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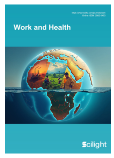

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# Evaluation of a Web-Based Silica Exposure Risk Assessment Tool in Construction: Data Appraisal and User Trial

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**Abstract:** Background: Respirable crystalline silica (RCS) presents persistent health risks in construction, and predictive exposure models offer a potential complement to traditional monitoring. This study evaluated the applicability of the British Columbia Construction Safety Alliance (BCCSA) Silica Control Tool™ for use in the construction sector in Victoria, Australia. Methods: A two-phase evaluation was undertaken. First, a desktop interrogation of the Tool's underpinning data, statistical model development and documented limitations was performed, including statistical review. Second, a user trial was conducted with 12 Victorian industry stakeholders who completed realistic task scenarios within the Tool and generated Exposure Control Plans (ECPs). Qualitative feedback was obtained through observation and focus group discussion. Results: The interrogation demonstrated that the Tool is built on a large, iteratively improved North American exposure database, with well developed and statistically sound modelling framework; however, its predictive validity has not yet been independently evaluated using Australian exposure data. Stakeholders produced 14 ECPs across diverse silica-generating tasks, showing that the Tool responded sensitively to changes in task parameters and control selections. Thematic analysis identified five key themes: usability, regulatory alignment, clarity of terminology, gaps in task representation, and adherence to the hierarchy of controls. Participants saw strong potential for the Tool but emphasised the need for Australian data integration, clearer definitions, enhanced usability, and localised terminology. Conclusions: The BCCSA Silica Control Tool™ demonstrates a technically robust North American modelling framework and strong stakeholder acceptability, but Australian-specific validation and adaptation are required before adoption in Victoria. Incorporating Australian exposure data, tailoring terminology and ensuring alignment with local legislation are critical next steps.

**Keywords:** silica; exposure; predictive exposure modelling; construction; risk assessment

## 1. Introduction

Respirable crystalline silica (RCS) remains a priority occupational hazard in the construction industry, where high-energy mechanical activities such as cutting, drilling, grinding, or demolition of silica-containing materials can generate airborne concentrations capable of causing serious disease [1]. Long-term exposure to RCS is causally linked with silicosis, chronic obstructive pulmonary disease and lung cancer, and in recent years jurisdictions worldwide—including Australia—have tightened regulatory requirements in response to increasing concern about worker health outcomes [2–4]. This is evidenced by Australia's world-first decision to ban engineered stone (containing >1% crystalline silica) in response to a silicosis crisis in the workforce [5]. Despite strengthened standards, effective exposure prevention in construction remains challenging. Quantitative exposure characterisation in construction is complicated by inherently variable work practices, transient worksites, task-specific determinants, environmental heterogeneity and short-duration or intermittent activities that often fall outside the practical scope of conventional personal air monitoring programs. While gravimetric sampling remains the regulatory gold standard, its logistical barriers, cost and latency of results have prompted increasing interest in predictive exposure modelling tools that leverage existing datasets to support risk assessment and selection of appropriate controls [6–8].

One such tool is the Silica Control Tool™ developed by the British Columbia Construction Safety Alliance (BCCSA). The Tool integrates an extensive North American exposure measurement database with statistical modelling to estimate task-specific RCS exposures [9] and incorporates these model outputs into a web-based interface that generates task-specific exposure predictions and corresponding Exposure Control Plans (ECPs) for regulatory compliance. The Tool has undergone multiple iterations, including incorporation of Bayesian methods adopting local regional exposure data, and it is now used as a regulatory compliance pathway in parts of Canada [10].

Despite its maturity, the applicability of the BCCSA Silica Control Tool™ to jurisdictions outside Canada remains uncertain. RCS exposure distributions are known to vary between regions due to differences in construction methods, task execution, silica content of materials, formulation of manufactured products, climatic conditions, regulatory requirements and workforce practices [1,3,11]. For Australia, additional uncertainties arise from local material composition (including geological variability), construction sequencing, tool inventories, control preferences, terminology, and regulatory obligations embedded in state-based health and safety legislation. To date, no systematic evaluation has been undertaken to determine whether the BCCSA Silica Control Tool™ can be validly applied within the Australian construction context without modification. Assessing its suitability requires interrogation of multiple components: the representativeness of underlying exposure data; the statistical assumptions and modelling structure; the adequacy of determinant definitions relative to local work practices; and the congruence between Tool outputs and Victorian regulatory requirements, including the mandated hierarchy of controls requirements.

Accordingly, this study conducted a two-phase technical assessment of the BCCSA Silica Control Tool™. Phase I comprised a structured interrogation of the Tool's underpinning data sources, statistical development, model assumptions and documented limitations, augmented by statistical review. Phase II involved a controlled User Trial with Victorian construction industry stakeholders to examine practical utility, user interpretation of model outputs, and alignment with local regulatory and operational conditions.

## 2. Materials and Methods

### *2.1. Study Design Overview*

A two-phase mixed-methods evaluation was conducted: (i) a desktop interrogation of the Tool's underpinning data and modelling approach, and (ii) a stakeholder user trial using realistic scenarios to generate Exposure Control Plans.

### *2.2. Underpinning Data Interrogation*

The approach involved evaluating the applicability of the BCCSA Silica Control Tool™ for Victorian construction settings, identifying data gaps, and understanding limitations associated with region-specific determinants. We assessed the relevance and suitability of the tool in the context of construction industry practices in Victoria. For the underpinning data interrogation, we assessed the BCCSA Silica Control Tool™ (via a temporary trial user account) and conducted a comprehensive review of its publicly available database and modelling using a specific set of criteria. Close scrutiny was paid to whether the tool adequately aligns with the diverse spectrum of tasks inherent in Victorian construction industry. Our examination focused on various critical factors, including task definitions, the use of locally sourced materials, tools, and the implementation of controls.

Furthermore, we actively sought out any potential data gaps. The approach sought to understand the basis to the BCCSA Silica Control Tool$^{TM}$ model through evaluation of the relevant published papers in chronological order of publication. The latter process detailed the progressive development of the model and enabled key elements to be understood and uncertainties and limitations to be identified. Due to the statistical complexity of model development, statistical review was incorporated into the reporting. Upon completion of this review process and with a grasp of the limitations, evaluation of the final on-line Tool was carried out via a user trial.

### *2.3. User Trial*

A utility test (described hereafter as a User Trial) of the BCCSA Silica Control Tool$^{TM}$ with key Victorian industry stakeholders was undertaken to assess its performance under realistic tasks and exposure scenarios. The User Trial was conducted in a focus group discussion approach with 12 Victorian stakeholders drawn from key construction sector groups, including unions, national construction organisations, demolition, and industry associations. Participants invited as representative industry stakeholders and self-selected into small breakout groups (4 to 5 per group) to complete structured scenarios using the Tool.

Four scenarios were provided (see Appendix A, Boxes A1–A4). Participants were also encouraged to use their own relevant scenarios to input into the Tool. A total of five small breakout groups participated, resulting in 14 Exposure Control Plans (ECPs) being generated.

A member of the research team was positioned as Observer with each group and recorded contemporaneous notes. Engaging with the Tool and exploring different scenarios, participants within each group shared opinions on utility and their overall thoughts on applicability, suitability and feasibility of the Tool for a Victorian construction context. Following hands-on interaction with the Tool, all participants were returned to a single group, and the Research Lead conducted a question and answer (Q&A) style feedback discussion.

Structured questions included:

i. In the context of Victoria, how does the tool align with industry standards for conducting silica dust exposure risk assessments and implementing effective controls?
ii. Considering the diversity of construction projects, how adaptable is the tool in tailoring Exposure Control Plans to different conditions and project requirements?
iii. In your opinion, how will the tool influence decision-making processes related to the development and execution of exposure control plans in the Victorian construction sector?
iv. Looking forward, what specific features or improvements would you recommend the tool to have to accurately assess RCS exposure risk and generating exposure control plans in the Victorian context?
v. Which industry stakeholder group/s do you think could manage/host the Tool if released in Victoria?

This Q&A component of the Trial was audio recorded (with participant permissions) using portable recording devices (Zoom H2n Handy Recorder, Tokyo, Japan). Recordings were used for transcription purposes and thematic analysis of non-identifiable participant feedback. Content analysis of the User Trial was performed to elucidate themes in the data. Qualitative data from the User Trial were analysed using a structured content analysis approach. De-identified audio recordings were transcribed and analysed alongside contemporaneous field notes recorded by the research team. Initial coding was undertaken by one member of the research team (SS) through iterative review of the transcripts and field notes. Codes were grouped into broader themes and sub-themes through comparison and refinement across the dataset. Emerging codes and themes were subsequently reviewed and discussed with the research lead (SG) to assess consistency of interpretation and thematic fit. Any differences in interpretation were resolved through discussion with the research team and reference back to the original transcripts and notes, with consensus reached on the final thematic framework. Examples of initial codes generated during analysis included “usability/ease of navigation”, “clarity of terminology”, “alignment with Victorian regulations”, “limitations in task representation”, and “practical constraints” (e.g., time, connectivity). These codes were iteratively grouped into higher-level themes and sub-themes reflecting stakeholder perspectives on usability and real-world applicability of the Tool.

## 3. Results

### *3.1. Underpinning Data Interrogation—Document Review*

A review and synthesis of evidence focused on historical model development and sought to understand the iterative steps in model construction. This sought to clarify what was considered, reviewed and updated at progressive stages. The documentation review and synthesis are summarised in detail in Supplementary Materials (S1) and describes key points from the papers, any key issues relating to data gaps and the objective for the respective paper review. Key limitations are highlighted in bold. A synopsis of the content detailed in Supplementary Materials is provided below.

In its most basic construct, the model is a predictive model based around literature-derived and later additional empirical data associated with trades or tasks and including additional influencing variables to estimate exposure concentrations which are then compared against occupational exposure limits (OELs). This comparison then lends itself to the recommended controls associated with the standard hierarchy of controls. There are no risk estimations here that would traditionally use a toxicological dose-response approach to determine quantitative risk assessments and the exposure in itself presents the method of assessment against target regulatory exposure criteria, i.e., the OELs.

The process of evaluation was multifactorial in nature and focussed on the publications that underpinned the development of the model including subsequent approaches that adopted Bayesian methods. All these papers and associate reports were reviewed. The evaluation considered a series of questions including but not limited to:

- What initiated the model development?
- What dependent and independent variables were considered and how did they change with continued model development?
- What data sources were considered and how were the data standardised?
- What statistical methods were used and were they sound?
- What were the limitations and residual uncertainties and how did they affect the exposure predictions?
- How were some of these subsequently addressed?
- How well did model predictions match reality?
- How did the model deal with uncertainties when recommending exposure management?
- Which variables might require review if considering Australian application?

Synopsis of Publication Reviews and Synthesis

In 2013, the British Columbia OHS regulator, WorkSafeBC proposed amendments to its OHS regulation pertaining to RCS that included a specific requirement for quantitative risk assessment and the use of exposure monitoring. This new regulation also allowed for the use of objective air monitoring data collected from equivalent work operations that could be obtained from peer-reviewed or scientific studies. This provision subsequently enabled an approach which could use existing measurement data and this development was supported by the BCCSA. This process commenced with review of personal RCS monitoring data across the available literature with preliminary predictive modelling efforts and was published in 2012 [12]. This initial work has continued up to the most recent publication in 2023 [10] where further exposure and determinant evaluation informed modelling efforts as part of an iterative development process.

The initial work reviewed published RCS exposure data, including measurements and influencing factors, from 1987 to 2009. Statistical evaluation was undertaken and regression modelling reported poor explanation of variance (22%) if the 'trade' variable only (i.e., the nature of the occupational group) was considered. Subsequent work sought to improve the understanding around the initial database through more detailed evaluation and identification of uncertainties. For example, grouped measurements tended to average out variance compared to single measurements while some measurements reflected exposure to multiple tasks or tools resulting in confounding. The former would have underestimated exposure while in the latter over-estimation would have resulted in conservatism in control methods and potentially unnecessary control costs.

Progressive evaluations sought to obtain more detail and generate model improvement through greater understanding of influencing variables, for example the shift to task determinants rather than 'trade', reported an almost three-fold improvement in the explanation of variance. Sauve et al., [13] progressed the model construct with increased statistical inference while reevaluating the original measurement information and reinforced previous key findings including the significance of task determinants; that increased sampling duration lowered results; that indoor environments had an 1800% increased RCS exposure compared with outdoors and that the residential sector and indoor/without ventilation determinants correlated highly with RCS exposures even with limited numbers of results.

Work by Gorman-Ng and Davies [14] examined the RCS risk assessment model for Alberta, Canada in order to extend the predictions to incorporate regional information. Of the thirty-six common silica processes (CSP), eleven were previously not reported and seven were subsequently incorporated into the model. One hundred and thirty nine measurements across twenty seven CSPs were incorporated into the model which reported a 0.5 Pearson's correlation coefficient between estimates and measurements. Recognised limitations included poor seasonal data distribution, limited task diversity and small sample size. Further work by the same authors in 2020 [9] resulted in the online adaptation of the BCCSA Silica Control Tool™ and subsequent incorporation of Alberta and Manitoba data in 2021 [15]. Design objectives included a tool to reduce industry RCS exposures; a user-friendly interface; information consistent with the regulatory framework; and as an educational tool and a method to explore novel methods for exposure data collection and use. The model enabled iterative development as new information was acquired and represented a multiple linear regression model with exposure level as the dependent variable and a range of influencing variables as the independent variables.

Davies et al., [15] presented an assessment of RCS exposures across Manitoba from June 2018 to August 2020 and incorporated these into the BCSSA Silica Control Tool™ on-line model. Some key findings included source material/formulation composition variance; daily task and site-to-site variance; renovations and that indoor/confined environments produced higher results while the water spray on-tool method was the best exposure reduction measure. It was reported that variances between provinces was a result of regional differences such as compositional variance of source materials and formulations.

### *3.2. Statistical Review of Development Methodology*

#### 3.2.1. Model Construct

The questions relevant to this assessment were:

(1) What data was used to build the initial model in 2012/13?
(2) How was this data transformed prior to analysis and were the methods used valid and consistent with published statistical approaches?
(3) What statistical methods were used to build the predictive model and were these effective approaches for the data acquired and objectives?

Detailed responses are provided in Supplementary Material (Table S1) incorporating analysis of the key elements [9,10,12–16] being

- A strong emphasis on exposure measurements from North American settings with an initial limited range of influencing variables and consideration of missing data.
- The use of a statistical methodology examining data distribution and variance.
- The use of simulations to recreate individual exposures from summary parameters.
- Statistical modelling using a multi-model approach.
- Model construct evaluations using goodness-of -it measures across developed models.
- The adoption of Bayesian techniques to enable improved model confidence in predictions by incorporation of measurement data and also additional tasks and other influencing variables where data were available.
- Ultimately a forward stepwise regression to predict the main risk exposures for the original data was employed across the Manitoba data with Bayesian techniques used to combine the results from the original model and the Manitoba specific model.

#### 3.2.2. Australian Applicability and Uncertainty Analyses

We assessed whether the model would be suitable for Australia and determined the following:

a. The Manitoba study showed that RCS levels in Manitoba were approximately half that of those found in British Colombia and double those found in Alberta. These differences may be attributable to difference in work practices, but also source material composition and regulatory environment in the different provinces. Considering this, it is highly probable the RCS levels in Australia vary from those in Canada due to similar reasons.
b. The initial Silica Control Tool™ developed for BC, would not be suitable for Australia due to the underlying data used for the model development being unrepresentative. However, the updates to the model, as seen in Manitoba [15] (Davies et al., 2021), has made the model more fluid and transferable across jurisdictions. The Bayesian approach would allow the model exposure estimates to be amended based on Australian data, thus leading to higher confidence in the predictive ability of the model for Australian conditions.
c. It should be noted that it is the variation in exposure levels between Canada and Australia that would impact the model, rather than differences in the volume of tasks. As an example, if the RCS levels for drilling were much higher in Australia than Canada, then you would require the addition of Australian data into the model, to account for this variation. However, if the RCS levels for drilling were the same for Australia and Canada, but Australia performs 50% more drilling tasks than Canada, this would not impact the model. As the Tool outputs exposure levels by Task, a company in Australia would see the same level of risk as a company in Canada for drilling in this instance (provided all other exposure determinants are constant between the two jurisdictions).

d. The BCCSA Silica Control Tool$^{TM}$ has positively evolved over the last decade from a tool specific to BC, to a versatile tool that can be incorporated into numerous jurisdictions and scenarios.
e. The transition of the exposure level modelling from a multi-model approach to a stepwise regression approach has positively simplified the model and made it comparable with other predictive modelling studies. As a measure of model efficiency, some of the earlier models were able to explain 22% of the variability in the measurements, whilst the most recent Manitoba modelling explained approximately 40% of the variability. Although, this is by no means a high value, it shows the improvement in the database and model fitting.
f. Furthermore, the decision to undertake a Bayesian approach has made the Tool more versatile and transferable across jurisdictions, by allowing users to incorporate data that is relevant to their area of interest.
g. Without having access to the underlying data, it appears all the data transformation techniques are sound, as are the modelling techniques.
h. Prior to the usage of the BCCSA Silica Control Tool$^{TM}$ in Australia, it is highly recommended that RCS data representative of Australia be incorporated into the model. This may include capturing additional data from literature; accessing monitoring data from regulatory purposes or from monitoring undertaken by construction industry bodies.

#### 3.2.3. Key Limitations and Uncertainties Applicable to Australia and Reflecting Model Elements

Technical Robustness

The technical robustness of the model construct is based on our evaluation of the core literature and the statistical underpinning of the BCCSA model as applied to North American conditions. The focus group evaluations were to consider preliminary Australian conditions through a user trial. It is recognised across these assessments that independent Australian application would require in-depth validation and was subsequently a recommendation in the final discussion.

Risk Ranking Logic

The risk rating logic is an exposure prediction tool which compares predictions to occupational guideline values. The limitations arise when there are limited measurement data in the BCSSA for particular tasks or settings that results in: (a). No confident prediction and no risk remediation measure. (b). A prediction that forces a highly conservative risk mitigation measure well above what may be normally considered. (c). The inclusion of PPE does not rate the efficacy of the PPE and the wearers (e.g., beards, etc) so there are again conservative estimates of exposure (and hence risk) reduction the last step). (d). The user trial (Section 3.3) brought this out where there was questioning regarding the type of protection which is not detailed in the tool but due to the Bayesian construct if data were available this could be included. (e). This then lends itself to refinement and reductions in inconsistent elements due to generalisations and conservative approaches.

Statistical Elements

The statistical review was consistent with the commentary in the referenced published papers concerning the limitations and uncertainties inherent in the RCS BCCSA Silica Control Tool$^{TM}$ predictive model. A summary of these limitations and residual uncertainties is provided in Table 1.

While there are a range of variables that have been reported, the fundamental aspects relate to region-specific variables that require identification. These include such key factors as:

- Ensuring Australian tasks are the same as Canadian tasks, including the nature of the tools used.
- That the source geological silica composition and formulated product are similar or if not, are well understood such that model adjustment can occur.
- That Australian data are reviewed and incorporated in a manner consistent with the Canadian approaches.
- That un-reporting (i.e., missing information) is minimised to avoid residual error.
- That Australian data for confined and indoor settings is comprehensively explored as these settings for the Canadian environment were limited but were identified as reflecting significant impact on exposures.
- The approach to secondary sources is developed and the issue of confounding addressed.
- That all Australian construction CSPs are captured.
- That Australian measurement methods are consistent in keeping with legislated requirements; are undertaken to include seasonal variation; are undertaken as single measurements and consider both short-term and long-term tasks through sampling flow adjustments.

- That the tool as it exists, is only as robust as the site- and region-specific exposure data relevant to the area where it is being used.
- That daily site-to-site variability is captured.
- That no exposure prediction will be forthcoming if there is no exposure data in the model.
- That consideration be given to the nature of the reported exposure, e.g., geometric mean, 75th percentile, 95th percentile.
- That Australian concrete construction techniques be evaluated to provide confidence to the exposure predictions associated with tasks such as concrete demolition and grinding, cutting and sanding methods, where the concrete laying techniques result in silica layering. This means more silica is at the top using such techniques and exposure would be greater under such circumstances.
- That Australian control methods are compared and incorporated as may be required.

#### 3.2.4. Validation of Exposure Measurements

There are six key areas that consider the validation of exposure predictions presented by the predictive model. These include validity of sampling methods; validation of the analytical methods; data quality and standardization; how representative the predictions are relative to reality (i.e., measurement comparisons); statistical validation techniques and validation across consistency and plausibility. All of these elements lend themselves to identification of limitations. Across the presented papers sampling and analytical methods were reviewed (e.g., consideration of standardised methods (e.g., NIOSH 7500)) data quality examined and addressed, (e.g., examination of data distributions and harmonising heterogeneous data from different sources across variables); the use of censored regression (Tobit regression) and comparisons with measured data against predictions (e.g., the Alberta data where 65 exposure measurements were compared). In addition, plausibility was supported by examination of predictions for ‘high load’ tasks such as abrasive blasting compared to outdoor exposure settings while bias and accuracy was examined through validation metrics such as the correlation coefficient, mean ratios, and the standard deviation.

#### 3.2.5. Comparison of Key Task Listings from Canadian and Australian Data

An examination of key task listings was undertaken across Canadian information (as obtained from reports and published papers) and from Australian information sources. The detailed list for Australia is presented in (Supplementary Materials B1). The specific comparisons were made against Australian tasks and those reported from British Columbia, Alberta and Manitoba. Appendix B presents the differences across tasks between Australia and Canada and includes all cases where a difference occurs even within Canadian jurisdictions to enable identification of specific differences across Canadian jurisdictions that may have relevance for the Australian setting. There were 46 CSPs for Manitoba, 5 for Albert, 22 for British Columbia and 28 for Australia. There were 7 Australian CSPs that were unique with variance across the Canadian jurisdictions suggesting that detailed jurisdictional investigation may be required even within Australian States and Territories to provide confidence across the Australian listing.

**Table 1.** Summary of identified BCCSA Silica Control Tool$^{TM}$ limitations.

| Issue | Factor | Resolution | Comment |
|---|---|---|---|
| Variable used to assess exposure measure. | Trade variable to assess exposure associated with that Trade e.g., bricklayer. | Task variable to assess exposure due to the task or activity e.g., power-cutting bricks. | The current model is based on North American trades and tasks which may differ from the Australian setting and would need to be assessed. |
| Measurement accuracy. | Grouped data. | Single data. | Results in measurement averaging and lower results which under-reports controls. |
| Data US dominant. | Regional influence. | Need Australian data. | Need to check data alignment between North America and Australia. |
| Multiple tasks/tools. | Task determinant. | Single task application only. | Confounding if not resolved. |
| Sampling methods.<br>Sampling duration. | Measurement accuracy.<br>Measurement methods require high-flow and low-flow techniques. | Consistent method application.<br>Ensure sampling techniques match task durations. | Need to avoid exposure averaging which may lower results.<br>Over-sampling reduces exposure measurements thus underreporting the exposure. |
| Un-reporting and unreported descriptions. | Task, material and tool<br>Confounds influence of determinants. | Require detail to be addressed<br>Ensure adequate descriptions. | Un-reporting results in residual error and needs to be avoided.<br>Can be achieved for prospective investigations. |
| Limited industry sector data. | Initial database only had 35 measurements for the Residential sector.<br>Limited residential sector data (2%) but 30% of workers. | Increased measurements across relevant sector. | Particularly relevant for Australian indoor RCS exposures in renovations and new housing constructions.<br>Lack of data will under-represent the exposure prediction. |
| Variable measurement data quality. | Affects comparisons across data sets. | Consistent methodology. | This requires a consistent methodology to be identified and promoted. |
| Source material/formulation variance.<br>Product composition. | Variance in bulk silica content. | Requires further regional investigation. | Source material (geological) and product silica content introduces significant variability across estimations. This requires better understanding of the degree of influence. |
| Secondary sources. | Exposure measurement confounding. | Requires better understanding of individual contributions. | Using additive approaches for multiple sources may be an option here. |
| Indoor/outdoor characteristics. | Nature and extent of enclosure not provided. | Improved detail required. | Variance in the nature of the enclosure will impact exposure due to ventilation changes. This requires better understanding. |
| Control methods. | Control techniques undefined. | Further data required. | Control method detail influences exposure mitigation efficacy. |
| Lack of CSPs. | Task not represented. | Requires further data collection. | Highlights the importance of regional information across tasks. |
| Data distribution. | Seasonal influences on tasks and exposure. | Need to capture seasonal variance through monitoring distribution. | Measurement bias may occur of seasonal variance in tasks and exposures is not considered. |
| On-line tool quality. | The tool is only as robust as the site- and region-specific exposure data. | Requires comprehensive regional data. | Regional-relevance and robustness is improved through local data acquisition. |
| Data variability. | Quality of exposure data. | 95th percentile data reported. | The more robust the data set the greater the conservatism could be reduced with confidence. |
| No exposure prediction forthcoming if no exposure data in the model. | Unknown CSPs and exposure measurements. | Comprehensive evaluation. | Australian-specific investigations and exposure data gathering would be required. |
| Daily site to site variability. | Unless captured, will introduce bias in exposure estimations. | Increased monitoring and surveillance. | The model is only as robust as the data that supports it. Improved data will reduce conservatism and costs. |
| Exposure due to construction method. | Concrete processing and silica at surface. | Identification of concrete processing methods. | Concrete laying methods including in-situ vibration may result in layering of sand or aggregate resulting in less silica at the surface. |

### *3.3. BCCSA Silica Control Tool$^{TM}$ User Trial*

3.3.1. Exposure Control Plans (ECPs) Generated from Hands-on Use of the Tool by User Trial Participants

A total of 14 ECPs were generated by the five small breakout groups participating in the User Trial. The ECP outputs demonstrated the specificity and nuance of the Tool advice based on user input decisions, even for the same 'Task, Material and Tool' exposure scenarios. Table 2 provides an overview of the input decisions by each group for each scenario used in the Trial, and the resulting Final Risk Rating. For example, multiple groups chose the same scenario but used differing inputs such as controls or other parameters. This allowed for a granulated comparison between predicted exposures and resultant risk outcomes. Some examples are provided below for illustrative purposes. As shown in Table 2, three groups chose the same scenario for 'Task, Tool and Work area' (Cutting concrete with a Saw Outside), with the same Engineering Controls (Wetting integrated to tool). However, one group chose different Administrative Controls (Barriers only) compared with the other two groups (all available Administrative controls selected). Although the predicted exposure after controls was comparable among all groups, the resulting Final Risk statement was different for one group who selected fewer Administrative controls, i.e., "Hazardous Level—Recommended to NOT PROCEED without required PPE or perform air sampling test", compared to "Low Risk/Proceed with Caution".

Another point of difference was shown when two groups selected 'Outside' as the work area while another group selected 'Inside' for the 'Task, Tool and Work area' of 'Drilling concrete with an electric hammer drill'. The variation in results was shown in predicted exposure (before and after controls), and dependent on Engineering and Administrative controls selected. Final Risk also varied, ranging between "Acceptable Risk" and "Low Risk/Proceed with Caution". We note that for some of the Final Risk outputs in the ECPs, there may be residual uncertainty in the model post-control predictions which suggests the Tool may then default to a protective cautionary principle and apply PPE for residual control.

The relationship between predicted exposure levels and final risk ratings was not always transparent. In some cases, relatively high post-control exposure estimates (e.g., 0.128 mg/m$^3$) were associated with a "Low Risk" classification, while in others, similar or lower exposure levels resulted in a "Hazardous" rating. One possible explanation is that the Tool incorporates additional assumptions—such as the effect of PPE or the availability of baseline exposure estimates—into its final risk categorisation. However, in the absence of access to the Tool's underlying decision rules and thresholds, these interpretations remain speculative. Greater transparency in the Tool's risk classification logic is therefore necessary to support user confidence and appropriate interpretation of outputs. Lastly, two groups created new scenarios, which included 'Spraying shot-crete with a compressed air mixture', 'Removing plaster with a chipper' and 'Grinding concrete with a surface grinder'. These illustrate other potential exposure scenarios relevant and of interest to the sector, according to participants. Importantly, the Tool was able to predict exposure (before and after controls, if selected) and provide a Risk Rating for these potential high-exposure tasks. Again, it was interesting to note that these scenarios all resulted in a Final Risk output of "Low Risk" despite predicted levels being high. One would have expected the post 'no control' value to be 0.314 mg/m$^3$ (Group D). The general default appears to be respiratory protection which then triggers the low-risk comment. This of course is dependent on mask fitting, correct use etc. which then brings in a range of other influencing variables. Collectively the ECPs generated in this User Trial suggest that further discussion with the Tool developer would be warranted to better understand these and other important decision points and resulting risk ratings.

In addition to scenario ECP outcomes described above, it is important to highlight that some terms used in the Tool also lack clarity. For example, in the section of the Tool related to PPE, "Respiratory protection is available" is an option for the user to select, however it remains unclear as to whether this means in practice that respiratory protection is worn, or simply whether it is available. This would be an important distinction to address for any future Tool developments.

**Table 2.** Scenarios used in the Industry Stakeholder User Trial of the Silica Control Tool™ and resulting outputs in ECPs. Similar tasks are grouped.

| Group | Task, Tool & Work Area | Duration per Shift | Job Sector & Project Type | Exposure, before Controls ($mg/m^3$) | Exposure, after Controls ($mg/m^3$)# | Engineering Controls Selected | Administrative Controls Selected | PPE Advised for Residual Exposure Control | Final Risk |
|---|---|---|---|---|---|---|---|---|---|
| A | Cutting concrete with a saw Outside | <4 h | Civil Engineering & Roadwork; Renovation | 0.319 | 0.037 | Wetting integrated to tool | Barriers | 10 PF, half-facepiece non-powered with P100 filter | Hazardous Level—Recommended to NOT PROCEED without required PPE or perform air sampling test. |
| C | Cutting concrete with a saw Outside | <4 h | Civil Engineering & Roadwork; Renovation | 0.304 | 0.034 | Wetting integrated to tool | Barriers, Exposure emergency preparedness, Housekeeping, Inspections & Maintenance, Instruction and Training. | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| D | Cutting concrete with a saw Outside | <4 h | Civil Engineering & Roadwork; Renovation | 0.294 | 0.033 | Wetting integrated to tool | Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| A | Drilling concrete with an electric hammer drill Outside | <4 h | Civil Engineering & Roadwork; Renovation | 0.037 | N/A | None selected | Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| E | Drilling concrete with an electric hammer drill Outside | <4 h | Industrial, Institutional & Commercial; New Construction | 0.037 | 0.023 | LEV integrated to tool | Barriers, Exposure emergency preparedness, Housekeeping, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | None. Protection optional. | Acceptable Level |
| C | Drilling concrete with an electric hammer drill Inside | <4 h | Residential; New Construction | 0.05 | 0.031 | LEV integrated to tool | Barriers, Exposure emergency preparedness, Housekeeping, Inspections & Maintenance, Instruction and Training. | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| B | Concrete breaking with excavator with jackhammer attachment Outside | 4–8 h | Civil Engineering & Roadwork; New Construction | 0.066 | 0.05 | Closed Cab | Barriers, Enclosures, Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| C | Concrete breaking with excavator with jackhammer attachment Outside | 4–8 h | Industrial, Institutional & Commercial; Demolition | 0.169 | 0.128 | Wetting separate from tool | Barriers, Exposure emergency preparedness, Housekeeping, Inspections & Maintenance, Instruction and Training. | 10 PF, half-facepiece non-powered with P100 filter | Low Risk/Proceed with Caution |
| E | Breaking concrete with a jackhammer Inside | 4–8 h | Residential; Demolition | 0.295 | 0.047 | Wetting integrated to tool | Barriers, Enclosures; Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | 10 PF, half-facepiece non-powered with P100 filter shown | Low Risk/Proceed with Caution |

**Table 2.** *Cont.*

| Group | Task, Tool & Work Area | Duration per Shift | Job Sector & Project Type | Exposure, before Controls (mg/m$^3$) | Exposure, after Controls (mg/m$^3$)# | Engineering Controls Selected | Administrative Controls Selected | PPE Advised for Residual Exposure Control | Final Risk |
|---|---|---|---|---|---|---|---|---|---|
| C | Cutting tiles with a powered tile saw Outside | 4–8 h | Residential; Renovation | N/A. "We do not have uncontrolled exposure data for this work activity" | 0.029 | LEV integrated to tool | Barriers, Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training. | 10 PF, half-facepiece non-powered with P100 filter | Hazardous Level—Recommend to NOT PROCEED without required PPE and air sampling test. |
| D | Cutting tiles with a powered tile saw Inside | 4–8 h | Industrial, Institutional & Commercial; New Construction | N/A. "We do not have uncontrolled exposure data for this work activity" | 0.019 | LEV integrated to tool | Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | None. Protection optional. | Acceptable Level |
| B | Spraying Shot-crete with a compressed air mixture in Restricted space (e.g., staircase, shrouded area, narrow hallway, tunnel, confined space) | 4–8 h | Civil Engineering & Roadwork; New Construction | 0.289 | No exposure level (with Controls) listed as Engineering Control not listed | "the desired Eng Control is not listed, the user has indicated that the following control will be used" Capsulation | Barriers, Enclosures, Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling | 25 PF, Loose-fitting facepiece, powered (PAPR) equipped with N100 filter. | Low Risk/Proceed with Caution |
| D | Grinding concrete with a surface grinder Inside | 4–8 h | Civil Engineering & Roadwork; New Construction | 0.739 | 0.273 | Wetting integrated to tool | Barriers, Exposure emergency preparedness, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | 25 PF, Loose-fitting facepiece, powered (PAPR) equipped with N100 filter. | Low Risk/Proceed with Caution |
| D | Removing plaster with a chipper in Restricted Space (e.g., staircase, shrouded area, narrow hallway, tunnel, confined space) | <4 h | Industrial, Institutional & Commercial; Renovation | 0.314 | N/A. "An Eng Control is NOT being used" | None selected | Barriers, Enclosures, Exposure emergency preparedness, Housekeeping, Hygiene, Inspections & Maintenance, Instruction and Training, Work shift scheduling. | 25 PF, Loose-fitting facepiece, powered (PAPR) equipped with N100 filter. | Low Risk/Proceed with Caution |

# The Tool displays an output in the ECP showing predicted exposure "After Controls" only when/if an engineering control is selected.

### 3.3.2. Emergent Themes from Hands-on Use of Tool by User Trial Participants

Emergent themes from the User Trial of the BCCSA Silica Control Tool™ are presented in Table 3.

Participants in the User Trial broadly viewed the BCCSA Silica Control Tool™ as a valuable and necessary baseline for improving the consistency, transparency and structure in silica exposure risk assessment within the construction sector. The Tool was generally perceived as intuitive and easy to use, even for first-time users, reinforcing its potential across a broad range of stakeholders. Nevertheless, its practicality for routine frontline application was questioned. Participants noted that fast-paced work environments, time pressures, internet connectivity onsite and reliance on mobile devices may constrain meaningful engagement by workers. The length and detail of the generated exposure control plan (ECP) were frequently highlighted as barriers for field use, leading to strong support for tiered outputs. For example, a concise worker-focused summary was seen as essential for practical implementation, while the existing detailed output was considered more suitable for supervisory, planning, auditing, or regulatory purposes.

Beyond regulatory compliance, the Tool's education value was a dominant and consistently endorsed theme. Participants emphasised that guiding users through exposure estimation and control selection fostered a clearer understanding of RCS risks and illuminated the limitations of commonly relied-upon measures, particularly PPE. This structured exposure "journey" was viewed as a powerful mechanism to challenge habitual practices and to promote higher order controls. Importantly, this educational function was regarded as especially beneficial for small contractors and subcontractor workforces where formal occupational hygiene support is often limited.

Regulatory alignment and localisation were identified as prerequisites for credible adoption. Participants expressed uncertainty around whether the Tool adequately reflected Victorian (and Australian) legislative requirements, particularly in relation to the hierarchy of controls and the framing of administrative measures. Jurisdictional differences between Canadian and Australian frameworks along with the use of non-Australian terminology were perceived as potential sources of misinterpretation. Participants therefore stressed the importance of explicit localisation including integration with Victorian regulatory instruments, guidance materials and familiar industry language.

Several functional limitations were also noted. The Tool's limited capacity to account for short duration tasks, combined or sequential tasks, cumulative daily exposure, environmental conditions and bystander exposure was viewed as misaligned with real-world construction practice. In addition, participants expressed concern that alert mechanisms may understate urgency when high exposures are estimated and higher order controls are not selected. While some viewed the Tool as reinforcing the hierarchy of controls, others cautioned that users could bypass engineering and administrative measures in favour of PPE. Stronger warnings, prompts, and justification requirements were therefore recommended to ensure risk-based decision making is consistently prioritised.

Overall, participants considered the Tool a substantial improvement over current fragmented or informal approaches to silica risk management. With refinement, particularly in localisation, accessibility, task realism and transparency of decision thresholds, the Tool was viewed as capable of driving meaningful improvements in both regulatory compliance and practical risk control across the Victorian construction industry.

**Table 3.** Emergent Themes from User Trial of the BCCSA Silica Control Tool™.

| Theme | Key Findings | Implications for Implementation |
| --- | --- | --- |
| Usability and Accessibility | Tool perceived as intuitive and easy to navigate; concerns about practicality for frontline workers in fast paced, onsite settings, internet dependence, mobile accessibility, and length of ECP output. | Tiered outputs recommended: a concise, worker focused summary and a detailed management/planning version; offline and mobile friendly access needed. |
| Educational Value | Tool viewed as a strong educational aid beyond compliance, supporting awareness of RCS risks, limitations of PPE, and best practice controls; suitable for training and toolbox talks. | Potential to improve industry understanding of RCS risk and reduce over reliance on PPE. |
| Regulatory Alignment and Localisation | Participants questioned alignment with Victorian/Australian legislation; differences between Canadian and Australian frameworks and terminology raised concerns. | Localisation required, including jurisdiction specific controls, terminology, and explicit linkage to Victorian regulatory instruments. |
| Terminology and Clarity | Ambiguous terms (e.g., "sufficient," "adequate"), technical classifications, and non-Australian terminology risk misinterpretation. | Clear definitions, thresholds, visual aids, and embedded links to authoritative guidance (e.g., WorkSafe Victoria) recommended. |
| Coverage Gaps | Limited capacity to account for short duration tasks, combined or sequential activities, cumulative exposures, bystanders/spotters, and environmental conditions. | Expanding task logic and cumulative exposure assessment would improve real world applicability and accuracy. |
| Risk Hierarchy and Decision Logic | Perceived ability to bypass higher order controls and default to PPE; alert messaging viewed as insufficiently forceful when high exposures predicted. | Stronger prompts, warnings, and justification requirements needed to reinforce hierarchy of controls and prevent complacency. |

## 4. Discussion

This evaluation provides the first systematic appraisal of the BCCSA Silica Control Tool™ for potential use in the Australian construction context. It combined technical integration of the underpinning model with applied usability testing among Victorian construction stakeholders. Importantly, this assessment of technical robustness reflects the quality of the North American evidence base, model development process and statistical methods underpinning the Tool, rather than demonstrated predictive validity under Australian. Conditions. The findings highlight the Tool's strong technical foundation and positive user reception, while also identifying critical areas requiring adaptation before implementation in Victoria. Collectively the results demonstrate the feasibility and essential conditions required for Australian application of an established Canadian predictive exposure model within a new regulatory and operational setting.

The technical robustness of the BCCSA Silica Control Tool™ based on application to North American settings, has important implications for its potential application in the Australian construction context. Our review of the Tool's development revealed an evidence-based, iteratively improved modelling framework drawing on extensive North American exposure data and contemporary statistical approaches including stepwise regression and Bayesian method. These findings reaffirm previous evaluations that predictive tools can complement traditional exposure monitoring in dynamic work settings, enabling rapid risk-based decisions [6,7]. However, the analysis also confirms a core limitation: region-specific variability in exposure determinants. Differences in materials, construction methods and regulatory requirements mean that the current Tool, without modification, may not be assumed to provide accurate risk estimates for Victorian worksites. A key factor is the distinct material profile, particularly the widespread previous use of high-silica engineered stone, alongside variability in local construction materials. These differences suggest recalibration of material-related determinants is required to reflect Australian conditions accurately. Task profiles and work practices are another key exposure determinant and Australian construction commonly involves short-duration, high-intensity activities (e.g., cutting, grinding) often occurring intermittently and alongside other trades. This increases the likelihood of peak and bystander exposures that may not be well captured by shift-based models and highlights the need for greater sensitivity to task duration, frequency and overlap. Regulatory and operational factors are equally important. Recent Australian WHS amendments emphasise higher-order controls requiring alignment of the Tool with local regulatory frameworks and terminology. In practice, control effectiveness varies due to differences in equipment, maintenance and user compliance suggesting that incorporating Australian-specific performance data and accounting for implementation variability would improve model accuracy. Finally, workforce and site characteristics contribute to exposure variability. A fragmented workforce, variable training levels and linguistic diversity can affect control implementation. Together these local factors indicate that effective adaptation of the Tool would require both Australian exposure data and broader contextual adjustments reflecting local materials, practices, environment and regulatory expectations. This mirrors findings from Canada [10] where exposure levels differed significantly between provinces, necessitating regional datasets to refine the predictive accuracy. Therefore, the incorporation of Australian exposure measurements, especially for high-risk tasks, indoor/confined space environments and commonly used local materials, would be essential to improve representativeness and reduce predictive uncertainty.

The User Trial highlighted several features of the Tool performance that warrant further investigation and potential clarification. Although exposure predictions responded appropriately to user-selected determinants and control measures, participants noted instances where the final risk rating appeared inconsistent with predicted exposure values. These inconsistencies may reflect conservative default rules or internal logic that prioritises precautionary recommendations when model uncertainty is high. Similar tools are often designed to default to precaution during uncertainty, a principle also reflected in tiered exposure modelling paradigms [1,6,9]. Without access to internal decision thresholds, however, these interpretations remain speculative. Further collaboration with the Tool developers including transparency around threshold-setting and decision logic would be beneficial to support effective adaptation and user confidence.

Stakeholders strongly valued the Tool's intuitive interface, educational potential and capacity to standardise risk assessment. The Tool was broadly viewed as beneficial for users ranging from onsite workers to safety managers. However, concerns were raised regarding the practicality of use in fast-paced or low-connectivity worksites and the complexity of the ECP output. Participants overwhelmingly supported a tiered or multi-version format such as a concise one-page field version for workers and toolbox meetings, a detailed planning version for supervisors and project managers, and a training-oriented version with enriched visual aids and explanatory resources. Addressing accessibility concerns including language complexity, technical terminology and usability for people with lower literacy or English proficiency will ensure equitable implementation. These recommendations align with best practice for deploying control guidance in high-risk environments and match the international experience that modelled outputs should be usable at the point of work [6,9]. It must be acknowledged that while the participant recruitment approach ensured inclusion of knowledgeable and experienced perspectives across multiple sectors, recruitment was purposive rather than random and limited to a small sample size. As such, the cohort may not fully represent the broader Victorian construction workforce (e.g., small contractors, regional operators), introducing potential selection bias toward more engaged or higher-level stakeholders. Consequently, findings from the User Trial should be interpreted as indicative of stakeholder perspectives rather than generalisable across the entire industry.

Addressing gaps and missing links in the Tool's structure and content will be essential to ensure comprehensive and accurate assessment of real-world construction scenarios. A major theme arising from the user trial concerned the alignment with Victorian regulations, particularly the hierarchy of controls under the Victorian WHS framework. While the tool includes engineering, administrative and PPE selections, participants questioned whether the current structure sufficiently emphasises higher-order controls or provides clear prompts to avoid over-reliance on RPE. Clear guidance on the hierarchy of controls should be embedded within the Tool to reflect Australian WHS expectations, prioritising elimination and substitution wherever practicable, followed by engineering controls, before administrative measures and PPE. The Tool should actively prompt users toward Australian-relevant higher-order controls and avoid reframing respiratory protection as a primary solution. Structuring outputs to visibly reinforce this hierarchy would support regulatory alignment and encourage more effective risk management practices on Australian worksites. Adapting the Tool to Australian conditions would also require embedding Victorian terminology and definitions as well as linking directly to relevant Victorian and Australian guidance (e.g., Safe Work Australia's 2024 amendments strengthening control obligations for crystalline silica substances and associated guidance resources) [4]. Clarifying equivalency between outputs (ECP) and Victorian regulatory documentation (e.g., Safe Work Method Statements (SWMS) and Crystalline Silica Hazard Control Statements) will also be advantageous. Participants also emphasised the importance of recognised bystander exposures, which is not something traditionally incorporated readily into workplace monitoring programs. Similarly, concurrent tasks and short-duration activities which are common features of Australian construction sites, warrants attention.

A key strength of this evaluation is its combination of detailed methodological scrutiny with applied stakeholder testing. The thematic analysis provides direct insight into sector expectations, perceived utility and practical considerations for Tool adoption. However, this study did not assess predictive accuracy of the Silica Control Tool™ under Australian conditions. While one participant informally compared the Tool predictions with measured values, a systematic validation study using Australian exposure monitoring data remains a necessary next step. The broader exposure-modelling literature stresses the value of external validation and clarity on model applicability (as reviewed by Jacobs et al., [1]), steps that should precede regulatory adoptions in new jurisdictions. Additionally, the research team did not have access to underlying model parameters or internal decision algorithms which limited the extent to which observed output anomalies could be formally interpreted.

With regard to implications of the outcomes and future directions, stakeholders were highly receptive to the Tool's potential value for training, planning, and compliance. The Tool may address longstanding gaps in consistent and transparent silica risk assessment practices and could serve as a foundational platform for national harmonisation. Priority future steps could include development of an Australian silica exposure dataset for incorporation into the model via Bayesian method application. Strategies for incorporating Australian exposure data into the Tool could involve developing such a national exposure database drawn from personal monitoring campaigns across high-risk tasks, materials and work environments. This data could then be integrated using the Tool's existing Bayesian framework to recalibrate the model parameters and update exposure estimates while accounting for uncertainty. Prioritising datasets for engineered stone, confined spaces and short-duration high-intensity tasks would improve relevance. Ongoing data interrogation supported by partnerships with regulators, industry and researchers would enable continuous model refinement and validation under real-world Australian conditions. It would be sensible to conduct predictive validation studies comparing the Tool outputs with personal exposure measurements under Australian conditions. The co-design of a Victorian-adapted interface with industry, regulators and end-user groups may also be beneficial. In terms of governance, establishing Tool hosting arrangements, such as through WorkSafe Victoria, will be essential to ensure ongoing maintenance, data security and continuous improvement. Finally, evaluating the feasibility of implementation in Victoria and other jurisdictions in Australia would ensure successful adoption, including training needs, digital access constraints and industry readiness. Practical implementation in construction settings may be constrained by time pressures, variable site conditions and possibly digital access particularly on smaller or regional projects. Workers and supervisors require rapid and straightforward tools that can be used at the point of work which may limit engagement with more complex inputs and outputs. In addition, competing priorities, workforce turnover and inconsistent training could affect the correct and consistent use of the Tool in practice. Addressing these challenges requires simplified interfaces, potentially offline functionality and integration with existing site processes such as toolbox talks and SWMS to support routine uptake and sustained use.

## 5. Conclusions

This evaluation shows that the BCCSA Silica Control Tool™ is based on a technically robust North American evidence and modelling framework and is well-received by industry stakeholders, but has not yet been independently validated using Australian exposure data and is not immediately transferrable to Victoria without adaptation. The underlying model has been over a decade in development and undergone an iterative understanding of its uncertainties and limitations with subsequent improvement. The statistical basis to the model is sound and consistent with standard statistical methods. Model improvements have included a Bayesian approach which enables new data to be incorporated providing improved confidence in RCS exposure model predictions and the resultant exposure control programs. As such, the model is capable of integrating Australian exposure data and offers a strong foundation for regional application. User trial participants recognised the Tool's value for improving silica risk assessment in construction, strengthening control planning and enhancing industry awareness. Essential modifications were also highlighted including alignment with local regulations, clearer terminology and improved usability across diverse work contexts to ensure better representation of real-world construction scenarios. Overall, the Tool has significant potential to support safer work practices in the Victorian construction sector. With incorporation of Australian exposure data, input on design from regulators and industry, and rigorous validation an adapted version could become a reliable and practical resource for managing respirable crystalline silica risks in Victoria and the rest of Australia.

## Supplementary Materials

The additional data and information can be downloaded at: https://media.sciltp.com/articles/others/2608311657259271/WAH-26050100-SM.zip. Figure S1: BCCSA Silica Control Tool™ model development. Figure S2: Improvements incorporating additional data. Figure S3: Original model improvements. Table S1: Summary of key documentation, presented in chronological order. The table describes key points from the papers, any key issues relating to data gaps and the objective for the respective paper review. Key limitations are highlighted in bold.

## Author Contributions

S.G.: conceptualization, methodology, data acquisition and analysis, data curation, supervision, writing—original draft preparation; L.T.: methodology, formal analysis, writing—original draft preparation; S.S.: data acquisition, data interpretation (thematic analysis); C.R.: data acquisition, writing—reviewing and editing; Y.T.: conceptualization, writing—reviewing and editing; H.A.: supervision; data acquisition. All authors have read and agreed to the published version of the manuscript.

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## Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Adelaide University (protocol code H-2024-086 and date of approval 26 June 2024).

## Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

## Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

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## Conflicts of Interest

Given the role as the editorial board member, Sharyn Gaskin had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. WorkSafe Victoria had involvement in the development and oversight of the project and provided funding to support the work. The authors take full responsibility for the content of the published article.

Given the role as WorkSafe Victoria (WSV) Principal Hygienist, Halil Ahmet was involved in the development and oversight of the project with the intent of ensuring the process objectively looked at all of the available information to understand the capability of the BCCSA Silica Control Tool in the Victorian setting, to further understand whether it's purchase and implementation by WSV would be beneficial for Victorian workplaces.

## Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used Microsoft Copilot at the revision stage to reduce word count in some sections and assist with grammar checks. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

## Appendix A. Example Exposure Scenarios Developed for the User Trial

Several 'task, material and tool' scenarios were developed for participants in the User Trial to input into the Tool and familiarise themselves with the parameters of the Tool requirements and resulting ECPs. These included: cutting a concrete footpath using a powered saw, drilling concrete with a hammer drill, cutting landscaping pavers with a tile saw, and demolition of a commercial structure with an excavator. Participants were also encouraged to choose their own scenarios for input into the Tool. Boxes A1 to A4 show the input parameters for each of the provided construction scenarios. These were created specifically to match the sequence and specific terms of available options displayed in the Tool. They were not intended to be exemplary scenarios of best practice.

**Box A1.** Scenario 1—Cutting Concrete Footpath.

*City: Vancouver, Province: BC, Postal Code: 395540*

A worker needs to use a **powered concrete cutting saw to cut a section of footpath** (choose Job sector: Civil Engineering & Roadwork) (Project type: Renovation)

This activity requires less than 4 hours of work outside.

Risk control measures implemented by the employer include:

- **on-tool water suppression** (Engineering Controls),
- **preventing access to the work area** (Administrative Controls),
- **good housekeeping during the work and at the completion of the task** (Administrative Controls),
- **ensuring wet residue is not permitted to remain in the area to dry** (Administrative Controls), **but**
- **no enclosure to contain the dusty atmosphere** (Administrative Controls).

**Respiratory protection is available** (PPE).

**Box A2.** Scenario 2—Drilling Concrete.

*City: Vancouver, Province: BC, Postal Code: 395540*

A worker needs to **drill concrete with an electric hammer drill** (choose Job sector: Civil Engineering & Roadwork) (Project: Renovation)

This activity requires less than 4 hours of work outside.

Risk control measures implemented by the employer include:

- **water suppression, separate from tool** (Engineering Controls),
- **preventing access to the work area** (Administrative Controls),
- **good housekeeping during the work and at the completion of the task (**Administrative Controls**),**
- **training and maintenance** (Administrative Controls), **but**
- **no enclosure to contain the dusty atmosphere** (Administrative Controls).

**Respiratory protection is available** (PPE).

**Box A3.** Scenario 3—Cutting Landscaping Pavers.

*City: Vancouver, Province: BC, Postal Code: 395540*

A worker needs to use a **powered tile saw to cut a paver tile** (choose Job Sector: Residential) (Project Type: Renovation)

This activity requires less than 4 hours of work outside.

Risk control measures implemented by the employer include:

- **LEV system Integrated to tool (e.g. vacuum extraction)** (Engineering Controls)
- **good housekeeping and hygiene during the work and at the completion of the task** (Administrative Controls)
- **preventing access to the work area** (Administrative Controls), **but**
- **no enclosure to isolate the area (Administrative Controls).**

**Respiratory protection available** (PPE).

**Box A4.** Scenario 4—Demolition of a Structure.

*City: Vancouver, Province: BC, Postal Code: 395540*

A contractor needs to **demolish** a commercial structure consisting of bricks and cement-based materials. (choose Job sector: Industrial, Institutional, and Commercial) (Project Type: Demolition)

The work will involve using a **jackhammer attachment on an excavator** to demolish the structure.

This activity requires **4-8 hours of work outside**.

Risk control **(**Engineering Controls**)** measures implemented by the employer include:

**The excavator cabin is:**

- retrofitted with a positive-pressure, HEPA filtered system to reduce the risk of dust being drawn into the cabin, and
- enclosed and the doors and windows kept shut, air flow will be put on recirculation and the cabin will be cleaned every day using wet wiping/cleaning methods or a H or M-class industrial vacuum.

**A water-spraying system attached to the hammer** to produce a fine mist to suppress dust at the working area. **A water-mist fan** used to provide further fine water spray to the working area.

**Respiratory protective equipment is available** (PPE).

## Appendix B

**Table A1.** Construction Industry Task differences between Canada and Australia.

| S.N. | Reported CSPs (Respirable Crystalline Silica in the Manitoba Construction Sector: Advancing Knowledge to Reduce Exposure) | Evaluating a Respirable Crystalline Silica Risk Assessment Model for the Construction Industry in Alberta (Ng & Davies, 2018) | BCCSA CSPs | Australia CSPs (Sourced from the Construction Task Activity tables in Appendix B) |
|---|---|---|---|---|
| 1 | Cutting Asphalt with Walk-behind saw | Cutting Asphalt with Walk-behind saw | Cutting Asphalt with Walk-behind saw | Cutting Asphalt with Walk-behind saw |
| 2 | Milling Asphalt with Milling Machine | Milling Asphalt with Milling Machine | Milling Asphalt with Milling Machine | Milling Asphalt with Milling Machine |
| 3 | Cutting Concrete masonry unit with waterfed table saw | Cutting Concrete masonry unit with waterfed table saw | Cutting Concrete masonry unit with table saw | Cutting Concrete masonry unit with waterfed table saw |
| 4 | Cutting concrete masonry unit with portable saw | Cutting concrete masonry unit with portable saw | Cutting concrete masonry unit with portable saw | Cutting concrete masonry unit with portable saw |
| 5 | Cutting concrete with saw | Cutting concrete with saw | Cutting concrete with powered saw | Cutting concrete with saw |
| 6 | Coring concrete with coring machine | Coring concrete with coring machine | Coring concrete with coring machine | Coring concrete with coring machine |
| 7 | Drilling concrete with electric hammer drill | Drilling concrete with electric hammer drill | Drilling concrete with electric hammer drill | Drilling concrete with electric hammer drill |
| 8 | Grinding concrete with surface, angle or flat grinder | Grinding concrete with surface, angle or flat grinder | Grinding concrete with surface, angle or flat grinder | Grinding concrete with surface, angle or flat grinder |
| 9 | Grinding concrete with counterbalanced ceiling grinder | Grinding concrete with counterbalanced ceiling grinder | Ceiling Grinding with any tool | Grinding concrete with counterbalanced ceiling grinder |
| 10 | Grinding, Preparing and finishing concrete - Other | | | |
| 11 | Scarifying or bush hammering (concrete) | Scarifying or bush hammering (concrete) | Scarifying concrete with a bush hammer | Scarifying or bush hammering (concrete) |
| 12 | Demolition (any material) | Demolition (any material) | | Demolition (any material) |
| 13 | Sweeping (Any construction area) | Sweeping (Any construction area) | Sweeping Construction Dusts using any sweeping tool | Sweeping (Any construction area) |
| 14 | Shotcreting | Shotcreting | Spraying shotcrete with compressed air | Shotcreting |
| 15 | Cutting tiles with powered tile saw | Cutting tiles with powered tile saw | Cutting tiles with powered tile saw | Cutting tiles with powered tile saw |
| 16 | Manual moving of small rocks, soil etc. | Manual moving of small rocks, soil etc. | Manual moving of rock/sand/earth with hands | Manual moving of small rocks, soil etc. |
| 17 | Mechanised moving of rocks, soil etc. | Mechanised moving of rocks, soil etc. | Mechanised moving Rock/Earth/Sand with heavy equipment (i.e. backhoe, bobcat, etc.) | Mechanised moving of rocks, soil etc. |
| 18 | Crushing and processing rocks/sand/earth | Crushing and processing rocks/sand/earth | Crushing Rock/Sand/Earth with crusher | Crushing and processing rocks/sand/earth |
| 19 | Cutting marble/granite | Cutting marble/granite | Cutting marble/granite with powered saw | Cutting marble/granite |
| Cutting drywall | Cutting drywall | Cutting drywall with any tool | Cutting plasterboard | Cutting drywall |
| 21 | Sanding drywall | Grinding drywall | Sanding drywall with manual pole sander | Grinding plasterboard |
| 22 | | | Sanding drywall with manual handheld sander | |
| 23 | Mixing and pouring cementicious material | Mixing and pouring cementicious material | Mixing and pouring cementicious material | Mixing and pouring cementicious material |
| 24 | Tuckpoint grinding | Tuckpoint grinding | Tuckpoint grinding of mortar | Tuckpoint grinding |
| 25 | Spraying | | | |
| 26 | Other masonry-related tasks | | | |
| 27 | Other roadwork | | | |
| 28 | Breaking concrete with jackhammer | Breaking concrete with jackhammer | Concrete breaking with Jackhammer | Breaking concrete with jackhammer |
| 29 | Breaking-other | | | |
| 30 | Other cutting | | | |
| 31 | Abrasive blasting | Abrasive blasting | | Abrasive blasting |
| 32 | Tunnel boring | | | Tunnel boring |

**Table A1.** *Cont.*

| S.N. | Reported CSPs (Respirable Crystalline Silica in the Manitoba Construction Sector: Advancing Knowledge to Reduce Exposure) | Evaluating a Respirable Crystalline Silica Risk Assessment Model for the Construction Industry in Alberta (Ng & Davies, 2018) | BCCSA CSPs | Australia CSPs (Sourced from the Construction Task Activity tables in Appendix B) |
|---|---|---|---|---|
| 33 | Installation of acoustic ceiling tiles | | | |
| 34 | Other surface grinding | | | |
| 35 | Installation of concrete formwork | | | Installation of concrete formwork |
| 36 | Other cleaning | | | |
| 37 | Other drilling | | | |
| 38 | Foundation work | | | |
| 39 | Electrical maintenance work | | | Electrical maintenance work |
| 40 | Excavation work | | | Excavation work |
| 41 | Cutting fiber cement board with portable saw | Cutting fiber cement board with portable saw | | Cutting fiber cement board with portable saw |
| 42 | Loading concrete mixer truck | Loading concrete mixer truck | Loading Concrete with Mixer | Loading concrete mixer truck |
| 43 | Crushing and processing concrete | | Crushing and processing concrete | Crushing and processing concrete |
| 44 | Cutting concrete with walk-behind saw | | Cutting concrete with walk-behind saw | Cutting concrete with walk-behind saw |
| 45 | Chipping concrete | Chipping concrete | Chipping concrete | Chipping concrete |
| 46 | Mixing gypcrete | Mixing gypsum | Mixing gypcrete | Mixing gyprock |
| 47 | Walk-behind concrete grinding | Walk-behind concrete grinding | | Walk-behind concrete grinding |
| 48 | Power Sweeping concrete | Mobile road sweeping | | Mobile road sweeping |
| 49 | Concrete breaking with excavator | Concrete breaking with excavator | Concrete breaking with excavator | Concrete breaking with excavator |
| 50 | Drilling rock | Drilling rock | Drilling rock with drilling machine | Drilling rock |
| 51 | Asphalt breaking with excavator | Asphalt breaking with excavator | | Asphalt breaking with excavator |
| 52 | Cement plant helper | | | |
| 53 | Cement plant operator | Cement plant operator | Operating a Concrete Plant | Cement plant operator |
| 54 | Cement Loader Operator | Cement Loader Operator | Operating a Loader at a Concrete Plant | Cement Loader Operator |
| 55 | Cement truck driver | Cement truck driver | Receiving and Delivering concrete with a concrete mixer truck | Cement truck driver |
| 56 | Cement Plant Mechanic | | | |
| 57 | Cement Plant Lead Hand | | Working as a Concrete Plant Groundsperson | |
| 58 | Asphalt Plant Operator | | Operating an Asphalt Plant | |
| 59 | Asphalt Loader Operator | | Operating a Loader at an Asphalt Plant | |
| 60 | Asphalt Truck Loading | | | |
| 61 | Asphalt Plant helper | | Working as an Asphalt Plant Groundsperson | |
| 62 | Concrete breaking with excavator with jackhammer attachment | | Concrete breaking with excavator with jackhammer attachment | Concrete breaking with excavator with jackhammer attachment |
| 63 | Cutting concrete with electric wire saw | | Cutting concrete with electric wire saw | Cutting concrete with electric wire saw |
| 64 | Indoor mini batch plant operator | | Operating a Mini Batch Plant | |
| 65 | Sweeping drywall | | Sweeping concrete with a power-sweeper (non-vac) | Sweeping plasterboard |
| 66 | Shotblasting | | Shotblasting concrete with shotblasting machine | Shotblasting |
| 67 | Housing during concrete demolition with excavator | | | |
| 68 | Pinning Wood to concrete | | Pinning wood with a drill | |
| 69 | Screeding concrete with Has-powered screed | | Screeding concrete with gas powered screed | |
| 70 | Concrete floor scraping | | Floor scraping with Ride-on Scraper | Concrete floor scraping |

**Table A1.** *Cont.*

| **S.N.** | **Reported CSPs (Respirable Crystalline Silica in the Manitoba Construction Sector: Advancing Knowledge to Reduce Exposure)** | **Evaluating a Respirable Crystalline Silica Risk Assessment Model for the Construction Industry in Alberta (Ng & Davies, 2018)** | **BCCSA CSPs** | **Australia CSPs (Sourced from the Construction Task Activity tables in Appendix B)** |
|---|---|---|---|---|
| 71 | Cutting Artificial Stone and/or Granite Countertops | | Grinding Artificial Stone or Granite Countertop | |
| 72 | Grinding Artificial stone countertops | | Disc polishing Artificial Stone or Granite Countertop | |
| 73 | Vacuuming drywall | | | Vacuuming plasterboard |
| 74 | Mechanical street sweeping | | Mechanical street sweeping | Mechanical street sweeping |
| 75 | Cleaning vacuum filter | | | Cleaning vacuum filter |
| 76 | Concrete drilling (overhead) | | | Concrete drilling (overhead) |
| 77 | Concrete dowel drilling | | Dowel Drilling Concrete with Drill | Concrete dowel drilling |
| 78 | Other/Not specified | | | |
| 79 | | | | Road construction |
| 80 | | | | Wall Chasing |
| 81 | | | | Chiselling |
| 82 | | | | Dry coring |
| 83 | | | | Wet coring |
| 84 | | | | Sanding taped and covered plasterboard joints |
| 85 | | | | Polishing and Buffering with Tripoli |
| 86 | | | Removing plaster with chipper | |
| 87 | | | Removal and/or Demolition of Ceramic Tiles using Hand Tools | |
| 88 | | | Removal and/or Demolition of Ceramic Tiles using Rotary Hammer | |
| | **Links to literature:** | | | |
| | CSPs reported in Manitoba Construction Sector | https://www.wcb.mb.ca/uploads/2025/01/Final-Report-17-05.pdf?x35486 (accessed on 13 August 2026) | | |
| | CSPs reported in Construction Industry in Alberta | Evaluating a respirable crystalline silica risk assessment model for the construction industry in Alberta–Open Government | | |
| | BCCSA CSPs | https://pubmed.ncbi.nlm.nih.gov/32850594/ (accessed on 13 August 2026) | | |
| | Australian CSPs | Guidance-note-Managing-silica-dust-at-construction-sites.pdf (act.gov.au) | | |
| | | Working with crystalline silica substances (safeworkaustralia.gov.au) | | |

## References


1. Jacobs, N.F.; Zisook, E.; Tarpey, T.A. Reported exposures to respirable crystalline silica during construction tasks and guidance for harmonizing future research. *J. Occup. Environ. Hyg.* **2024**, *21*, 602–622.
2. Mundt, K.A.; Thompson, W.J.; Dhawan, G.; et al. Systematic review of the epidemiological evidence of associations between quantified occupational exposure to respirable crystalline silica and the risk of silicosis and lung cancer. *Front. Public Health* **2025**, *13*, 1554006. https://doi.org/10.3389/fpubh.2025.1554006.
3. Kalatehjari, R.; Rotimi, F.E.; Sachinthaka, R.; et al. Trends and Future Directions in Mitigating Silica Exposure in Construction: A Systematic Review. *Buildings* **2025**, *15*, 2924. https://doi.org/10.3390/buildings15162924.
4. Safe Work Australia. Model Work Health and Safety Regulations (Crystalline Silica Substances) Amendment 2024. Available online: https://www.safeworkaustralia.gov.au/sites/default/files/2024-06/model_work_health_and_safety_regulations_crystalline_silica_substances_amendment_2024.pdf (accessed on 27 May 2025).
5. Tefera, Y.; Cole, K.; Ramkissoon, C.; et al. Opening the policy window: How Australia banned engineered stone. *Public Health Res. Pract.* **2025**, *35*, 25031. https://doi.org/10.1071/PU25031.
6. Tischer, M.; Lamb, J.; Hesse, S.; et al. Evaluation of Tier One Exposure Assessment Models (ETEAM): Project Overview and Methods. *Ann. Work Expo. Health* **2017**, *61*, 911–920.
7. Wolfe, C.; Chubb, L.; Walker, R.; et al. Monitoring Worker Exposure to Respirable Crystalline Silica: Application for Data-driven Predictive Modeling for End-of-Shift Exposure Assessment. *Ann Work Expo Health* **2022**, *11*, 1010–1021. https://doi.org/10.1093/annweh/wxac040.
8. Kalyva, M.E.; Vist, G.E.; Diemar, M.G.; et al. Accessible methods and tools to estimate chemical exposure in humans to support risk assessment: A systematic scoping review. *Environ. Pollut.* **2024**, *352*, 124109.
9. Davies, H.; Gorman-Ng, M. Development of a Web-Based Tool for Risk Assessment and Exposure Control Planning of Silica-Producing Tasks in the Construction Sector. *Front. Public Health* **2020**, *8*, 1–10. https://doi.org/10.3389/fpubh.2020.00371.
10. Gorman-Ng, M.; Li, A.M.; Lavoué, J.; et al. Determinants of respirable crystalline silica exposure in construction in western Canada. *Ann. Work Expo. Health* **2023**, *67*, 847–857.
11. Park, H.; Hwang, E.; Yoon, C. Respirable crystalline silica exposure among concrete finishing workers at apartment complex construction sites. *Aerosol Air Qual. Res.* **2019**, *19*, 2804–2814.
12. Sauvé, J.F.; Beaudry, C.; Bégin, D.; et al. Statistical modeling of crystalline silica exposure by trade in the construction industry using a database compiled from the literature. *J. Environ. Monit.* **2012**, *14*, 2512–2520. https://doi.org/10.1039/c2em30443k.
13. Sauvé, J.F.; Beaudry, C.; Bégin, D.; et al. Silica Exposure During Construction Activities: Statistical Modeling of Task-Based Measurements from the Literature. *Ann. Occup. Hygiene. May* **2013**, *57*, 432–443. https://doi.org/10.1093/annhyg/mes089.
14. Gorman-Ng, M.; Davies, H.W. Evaluating a Respirable Crystalline Silica Risk Assessment Model for the Construction Industry in Alberta. In *School of Population and Public Health*; University of British Columbia: Vancouver, BC, Canada, 2018.
15. Davies, H.; Gorman-Ng, M.; Lavoue, J. Respirable Crystalline Silica in the Manitoba Construction Sector: Advancing Knowledge to Reduce Exposure. In *Report for Research and Workplace Innovation Program of the Workers Compensation Board of Manitoba*; Workers Compensation Board of Manitoba: Winnipeg, MB, Canada, 2021.
16. Beaudry, C.; Lavoué, J.; Sauvé, J.F. Occupational exposure to silica in construction workers: A literature based exposure database. *J. Occup. Environ. Hyg.* **2013**, *10*, 71–77. https://doi.org/10.1080/15459624.2012.7473990.