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Influence of 5S-Based Chemical Storage and Handling on Environmental Performance in Building Construction Projects: The Mediating Role of Chemical Waste Reduction

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Abstract

Chemical storage on building sites is a recognised source of soil and water contamination, yet the management routines that prevent such losses have rarely been tested against environmental outcomes. This study examined the influence of 5S-based chemical storage and handling on environmental performance in building construction projects and tested chemical waste reduction as a mediating mechanism. Data were collected through a cross-sectional survey of 250 construction professionals engaged on residential, commercial and government building projects. Twenty-eight items measured 5S practice, chemical waste reduction and environmental performance on five-point agreement scales, and all three constructs recorded acceptable internal consistency. Descriptive statistics, correlation, hierarchical regression and bootstrapped mediation analysis were computed in SPSS. 5S practice predicted chemical waste reduction and environmental performance. Entering both predictors together reduced the direct effect from 0.552 to 0.345 while leaving it significant, and the indirect path through chemical waste reduction was significant at 0.207, with a bootstrap confidence interval of 0.131 to 0.290. Waste reduction accounted for 37.5 per cent of the total effect, which indicates partial mediation: storage discipline was associated with better environmental outcomes mainly, though not only, through the prevention of waste at source. Implications are drawn for site supervision and for the design of chemical storage protocols.

Keywords: 5S Methodology; Chemical Storage and Handling; Chemical Waste Reduction; Environmental Performance; Lean Construction; Building Construction Projects

Introduction

Few sectors consume material on the scale of building construction, and the pollution its sites generate does not stay inside the site boundary. Emissions, disturbed ground and heavy volumes of solid and liquid waste all follow from the extraction, transport and on-site working of materials (Bajjou & Chafi, 2024). Most of the waste literature has settled on demolition debris and inert fractions, where recovery routes are reasonably well established and recycling rates can be reported with some confidence (Kabirifar et al., 2023). Hazardous fractions have attracted far less work. Their share of total tonnage is small; their risk per unit of volume is not. What results is a category of site waste that matters out of proportion to how much of it there is.

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Solvents, adhesives, curing compounds, formwork release agents and epoxy resins are used routinely on building sites and are usually stored close to active work areas. Life cycle evidence shows that liquid chemical wastes exert high eco-toxicity impacts per unit volume, so even modest losses matter (Yeheyis et al., 2023). Containment failures occur most often where storage is improvised. Zhao et al. (2023) found that improper labelling, absent secondary containment and unstandardised inventory handling explained the majority of hazardous runoff incidents recorded on high-density building sites. Preventing loss at the storage stage costs considerably less than remediating contaminated ground (Al-Sareji et al., 2023).

The pathways running from storage practice to environmental damage are documented. Uncontained storage allows heavy metals and volatile organic compounds to accumulate in site runoff, whereas secondary bunding and spill kit readiness reduce contaminant leaching sharply (Zhang et al., 2024). Contaminated chemical packaging forms a second stream, and its presence obstructs the recycling of otherwise recoverable materials (Brooks et al., 2024). Decisions about where and how material is stored are not administrative details. Ostadnorouzi et al. (2025) attributed close to a third of the physical waste a project generates to layout and handling choices made during execution.

Responses to these problems have moved from end-of-pipe control toward operational discipline at source. The 5S method, developed within lean production, organises the workplace through sorting, ordering, cleaning, standardising and sustaining. Its visual controls are associated with reduced material spillage and steadier handling of volatile substances (Misztal & Ratajszczak, 2025). Recent syntheses of lean and green practice identify 5S as the operational tool most frequently reported for reducing site-level chemical hazards (Buhaya & Metwally, 2024). The mechanism behind that association remains less clear. If 5S improves environmental outcomes, the open question is whether waste reduction carries the effect.

Problem Statement

Evidence on 5S in construction comes largely from productivity studies, in which the reported outcomes are cycle time, material damage and layout efficiency. Where environmental gains are claimed, the link is usually asserted rather than tested, and the intermediate step is left unspecified. Research on chemical containment takes the opposite position, examining physical controls without locating them inside a management routine. Neither line of work establishes whether chemical waste reduction transmits the effect of 5S storage practice onto environmental performance, or whether the two are connected directly. Without that evidence, site managers have no basis for directing limited supervisory effort.

Research Objectives

1. To examine the influence of 5S-based chemical storage and handling on chemical waste reduction and on environmental performance in building construction projects.

2. To determine whether chemical waste reduction mediates the relationship between 5S-based chemical storage and handling and environmental performance.

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Research Questions

1. What influence do 5S-based chemical storage and handling practices exert on chemical waste reduction and environmental performance in building construction projects?

2. Does chemical waste reduction mediate the relationship between 5S-based chemical storage and handling and environmental performance?

Literature Review

Lean Construction

Lean construction carries production management thinking into project delivery. Site work is read as a flow, and any activity that consumes resources without adding value is treated as an interruption to it. What lean addresses is therefore not the removal of debris but the conditions that generate loss in the first place: ordering more than is needed, moving material repeatedly, storing it badly (Francis & Thomas, 2023). Aziz and Zainon (2023) followed expired site inventory back to unstandardised ordering, so that a purchasing decision ends up as a disposal problem. Ahuja et al. (2023) found material efficiency and hazardous waste control moving together once lean routines were set against environmental objectives, rather than competing for the same supervisory attention.

5S Methodology

Five steps make up the method. Sort separates what is needed from what is not; Set in Order gives every remaining item a labelled place; Shine covers cleaning and the inspection that accompanies it. The last two work on the routine rather than the space, since Standardise fixes procedure for recurring tasks and Sustain holds that procedure in place through audit and training. Applied to a chemical store, the first step clears expired and surplus stock, while designated bays cut both retrieval time and the container damage caused by moving plant (Dube & Gupta, 2023). Cabrera et al. (2023) recorded less material damage and expiry on building sites after implementation, and found that audit routines held compliance in place once the initial intervention had finished. Of the lean instruments assessed by Naeemah and Wong (2024), 5S ranked first for limiting the environmental impact of chemical storage.

Chemical Waste Management

Chemical waste management on building sites covers the procedures that prevent, contain and minimise hazardous liquid and solid waste. Prevention depends less on disposal arrangements at the end of the process than on the condition of the storage area itself. Makwana and Devkar (2024) applied automated auditing to site photographs and showed that visual clutter coincided with uncontained spills on active work decks, and that segregation compliance rose once standardised storage zones were enforced. Formal environmental management systems produce comparable effects by requiring documented storage procedures and routine chemical audits, which prevent unmanaged accumulation of stock (Silva & Gouveia, 2024). Survey evidence from building projects indicates that site-level organisation suppresses both spillage and runoff incidents during execution (Solaimani & van der Lelij, 2023).

Environmental Performance

Environmental performance, as the term is used in construction, refers to how far a project limits its ecological footprint, controls discharges and holds to regulatory requirements while work proceeds. Expert weighting by Tam et al. (2023) placed chemical waste management among the leading site indicators, alongside soil toxicity and runoff contamination. Survey measurement of the construct is almost always perceptual. Sampling soil and water directly across a large number of projects, each operating under different ground and weather conditions, is seldom practicable. Wang and Yuan (2023) found hazardous waste minimisation to bear on performance scores more heavily than reduction of general waste. Comparative work on production settings runs the same way, with lower physical waste volumes accompanying reduced toxic emissions rather than being traded against output (Rüdele et al., 2024).

Methodology

The study adopted a quantitative approach with a cross-sectional survey design, which suits the testing of specified relationships between operational practice and environmental outcomes at a single point in time. The population comprised construction professionals working on building projects where chemical materials are stored and handled on site. Sampling was purposive, with quotas set by professional role and by chemical handling experience so that project managers, site engineers, health and safety officers and chemical handling workers were each represented; 250 usable responses were obtained. The instrument was a self-administered structured questionnaire. A demographic section came first, followed by twenty-eight items rated on a five-point agreement scale: fifteen for the five dimensions of 5S-based chemical storage and handling, six for chemical waste reduction and seven for environmental performance. Items were adapted from survey work on lean practice and site environmental outcomes (Akram et al., 2024; Solaimani & van der Lelij, 2023), and a pilot with practitioners was run before distribution. Questionnaires were completed on active project sites and returned directly to the researcher. Reliability, descriptive statistics, correlation, hierarchical regression and bootstrapped mediation were computed in SPSS. Participation was voluntary and anonymous, informed consent was obtained before completion, and responses were held securely.

Theoretical Framework

Four positions support the proposed model. The resource-based view treats internal routines as capabilities that generate performance differences between firms, provided they are valuable and difficult to imitate (Barney, 1991). The natural resource-based view extends this reasoning to the environment and identifies pollution prevention, achieved through continuous operational involvement at source, as its first strategic pillar (Hart, 1995). Lean thinking supplies the mechanism by defining waste as resource consumption that adds no value, and by prescribing standardisation and workplace organisation as the remedy (Womack & Jones, 2003). That logic was carried into construction by treating the site as a flow process in which unsafe storage and unnecessary handling are non-value-adding (Koskela, 1992). The waste hierarchy places prevention above every downstream option (Lansink, 2018). These positions describe a sequence rather than parallel effects, and structural evidence confirms that physical waste reduction transmits the operational effect onto ecological outcomes (Fercoq et al., 2023).

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Conceptual Framework

The model proposes that 5S-based chemical storage and handling raises chemical waste reduction (H1) and environmental performance (H2), and that chemical waste reduction mediates the relationship between 5S practice and environmental performance (H3). H3 specifies the indirect path.

5S-Based Chemical Storage and Handling → Chemical Waste Reduction → Environmental Performance

Data Analysis and Discussions

The analysis addressed the two research objectives in sequence. Findings are reported in the order in which they were produced, beginning with the composition of the sample and the quality of the measures, and moving through correlation, regression and mediation testing to a supplementary comparison across professional roles.

Profile of Respondents

The composition of the achieved sample is set out in Table 1. Respondents with routine oversight of chemical materials predominate. Health and safety officers and site engineers together made up three-fifths of the sample, and only three respondents reported rare contact with chemicals in the course of their work. Close to nine in ten described their chemical management experience as moderate or high, which lends some support to the assumption that the ratings rested on informed judgement rather than casual impression. Commercial and residential projects supplied more than three-quarters of the responses, so the findings speak to private building work more than to public infrastructure. Medium-sized firms formed the largest group at 48 per cent, with small and large firms splitting the remainder in roughly equal shares.

Table 1: ***Profile of Respondents (N = 250)***

Characteristic	Category	n	%
Current Position	Health and Safety Officer	80	32.0
	Site Engineer	70	28.0
	Chemical Handling Worker	60	24.0
	Project Manager	40	16.0
Professional Experience	Less Than 5 Years	80	32.0
	5 To 10 Years	110	44.0
	More Than 10 Years	60	24.0
Project Type	Commercial Building	100	40.0
	Residential Building	90	36.0
	Government Building	45	18.0
	Other	15	6.0
Company Size	Small	60	24.0
	Medium	120	48.0
	Large	70	28.0
Chemical Management Experience	Low	30	12.0
	Moderate	150	60.0

	High	70	28.0
Daily Chemical Involvement	Directly Responsible for Handling	109	43.6
	Frequently Involved	112	44.8
	Occasionally Involved	26	10.4
	Rarely Involved	3	1.2

Note. Percentages are calculated on the full sample and rounded to one decimal place.

Data Screening, Reliability and Descriptive Statistics

No item values were missing from the returned questionnaires. Five respondents gave identical answers to all twenty-eight items; the analysis was rerun without them as a sensitivity check, and since the indirect effect moved only from 0.207 to 0.194 and no reliability coefficient shifted by more than .003, the full sample of 250 was retained. Table 2 reports descriptive statistics and reliability coefficients for the three constructs and for the five dimensions of the independent variable. Means clustered a little above four on the five-point scale, which indicated that respondents on the whole judged site chemical practice to be reasonably well managed. Sustain stood apart at both ends, recording the lowest mean at 3.92 and the widest dispersion at 0.80. Enforcement through audit and training thus appears to be the least consistently applied of the five steps, and the step on which sites differed most. All reliability coefficients exceeded .80. The composite figure of .961 for the fifteen-item 5S scale is high enough to raise a question of item redundancy rather than to be read as a strength, and the dimensional coefficients of .810 to .860 describe the structure of the scale more informatively. Skewness ran between -0.52 and -0.71 and kurtosis between -0.17 and 0.62, both inside the conventional limit of one, which supported the use of parametric procedures. Harman's single-factor test returned 48.4 per cent of variance on the first unrotated component, with three components carrying eigenvalues above one. That does not rule out common method variance, given that every measure came from one respondent on a single instrument, but it gives no sign that a single factor generated the relationships reported below.

Table 2: ***Descriptive Statistics and Internal Consistency of the Study Constructs***

Construct and Dimension	Items	M	SD	Skewness	Kurtosis	a
5S Chemical Storage and Handling	15	4.03	0.68	-0.52	-0.17	.961
Sort	3	4.05	0.72			.832
Set In Order	3	4.08	0.69			.810
Shine	3	4.02	0.69			.843
Standardise	3	4.07	0.73			.818
Sustain	3	3.92	0.80			.860
Chemical Waste Reduction	6	3.98	0.69	-0.54	0.14	.908
Environmental Performance	7	4.01	0.70	-0.71	0.62	.930

Note. Scores are composite means on a five-point scale. a denotes Cronbach’s alpha. Skewness and kurtosis are reported for the three composite constructs.

Correlation Analysis

Table 3 presents the correlations between the three study variables. All three associations were positive, moderate in size and significant at the .001 level. The strongest of them linked chemical waste reduction with environmental performance, an early indication that the mediator lay closer to the outcome than the independent variable did. The pattern is consistent with the direction stated in H1 and H2, although correlation establishes association rather than sequence. Examination at the dimensional level was more informative for practice. Standardise and Sustain correlated most strongly with chemical waste reduction, at .534 and .520, and Sustain also recorded the strongest association with environmental performance at .521. Set in Order returned the weakest coefficients on both counts, at .454 and .464. The physical arrangement of the storage area therefore tracked the outcomes less closely than the procedural and disciplinary elements of the method, an ordering that matches the structural results reported by Akram et al. (2024). No coefficient approached .80 and the variance inflation factor in the combined model was 1.41, so multicollinearity posed no threat to the regression estimates.

Table 3: ***Pearson Correlations between the Study Variables***

Variable	1	2	3
1. 5S chemical storage and handling	1		
2. Chemical waste reduction	.539*	1	
3. Environmental performance	.529*	.547*	1

Note. N = 250. * $p < .001$ (two-tailed).

Regression Analysis

Table 4 reports the three regression models used to test H1 and H2 and to set up the mediation test. In the first, 5S-based chemical storage and handling explained 29.0 per cent of the variance in chemical waste reduction, with each one-point rise on the 5S scale corresponding to an increase of 0.548 points in reported waste reduction. H1 was supported. The second model regressed environmental performance on 5S practice alone; it accounted for 28.0 per cent of the variance and returned an unstandardised coefficient of 0.552, so H2 was supported as well. Between them the two models answer the first research objective. 5S-based storage practice was associated with chemical waste reduction and with environmental performance, and the two effects were of comparable magnitude when each was estimated on its own. The third model entered both predictors at once. Explained variance rose to 37.7 per cent, 9.7 percentage points above the second model, and both predictors remained significant. Holding chemical waste reduction constant reduced the coefficient for 5S practice from 0.552 to 0.345, a fall of just over a third, while chemical waste reduction itself carried a coefficient of 0.378. Attenuation of this kind is what mediation predicts: part of the association between storage practice and environmental performance ran through the reduction of chemical waste rather than around it. A Durbin-Watson statistic of 2.01 indicated independent errors, and the residual diagnostics raised no other difficulty. Read in practical terms, 5S practice on its own gave a weaker account of environmental performance than 5S practice taken together with its effect on waste.

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Table 4: ***Regression Results for the Three Estimated Models***

Model	Predictor	B	SE	Beta	t	p
Model 1 (DV: Waste Reduction)	5S Practice	0.548	0.054	.539	10.08	<.001
Model 2 (DV: Environmental Performance)	5S Practice	0.552	0.056	.529	9.83	<.001
Model 3 (DV: Environmental Performance)	5S Practice	0.345	0.062	.331	5.55	<.001
	Waste Reduction	0.378	0.061	.368	6.18	<.001

Note. Model 1: $R^2 = .290$, $F(1, 248) = 101.51$, $p < .001$. Model 2: $R^2 = .280$, $F(1, 248) = 96.58$, $p < .001$. Model 3: $R^2 = .377$, $F(2, 247) = 74.59$, $p < .001$.

Mediation Analysis

Table 5 decomposes the total effect, and Figure 1 sets out the same model in path form with standardised coefficients. The indirect effect of 0.207 carried a bootstrap confidence interval running from 0.131 to 0.290. Because that interval excludes zero, the mediated path is significant; the Sobel test agreed, at $z = 5.27$. Chemical waste reduction accounted for 37.5 per cent of the total effect. The direct path remained significant with the mediator in the model, so the mediation was partial rather than complete and H3 is supported in that qualified form, which answers the second research objective. Waste reduction carried a substantial share of the association between 5S practice and environmental performance, yet close to two-thirds of the total effect travelled by other routes. Storage discipline may well improve environmental outcomes through channels the waste construct does not reach, among them regulatory compliance behaviour, containment infrastructure and the plain visibility that an organised store gives a supervisor. Rather than weakening the model, the qualification sharpens it: waste reduction is one mechanism among several and not the single conduit. Read off the unstandardised coefficients, each additional point of 5S practice corresponded to roughly two-tenths of a point of environmental performance transmitted through waste reduction and roughly three-tenths transmitted directly. On a five-point scale both components are meaningful in size, and dropping either would leave part of the account unexplained. Since the data were gathered at one point in time, these estimates describe a mediated association rather than a demonstrated causal sequence.

Table 5: ***Direct, Indirect and Total Effects of 5S Practice on Environmental Performance***

Effect	B	SE	LLCI	ULCI	Outcome
Total Effect (C)	0.552	0.056			p < .001
Direct Effect (C-Prime)	0.345	0.062			p < .001
Indirect Effect (A X B)	0.207	0.041	0.131	0.290	Supported
Proportion Mediated	37.5%				Partial Mediation

Note. Percentile bootstrap with 5,000 resamples. LLCI and ULCI denote the lower and upper limits of the 95% confidence interval. Sobel $z = 5.27$, $p < .001$.

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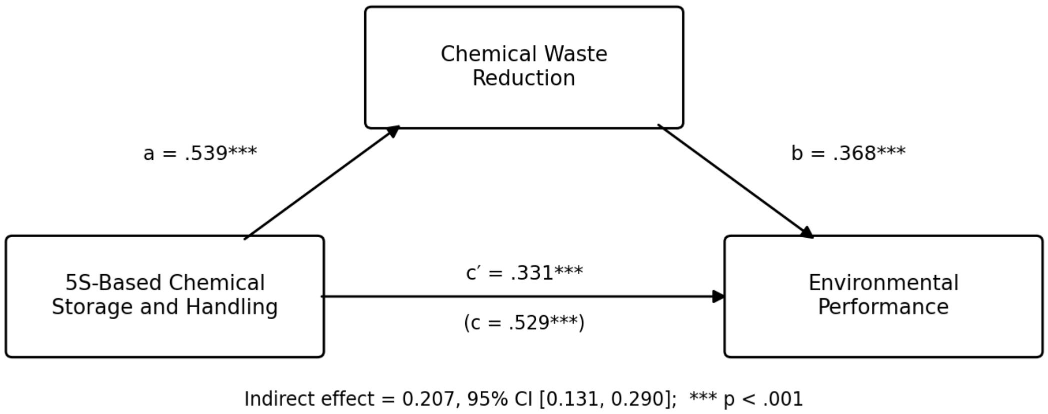
Figure 1: ***Mediation Model With Standardised Path Coefficients***



Variation by Professional Role

Environmental performance ratings varied by professional role, as Figure 2 shows. Chemical handling workers returned the lowest mean at 3.55 and health and safety officers the highest at 4.31, with site engineers and project managers between them. Analysis of variance confirmed that the differences were unlikely to have arisen through sampling, $F(3, 246) = 17.66$, $p < .001$. The gap of more than three-quarters of a point between the workers who handle chemicals and the officers responsible for monitoring them was the largest single contrast in the data. No other background characteristic produced significant variation in environmental performance. Differences by company size were negligible, $F(2, 247) = 0.20$, $p = .815$, and neither length of professional experience, $F(2, 247) = 0.94$, $p = .393$, nor level of daily chemical involvement, $F(3, 246) = 0.91$, $p = .437$, reached significance. Role was the only respondent attribute that shaped assessments of environmental performance in this sample. Because the measure is perceptual, the contrast is better read as a difference in vantage point, and possibly in evaluative interest, than as evidence that site conditions themselves differ between the groups.

Figure 2: ***Mean Environmental Performance by Professional Role, With Standard Error Bars***

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Results

The results locate chemical waste reduction inside the relationship between 5S storage practice and environmental performance without letting it occupy the whole of that relationship, which qualifies structural work treating waste minimisation as the complete conduit from lean routines to ecological outcomes (Cherrafi et al., 2024). At 37.5 per cent the mediated share sits nearer a partial pattern than the full mediation reported by Fercoq et al. (2023), and the difference is worth dwelling on. A perceptual measure of environmental performance takes in compliance and containment as well as waste volume, so a construct confined to waste was never going to absorb the entire effect. The dimensional results carry a more immediately practical point. Standardise and Sustain tracked both outcomes more closely than Set in Order did, which suggests that written procedure and enforced routine weigh more than the physical arrangement of a storage bay. Racking and bunding installed without audit routines behind them are unlikely to deliver the environmental benefit. That hazardous waste control bears heavily on performance ratings is consistent with earlier survey evidence (Wang & Yuan, 2023), and it argues for directing supervisory effort at the labelling, inventory and containment failures identified as the main sources of site runoff (Zhao et al., 2023).

Conclusion

This study tested a mediated model linking 5S-based chemical storage and handling to environmental performance in building construction projects, and found that chemical waste reduction carried part of that relationship. The contribution lies in specifying the mechanism rather than assuming one. That lean routines improve environmental outcomes has been reported before; what the present results add is an estimate of how much of the improvement passed through waste prevention and how much did not. For site management the implication is one of sequencing. Storage discipline appears to yield environmental benefit chiefly by stopping waste before it forms, so audit routines, labelling standards and inventory rotation warrant priority over rearrangement of the storage area on its own. The sustainability relevance needs little elaboration, since chemical losses on building sites contaminate soil and surface water long after a project closes, and prevention at source costs less than remediation. Four limitations frame the findings. Perceptions were measured rather than discharge volumes; all three constructs came from the same respondent on a single instrument, so common method bias cannot be excluded; the cross-sectional design cannot establish temporal order; and the 5S scale showed signs of item redundancy. Future work should test the model against objective waste and contamination data, follow projects over time, separate the sources of measurement, and estimate the structure with partial least squares in order to accommodate the dimensional model more fully.

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