awareness. In each domain, items are scored and aggregated into a domain percentage score (points earned divided by points available). We then compute an overall adoption index as the (unweighted) average of the four domain percentage scores. A kiln is classified as an "adopter" if its overall adoption index is at least 50% at endline.[3] We will estimate the LATE using two-stage least squares (2SLS), in which the first stage regresses a binary indicator for adoption (A_k), as defined above, on a binary indicator assignment to the treatment arm and randomization strata. In the second stage, we regress our outcomes (Y_{ik}) on the instrumented adoption indicator ($\hat{A}_k$). In both stages, we we will compute heteroskedasticity-robust standard errors adjusted for clustering at the kiln level.

To estimate the LATE, we use the following two-stage least squares (2SLS) approach:

$$A_k = \theta_0 + \theta_1 T_k + \mathbf{X}'_{ik}\boldsymbol{\theta} + \gamma_s + \epsilon_{ik} \tag{2}$$

$$Y_{ik} = \gamma_0 + \gamma_1 \hat{A}_k + \mathbf{X}'_{ik}\boldsymbol{\gamma} + \gamma_s + u_{ik} \tag{3}$$

where γ_1 represents the local average treatment effect (LATE) of adoption on compliers—those kilns induced to adopt by their assignment to treatment, and the remaining parameters are defined as in

[3]For items measured both by enumerator observation and by manager self-report, we will use enumerator observation when available; manager report will be used when the corresponding observational measure is not collected and for sensitivity analysis. We will conduct sensitivity analysis around this adoption measure using alternative thresholds (greater or less than 50%).

the OLS case.

While our primary analysis will be conducted at the worker level, we will conduct a complementary set of analyses at the kiln level. This approach allows us to distinguish between the intervention's impact on the presence of a practice (i.e., whether a kiln engages in a practice at all) and its impact on the prevalence (i.e., the prevalence or severity of the practice among surveyed workers at that kiln). For these kiln-level analyses, we will have baseline measurements of all primary outcomes from the kiln observation checklist administered during baseline data collection. Therefore, our preferred specification for kiln-level outcomes will follow the panel data approach (specification 2), including baseline values of the dependent variable to improve precision. The estimating equation will take the form:

$$Y_k = \beta_0 + \beta_1 T_k + \beta_2 Y_{k,t-1} + \mathbf{X}_k' \boldsymbol{\beta} + \delta_s + \epsilon_k \tag{4}$$

where Y_k represents the kiln-level outcome at endline, $Y_{k,t-1}$ is the baseline value, and other terms are defined as before but aggregated to the kiln level.

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