

Article

Exposure to Powdered Construction Materials: A Qualitative Analysis of Hazards and Sustainability Characteristics Based on the Identified Use

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Abstract

This study aimed to qualitatively analyze the identified use of dusty construction products in relation to hazard characteristics, occupational exposure limits, Safety Data Sheet features, and material composition. The secondary aim of the study was to explore the relationship between sustainability, expressed as Portland clinker percentage, and health-related indicators. A total of 283 Safety Data Sheets (SDSs) from six large construction companies operating in central Italy were analyzed. Data were extracted on identified use, risk classification, hazard score (H-score), occupational exposure limits (TLVs), composition, SDS update status, and clinker content. Associations between identified use and qualitative variables were explored, while differences in hazard score and clinker percentage were assessed across product categories. Univariate regression analyses were conducted to evaluate predictors of clinker content. The results show marked differences among construction products in terms of hazard profiles, exposure limits, and composition, closely linked to their intended use. Cement-containing products were predominant and associated with higher hazard scores and lower TLVs. Clinker percentage increased with product hazardousness and H-score, indicating a link between sustainability indicators and occupational risk. This study provides the first identified-use-based analysis of powdery construction materials. Overall, these findings emphasize the importance of use-specific risk assessment and targeted safety training in the construction sector.

Keywords: safety data sheet; construction industry; chemical risk assessment; identified use; cement; respirable silica; clinker sustainability; sustainable materials



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1. Introduction

Occupational health and safety (OHS) and the implementation of risk prevention strategies are critical concerns in the construction industry due to the constantly evolving work environment with health and safety implications [1]. Among the occupational hazards, exposure to hazardous inhalable or respirable dust (frequently present in dusty construction chemicals or released from materials such as concrete, plaster, and glues) can lead to chronic diseases caused by the inhalation of respirable crystalline silica dust and of other irritants or sensitizing agents [2,3]. Prolonged and unprotected inhalation of such dust can result in serious respiratory diseases, including silicosis, chronic obstructive pulmonary disease

(COPD), occupational asthma, and certain forms of cancer [4]. In particular, respirable crystalline silica (quartz) has been classified as a Group 1 carcinogen by the IARC [3].

The protection of workers from exposure to hazardous substances is mandated in Italy by Legislative Decree No. 81/2008 [5], specifically Title IX, which requires employers to carry out a detailed chemical risk assessment that evaluates the nature of the substances used, application methods, and exposure frequency and duration. Additional requirements stem from the European REACH Regulation [6] and CLP Regulation [7], which regulate the classification, labeling, and safe use of chemical substances and mixtures and also introduced the Safety Data Sheet (SDS). It provides information about a chemical or mixture, including its identification, hazards, and composition, along with instructions for first aid, firefighting, accidental release, handling, and storage. The SDS details exposure controls, personal protection, physical and chemical properties, stability, reactivity, and toxicological and ecological effects. Additionally, it covers disposal methods and transport and regulatory requirements and includes other relevant information such as revision dates and references. Occupational exposure limit values (such as Threshold Limit Values, TLVs, and Time-Weighted Averages, TWAs) serve as key reference points for defining and implementing preventive measures [8]. However, despite the well-documented risks associated with hazardous chemicals, inadequate OHS management remains prevalent in real-world construction contexts. This is also due to the low-risk perception in the workplace. Previous studies conducted on risk perception among construction workers have reported a widespread underestimation of the occupational risks [9]. Moreover, the insufficient or inconsistent use of personal protective equipment (PPE) seems to be critical: although workers identify the harmful effects of dust and acknowledged considerable exposure, only 36% declare that they use respiratory PPE [10]. Despite being fundamental for risk communication, SDSs remain an imperfect tool due to poor readability and occasional non-compliance with legal requirements [11,12].

Additionally, the growing awareness of climate change and the environmental impact of the construction industry has stimulated a significant evolution of cementitious materials. The cement industry is responsible for about 5–8% of global CO₂ emissions, mainly related to clinker calcination and high energy consumption [13,14]. Previous studies have shown that the embodied carbon of cementitious materials is strongly dependent on clinker content. Based on the analysis of published Environmental Product Declarations, Anderson and Moncaster [15] demonstrated that the carbon emissions of cement increase markedly with the proportion of clinker. Thus, replacing the clinker with cementitious materials is a key strategy to reduce the ecological footprint of the sector [16]. However, as demonstrated by relevant studies, the substitution of clinker with other products could expose workers to additional health risks. In fact, this is the case of fly ash, which may reduce greenhouse gas emissions linked to cement production but also be a threat for workers and the population [17,18]. Critical analysis of the characteristics of the materials, including potential chemical and safety risks, is essential to support a responsible and informed transition to more sustainable construction solutions. Thus, the present study aims to provide a qualitative analysis of the identified use of powdery construction products with regard to hazard score, risk classification, occupational exposure limits, and product composition. The secondary objective is to assess whether any association exists between sustainability characteristics, expressed as clinker percentage, the identified uses, and other relevant variables. Key findings may be leveraged to enhance risk awareness among workers and stakeholders.

2. Materials and Methods

Our qualitative analysis is based on the information reported in the SDSs of the dusty chemical products used in the building sites of six big construction companies operating in the territory of L'Aquila (central Italy). Participation was voluntary, and it is linked to a broader study about health and safety in the post-earthquake reconstruction of the above Italian city [9,10]. All the mixtures studied are in a solid physical state; more specifically, they are used in a powdery form.

We compiled a dataset by including various data from different sections of the Safety Data Sheet. Table 1 provides a detailed description of the studied variables and of the possible values or category they assumed. The SDS sections used to report or compute our variables are as follows:

- Identified use (Section 1.2 of the SDS).
- Risk classification through the hazard statements (Section 2.2 of the SDS). Based on these data, we calculated the H-score.
- Composition/information about ingredients through the Chemical Abstract Service (CAS) numbers (Section 3.2 of the SDS). Thus, we calculated the clinker percentage.
- Exposure controls/personal protection (TLV-TWA values or other European or National TWA limit values) (Section 8.1 of the SDS).
- Year of last SDSs update.

Table 1. Description of the analyzed variables. “Identified use,” “Risk classification,” “TLV,” “Year of the last update,” and “Composition” are categorical, meanwhile “Clinker percentage” and “H-score” are of a continuous type.

Variable	Value or Category	Variable	Value or Category
Identified use	Cement	TLV	0.025 mg/m ³
	Screed		0.05 mg/m ³
	Adhesive		1 mg/m ³
	Binder		2 mg/m ³
	Glue		3 mg/m ³
	Mortar		4 mg/m ³
	Stucco/putty		5 mg/m ³
	Sheath		10 mg/m ³
	Grout	Composition	Cement
	Skim coat		Quartz
Coating	Calcium carbonate		
Plaster	Hydrated lime		
Risk classification	Irritant	Year of last SDSs update	Hydraulic lime
	Irritant + sensitizing		Calcium oxide
	Irritant + specific toxicity		None
	Irritant + sensitizing + specific toxicity		Dichotomous
Clinker percentage	Not dangerous	H-score	Continuous
	Continuous		

Regarding the identified use, we categorized the mixtures as follows: cement, screed, adhesive, binder, glue, mortar, stucco/putty, sheath, plaster, grout, skim coat, and coating. Such information is provided by the supplier, and it can be found in Section 1.2.

All the mixtures were grouped and classified according to the following hazard identification based on the H-codes: H315, H318, H319, and H335 are classified as “irritants” as the mixtures can cause skin corrosion/irritation (H315), severe eye injury/irritation (H318, H319), and expiratory irritation (H335) according to the CLP Regulation [7]. Chemicals with the H-code H317 are classified as “sensitizing” since the mixtures can cause skin and

respiratory tract sensitization. Mixtures with the H-code H373 are classified as “specific toxicity,” as they may be harmful to organs, lethal, or toxic [7]. If no H-code was listed in the SDS, the mixture was classified as “not dangerous.” Therefore, the categories identified for the item “Risk classification” and based on the combination of the different H-codes of each mixture are as follows: “irritant,” “irritant and sensitizing,” “irritant and specific toxicity,” “irritant and sensitizing and specific toxicity,” and “not dangerous.”

We then created a quantitative variable that corresponds to the hazard score (H-score) assigned through the chemical semi-quantitative risk assessment based on the “Movarisch” algorithm [19]. This methodology assigns a hazard score from 1 to 10 to each H statement provided in the CLP regulation [7] that is related to health hazards (e.g., H317, skin sensitization = 6). For mixtures classified with multiple hazards, the highest corresponding value is taken into consideration. If the mixture is not classified as dangerous but contains one or more dangerous substances (even in low concentrations), the H score is assigned according to the H score table reported in the Movarisch methodology [19,20].

For each mixture, the SDS provides the TLV of each substance, if available. The lowest TLV with respect to the mixture was identified and reported in the dataset. In the SDS analyzed, TLVs are provided from several regulatory agency bodies (e.g., ACGIH, European Commission, OSHA). We reported the lowest limit value as mg/m³, regardless of the regulatory agency.

As to the powdery products composition, the most frequent substances (ingredients) were identified and reported as a nominal variable for each chemical product. The substances were reported only based on their presence as an ingredient, regardless of the composition percentage. The seven most frequent ingredients are listed in Table 1.

To assign a sustainability score to the mixtures or substances studied, we identified the maximum Portland clinker percentage. In SDSs, the concentration of solid mixtures is expressed as a percentage by weight. To comply with the precautionary estimate, the maximum percentage of Portland clinker has been considered (e.g., “Portland clinker cement 50–70%”: the percentage considered is 70). This choice is based on the fact that clinker production accounts for approximately 88% of total cement-related emissions, mainly due to process emissions from limestone calcination [21]. This methodology also aligns with the IPCC Guidelines for National Greenhouse Gas Inventories [22].

SDSs were considered “updated” when the last revision had been issued after the year 2022 (included). The participating construction enterprises provided datasheets that were not always up to date; consequently, the authors acquired the most recent online version whenever available.

Although this information is not included in our analysis, we also collected details about the suppliers of the Safety Data Sheets.

Statistical Analysis

Categorical variables are described through absolute and relative frequencies; meanwhile, continuous variables are described through mean and standard deviation values. In line with the aim of this study, we analyzed any possible associations between the “identified use” and the other described variables (Table 1). Due to the categorical nature of the variables “identified use,” “risk classification,” “TLVs,” “year of the last update,” and “composition,” we performed the Chi-square test for independence with the aim of identifying possible associations. The strength of potential associations was assessed using Cramer’s V, with values above 0.1, 0.3, and 0.5 indicating weak, moderate, and strong associations, respectively [23]. After conducting the Chi-square test for independence, all statistically significant results were further analyzed through a post hoc adjusted residuals analysis.

This procedure allowed the identification of specific associations and the evaluation of their strength. Adjusted residual values exceeding 2 were regarded as statistically significant.

Non-parametric tests were used for comparisons between continuous variables. This choice was made after the assessment of the normality of the distributions through a Shapiro–Wilk test. Possible differences among the classified mixtures with respect to quantitative variables were assessed by the Kruskal–Wallis test and a complete pairwise comparison by the Dwass–Steel–Critchlow–Fligner test. Univariable linear regression analyses were performed to evaluate the association between Portland clinker percentage and each covariate. Ingredients were excluded from this analysis, as they were considered neither informative nor reliable predictors of clinker content. The reasons lie in the fact that more than 72% of the mixtures contain cement; therefore, a regression analysis would highlight a multitude of associations that are of limited relevance to the purposes of the present study. Moreover, the nature of the variable and the high number of categories in which it occurs make a regression analysis minimally informative.

For each analysis, except for the adjusted residuals, an alpha level of 0.05 was considered to be statistically significant. Statistical analysis was performed using Jamovi software (version 2.6).

3. Results

Overall, 283 SDSs were included in our study. They correspond to their most recent and available revised version. The descriptive analysis of the composition/ingredients is fully reported in the Supplementary Materials (Table S1). Table 2 outlines the descriptive information related to the variables studied.

In our sample, we listed 11 different identified uses; the most represented are mortar (30.4%), plaster (21.2%), and adhesive/glue (13.1%). More than 71% of the products reported the lowest TLV-TWA equal to 1 mg/m³, and fewer than a quarter of the total reported 0.025 mg/m³. Almost 62% of the SDSs may be considered updated. Regarding the risk classification, most powdery products are classified as irritant + sensitizing (77.7%). The analysis of the composition shows that cement is the most represented ingredient (19.1%), followed by cement + hydrated lime (17.7%) and cement + quartz (12.8%). Overall, mixtures containing cement, either alone or in combination, accounted for the majority of the SDSs analyzed. Table 2 reports the most representative compositions only.

The descriptive analysis of quantitative variables shows that average hazard score for the studied construction products is 5.48 (ranging from 0 to 10) with a standard deviation of 1.15, and that the mean percentage of the Portland clinker is equal to 22.27 (21.67 SD).

According to the main aim of the study, we analyzed the possible associations between the identified uses and lowest TLV, updated status of the SDSs, risk classification of the mixtures, and composition/ingredients.

With regard to TLVs, we observed a significant difference between the identified uses and a moderate association (Table 3). An adjusted-residuals post hoc analysis (Table 4) revealed that adhesive/glue is more frequently associated with a TLV of 0.025 mg/m³, whereas a TLV of 1 mg/m³ appears to be less frequently associated with this identified use. Coating shows less commonly a TLV of 0.025 mg/m³ as compared to other products; stucco/putty appears to be strongly and positively associated with a relatively high TLV (2 mg/m³). No further significant associations were found between TLVs and the analyzed dusty products.

The updated status of the SDSs does not appear to be associated with the identified uses studied because the Chi-square test returned a non-significant *p*-value.

A significant and moderate association was observed between identified use and risk classification. Post hoc analysis (Table 4) showed that plaster mixtures appear to be

classified as irritants more frequently than expected, whereas stucco/putty mixtures appear to be “not dangerous” much more frequently than expected. Finally, the classification “irritant + sensitizing” appears to be very common across all the studied mixtures.

With regard to the composition/ingredients, we observed a significant association with the identified use, with a moderate effect size, thus indicating that ingredient distributions are not independent of product use (Table 3). Post hoc analysis reported in Table 4 highlights the size and the direction of the associations, suggesting that specific ingredients or combinations of ingredients are positively or negatively associated with specific identified uses. Limited to the ingredients, Table 4 only reports significant associations. The results are fully reported in the Supplementary Materials (Table S2). Adhesives/glue appear to be frequently characterized by the ingredient combination “cement + quartz”; meanwhile, “cement + hydrated lime” and “cement + hydraulic lime + hydrated lime” are less frequent in this product composition. The ingredient “cement,” as expected, is common in cement composition, and cement alone or in combination with quartz or calcium carbonate is uncommon in plaster. Meanwhile, it appears to be frequently made in “Hydrated lime,” sometimes in combination with calcium carbonate. Screed and sheath appear to commonly be composed of “Calcium carbonate + Cement” and of “Cement + Quartz,” respectively. A variable composition of calcium carbonate, hydraulic lime and quartz appear to be associated with skim coat. The absence of reported ingredients (“none”) or the presence of only “Calcium carbonate” are very common in stucco/putty products.

Table 2. Frequency distribution of the SDSs with regard to nominal variables. Categories referred to with the variable “ingredients” are fully reported in the Supplementary Materials: this table only reports the most frequently observed categories regarding this variable. Descriptive information about quantitative continuous variables is also provided. SD = standard deviation.

Identified Use	n (%)	Risk Classification	n (%)
Adhesive/Glue	37 (13.1)	Irritant	44 (15.5)
Binder	8 (2.8)	Irritant + sensitizing	220 (77.7)
Cement	26 (9.2)	Irritant + sensitizing + specific toxicity	3 (1.1)
Coating	11 (3.9)	Not dangerous	16 (5.7)
Grout	16 (5.7)	Ingredients/composition	n (%)
Mortar	86 (30.4)	Cement	54 (19.1)
Plaster	60 (21.2)	Cement + Hydrated lime	50 (17.7)
Screed	16 (5.7)	Cement + Quartz	36 (12.8)
Sheath	5 (1.8)	Calcium carbonate + Cement	24 (8.5)
Skim coat	11 (3.9)	Calcium carbonate + Cement + Hydrated lime	18 (6.4)
Stucco/putty	7 (2.5)	Hydrated lime	15 (5.3)
TLVs mg/m ³	n (%)	Cement + Hydraulic lime + Hydrated lime	11 (3.9)
0.025	64 (23.7)	None	11 (3.9)
0.05	1 (0.4)	Cement + Hydrated lime + Quartz	10 (3.5)
1	193 (71.5)	Cement + Hydraulic lime	7 (2.5)
2	2 (0.7)	Updated	n (%)
3	5 (1.9)	Yes	175 (61.8)
4	1 (0.4)	No	108 (38.2%)
5	2 (0.7)		
10	2 (0.7)		
Continuous variables	N	Mean	SD
Hazard score	283	5.48	1.15
Portland clinker %	283	22.27	21.67

Table 3. Independence analysis through Chi-square test to assess whether any association exists between the “Identified use” and the variables “Lowest TLV,” “updated SDS,” “Risk classification,” and “Composition.” Effect size is quantified through Cramer’s V index. Identified uses are categorized as follows: adhesive/glue = 1; binder = 2; cement = 3; coating = 4; grout = 5; mortar = 6; plaster = 7; screed = 8; sheath = 9; skim coat = 10; stucco/putty = 11.

	Identified Use											
Variables	1	2	3	4	5	6	7	8	9	10	11	Tot
Lowest TLV (mg/m³)												
0.025	20	2	6	0	8	12	10	2	3	1	0	64
0.05	0	0	0	0	0	1	0	0	0	0	0	1
1	16	6	19	11	8	66	43	13	2	9	0	193
2	0	0	1	0	0	0	0	0	0	0	1	2
3	0	0	0	0	0	3	1	1	0	0	0	5
4	0	0	0	0	0	0	1	0	0	0	0	1
5	0	0	0	0	0	1	1	0	0	0	0	2
10	0	0	0	0	0	0	1	0	0	1	0	2
Tot	36	8	26	11	16	83	57	16	5	11	1	270
Statistics	Value	Df	<i>p</i> -value									
χ²	204	70	<0.001									
N	270											
Cramer’s V	0.329											
Updated	23	6	15	4	11	48	47	10	3	6	2	175
Yes	14	2	11	7	5	38	13	6	2	5	5	108
No	37	8	26	11	16	86	60	16	5	11	7	283
Tot	23	6	15	4	11	48	47	10	3	6	2	175
Statistics	Value	Df	<i>p</i> -value									
χ²	15.9	10	0.102									
N	283											
Cramer’s V	0.237											
Risk classification												
Irritant	0	1	1	0	0	17	22	0	0	3	0	44
Irritant + sensitizing	34	7	25	11	15	66	34	15	5	8	0	220
Irritant + sensitizing + specific toxicity	1	0	0	0	1	0	1	0	0	0	0	3
Not dangerous	2	0	0	0	0	3	3	1	0	0	7	16
Tot	37	8	26	11	16	86	60	16	5	11	7	283
Statistics	Value	Df	<i>p</i> -value									
χ²	171	30	<0.001									
N	283											
Cramer’s V	0.449											

Table 3. Cont.

Variables	Identified Use											Tot
	1	2	3	4	5	6	7	8	9	10	11	
Ingredients/composition												
Cement	8	1	14	0	3	15	3	7	0	3	0	54
Cement + quartz	12	0	5	0	4	11	0	1	3	0	0	36
Calcium carbonate + Cement	5	0	6	0	1	2	0	6	2	2	0	24
Cement + Hydrated lime	2	2	1	4	1	19	17	2	0	2	0	50
Cement + Calcium oxide	2	1	0	0	1	0	0	0	0	0	0	4
None	1	0	0	0	0	3	2	0	0	0	5	11
Hydrated lime	0	1	0	0	0	0	14	0	0	0	0	15
Cement + Hydraulic lime	0	0	0	0	0	6	1	0	0	0	0	7
Hydraulic lime + Quartz	0	0	0	0	0	2	0	0	0	0	0	2
Hydraulic lime + Hydrated lime	0	0	0	0	0	1	0	0	0	0	0	1
Calcium carbonate	0	0	0	0	0	0	0	0	0	0	2	2
Hydrated lime + Quartz	0	0	0	0	0	0	2	0	0	0	0	2
Cement + Quartz + Calcium carbonate	2	0	0	0	0	1	1	0	0	0	0	4
Calcium carbonate + Cement + Hydraulic lime	2	0	0	0	0	3	1	0	0	0	0	6
Calcium carbonate + Cement + Calcium oxide	1	0	0	0	0	1	0	0	0	0	0	2
Cement + Hydraulic lime + Quartz	1	0	0	0	1	0	0	0	0	0	0	2
Cement + Hydraulic lime + Calcium carbonate + Quartz	1	0	0	0	0	0	2	0	0	0	0	3
Cement + Hydraulic lime + Hydrated lime	0	1	0	0	1	7	2	0	0	0	0	11
Calcium carbonate + Cement + Hydrated lime	0	1	0	7	0	7	3	0	0	0	0	18
Cement + Hydrated lime + Quartz	0	1	0	0	0	3	5	0	0	1	0	10
Cement + Hydraulic lime + Calcium oxide + Quartz	0	0	0	0	0	2	0	0	0	0	0	2
Cement + Hydraulic lime + Hydrated lime + Quartz	0	0	0	0	0	1	0	0	0	0	0	1
Calcium carbonate + Hydrated lime	0	0	0	0	0	1	5	0	0	0	0	6
Cement + Hydraulic lime + Calcium carbonate + Quartz	0	0	0	0	0	0	1	0	0	0	0	1
Cement + Calcium oxide + Hydrated lime	0	0	0	0	1	0	0	0	0	0	0	1
Cement + Calcium carbonate + Quartz + Calcium oxide	0	0	0	0	3	0	0	0	0	0	0	3
Calcium carbonate + Hydraulic lime	0	0	0	0	0	0	0	0	0	2	0	2
Calcium carbonate + Hydraulic lime + Quartz	0	0	0	0	0	0	0	0	0	1	0	1
Tot	37	8	26	11	16	86	59	16	5	11	7	282
Statistics	Value	Df	<i>p</i> -value									
χ ²	667	280	<0.001									
N	282											
Cramer’s V	0.486											

Table 4. Adjusted-residuals post hoc analysis for the variables that resulted in being statistically significant on the Chi-square test in relation to the identified uses. With respect to the variable “Composition/ingredients,” only statistically significant results are reported (rows that showed at least one value $> |2|$, in bold); meanwhile, they are fully reported in the Supplementary Materials (Table S2). Identified uses are categorized as follows: adhesive/glue = 1; binder = 2; cement = 3; coating = 4; grout = 5; mortar = 6; plaster = 7; screed = 8; sheath = 9; skim coat = 10; stucco/putty = 11.

Variables	Identified Use										
	1	2	3	4	5	6	7	8	9	10	11
Lowest TLV (mg/m ³)											
0.025	3.337	0.074	−0.065	− 2.283	1.878	−1.86	−1.001	−1.012	1.393	−1.139	−0.688
0.05	−0.516	−0.244	−0.438	−0.2854	−0.344	0.986	−0.649	−0.344	−0.192	−0.285	−0.086
1	− 2.064	0.116	0.095	1.054	−1.074	0.850	0.350	0.452	−0.908	0.393	−1.195
2	−0.730	−0.344	1.296	−0.404	−0.487	−1.109	−0.919	−0.487	−0.272	−0.404	2.797
3	−1.154	−0.544	−0.981	−0.638	−0.769	1.042	−0.054	1.012	−0.430	−0.638	−0.192
4	−0.516	−0.243	−0.438	−0.285	−0.344	−0.784	1.238	−0.344	−0.192	−0.285	−0.086
5	−0.730	−0.344	−0.621	−0.404	−0.487	0.450	0.754	−0.487	−0.272	−0.404	−0.122
10	−0.730	−0.344	−0.621	−0.404	−0.487	−1.109	0.754	−0.487	−0.272	1.783	−0.122
Risk classification											
Irritant	− 3.392	−0.226	−1814	−1.849	− 2.231	0.952	3.522	− 2.231	−1.247	0.890	−1475
Irritant + sensitizing	0.949	0.307	1.027	0.802	0.703	−0.105	−1.946	0.703	0.540	−0.191	− 3.299
Irritant + sensitizing + specific toxicity	0.810	−0.412	−0.742	−0.483	1.374	−1350	0.421	−0.582	−0.326	1.374	−0.385
Not dangerous	−0.064	−0.951	−1.714	−1.115	−1.345	−0.9095	−0.217	0.098	−0.751	−1.345	5.197
Composition/ingredients											
Cement	0.337	−0.459	3.302	− 2.053	−0.036	−0.367	− 2.939	1.922	−1.384	0.578	−1.637
Cement + quartz	2.797	−1.429	0.858	−1.676	1.209	0.006	− 3.881	−0.810	2.136	−1.675	−1.337
Calcium carbonate + Cement	0.960	−1.167	2.097	−1.368	−0.325	− 2.334	− 3.169	2.919	1.744	0.953	−1.092
Cement + Hydrated lime	− 2.090	0.460	− 2.040	1.283	−1.260	0.924	1.852	−0.525	−1.332	0.035	−1.576
None	−0.391	−0.790	−1.424	−0.926	−1.117	−0.197	−0.203	−1.117	−0.625	−0.926	4.430
Hydrated lime	−1.984	0.748	−1.663	−1.082	−1.304	− 3.024	4.489	−1.305	−0.729	−1.081	−0.863
Cement + Hydraulic lime	−1.355	−0.630	−1.136	−0.739	−0.891	2.161	−0.407	−0.891	−0.498	−0.739	−0.590
Calcium carbonate	−0.724	−0.337	−0.607	−0.395	−0.476	−1.104	−0.915	−0.476	−0.266	−0.395	3.299
Cement + Hydraulic lime + Hydrated lime	− 2.173	0.605	−1.822	4.427	−1.429	0.618	−0.409	−1.429	−0.799	−1.185	−0.945
Calcium carbonate + Hydrated lime	−1.255	−0.583	−1.052	−0.684	−0.825	−0.671	2.516	−0.825	−0.461	−0.684	−0.546
Cement + Calcium carbonate + Quartz + Calcium oxide	−0.887	−0.413	−0.744	−0.484	3.399	−1.352	−1.120	−0.583	−0.326	−0.483	−0.386
Calcium carbonate + Hydraulic lime	−0.724	−0.337	−0.607	−0.395	−0.476	−1.104	−0.915	−0.476	−0.266	3.021	−0.315
Calcium carbonate + Hydraulic lime + Quartz	−0.512	−0.238	−0.429	−0.279	−0.336	−0.780	−0.647	−0.337	−0.188	2.136	−0.223

Our study also relies on continuous variables concerning the hazardous characteristics of the mixtures (H-score) and the percentage of Portland clinker. Table 5 reports a descriptive analysis of H-score and Portland clinker percentage.

Table 5. Descriptive analysis of clinker percentage and hazard score with regard to the identified use.

Relevant Identified Use	Portland Clinker Percentage Mean (sd)	Hazard Score Mean (sd)
Cement	44.6 (30.6)	5.94 (0.294)
Screed	14.4 (11.7)	5.78 (0.875)
Adhesive/glue	31.4 (15.4)	5.76 (1.17)
Binder	36.3 (28.8)	5.81 (0.530)
Mortar	22.8 (20.6)	5.48 (1.11)
Stucco/putty	0.00 (0)	2.25 (0)
Sheath	25.4 (5.11)	6.00 (0)
Plaster	8.00 (12.3)	5.04 (1.28)
Grout	35.0 (17.6)	6.00 (0)
Skim coat	22.7 (16.2)	5.59 (0.701)
Coating	7.91 (9.49)	6.00 (0)

Differences in H-score and Portland clinker percentage across identified uses were assessed using the Kruskal–Wallis test. It revealed statistically significant differences (Table 6) between the identified uses for both H-score ($p < 0.001$) and Portland clinker percentage ($p < 0.001$). A pairwise comparison indicated that differences in H-score were primarily driven by consistently lower values observed for stucco/putty compared with other material types (Table 6). Regarding Portland clinker percentage, pairwise comparisons revealed multiple statistically significant differences across identified uses (Table 6). Plaster consistently exhibited lower clinker content compared with other materials, thus showing strong significant differences when compared with adhesive/glue, cement, mortar, binder, and sheath. Conversely, adhesive/glue and grout were characterized by high clinker percentages. Screed showed significantly lower clinker content than adhesive/glue and grout, while stucco/putty exhibited lower clinker values than screed. Table 6 reports only the statistically significant results of the pairwise comparisons. Tables S3 and S4 in the Supplementary Materials show the complete version of the analysis.

A univariate analysis (Table 7) was performed with Portland clinker percentage as the dependent variable to further explore the relationship between the sustainability characteristics represented by clinker percentage and the “lowest TLV” of the variables, the updated status of the SDS, the “risk classification,” and the “H-score.” The analysis revealed that clinker percentage is significantly higher in mixtures that report a lowest TLV of 0.025 mg/m^3 , especially when compared to products with a lowest TLV of 1 mg/m^3 , although the model fit indicates that TLV is a weak predictor of the sustainability of the mixtures. The updated status does not show any significant associations, while risk classification appears to be a solid predictor of clinker percentage. Specifically, dusty chemical products that are classified as less dangerous have a lower clinker percentage in their ingredients.

Finally, the linear regression analysis indicates that for each one-unit increase in the H-score, the clinker content increases on average by approximately 7.4 percentage points. As already demonstrated by the “risk classification” predictor, clinker percentage increases with the hazard level of the products.

Table 6. Kruskal–Wallis non-parametric test to evaluate possible differences in clinker percentage and H-score with regard to the identified use; the table also shows significant differences between the identified uses through a Dwass–Steel–Critchlow–Fligner test.

Identified use			
Kruskal–Wallis	χ^2	df	<i>p</i> -value
H-Score	70.8	10	<0.001
Portland clinker percentage	104.3	10	<0.001
Identified use			
Pairwise comparison–H-Score		Statistics	<i>p</i> -value
Adhesive/glue	Plaster	−5.218	0.010
Adhesive/glue	Stucco/putty	−7.398	<0.001
Binder	Stucco/putty	−5.123	0.013
Cement	Plaster	−4.946	0.020
Cement	Stucco/putty	−7.599	<0.001
Mortar	Stucco/putty	−7.394	<0.001
Screed	Stucco/putty	−6.344	<0.001
Stucco/putty	Coating	5.831	0.002
Stucco/putty	Grout	6.633	<0.001
Stucco/putty	Plaster	6.293	<0.001
Stucco/putty	Sheath	4.690	0.037
Stucco/putty	Skim coat	5.344	0.007
Identified use			
Pairwise comparison–Clinker %		Statistics	<i>p</i> -value
Adhesive/Glue	Coating	−5.8697	0.002
Adhesive/Glue	Mortar	−4.8042	0.028
Adhesive/Glue	Plaster	−9.2649	<0.001
Adhesive/Glue	Stucco/putty	−5.6748	0.003
Binder	Plaster	−4.9250	0.021
Cement	Coating	−5.4490	0.006
Cement	Mortar	−4.9995	0.018
Cement	Plaster	−8.6479	<0.001
Cement	Stucco/putty	−5.7026	0.003
Grout	Coating	−5.4887	0.005
Mortar	Plaster	−7.5642	<0.001
Mortar	Stucco/putty	−5.4399	0.006
Plaster	Grout	7.5255	<0.001
Screed	Adhesive/Glue	5.1828	0.011
Screed	Grout	5.0573	0.015
Screed	Stucco/putty	−5.4259	0.006
Sheath	Plaster	−4.6475	0.041
Stucco/putty	Grout	5.1486	0.012

Table 7. Evaluation of clinker % association with the variables' relevant identified use, lowest TLV, updated status, risk classification, and H-score through a univariate analysis.

Dependent Variable: Portland Clinker Percentage				
Predictor	β	95% CI		p
Lowest TLV- $R^2 = 0.0346$				
0.05–0.025	−4.52	−47.2	38.179	0.835
1–0.025	−7.69	−13.8	−1.576	0.014
2–0.025	−9.52	−39.9	20.904	0.538
3–0.025	−12.52	−32.2	7.154	0.211

Table 7. *Cont.*

Dependent Variable: Portland Clinker Percentage				
Predictor	β	95% CI		<i>p</i>
4–0.025	−9.52	−52.2	33.179	0.661
5–0.025	−29.52	−59.9	0.904	0.057
10–0.025	−14.52	−44.9	15.904	0.348
Update status- $R^2 = 0.00141$				
No-Yes	−1.67	−6.90	3.55	0.529
Risk classification- $R^2 = 0.180$				
Irritant–Irritant + sensitizing	−20.537	−26.9	−14.1	<0.001
Not dangerous–Irritant + sensitizing	−26.929	−37.0	−16.9	<0.001
Irritant + sensitizing + specific toxicity–Irritant + sensitizing	−0.325	−22.9	22.2	0.977
H-Score- $R^2 = 0.157$				
Hazard score	7.44	5.41	9.46	<0.001

4. Discussion

4.1. Identified Use Characteristics and Updated Status of the SDSs

Based on the information collected, we listed 11 different identified uses for dusty products involved in the construction process, as this was the leading characteristic in the commercial classification of chemicals. The data originates from the analysis of the safety data sheets provided by the construction industries participating in the study. In our sample, mortar, plaster, adhesive, and cement are the most represented products with the same identified use. They have many characteristics and associations with other variables under study; these will be appropriately discussed in the following sections.

Because the information collected, including that related to identified use, is available in the Safety Data Sheets, keeping these sheets updated is essential to ensure the accuracy of the information reported. This is because toxicological data regarding substances and mixtures evolve over time as new findings in toxicology emerge. In this regard, the SDSs included in our sample that can be considered up to date account for less than two-thirds of the total. This could pose a potential risk to construction workers, as this may result in a risk underestimation. In our analysis, we found that the updated status of our SDSs is not associated with the selected identified uses. This may be because the supply of updated SDSs is not dependent on or associated with the intended use of the product. The review and provision process of the SDSs, along with the interaction between the chemical product user and supplier, warrants further investigation.

To the best of our knowledge, neither a fully comparable study nor a specific chemical risk assessment on an identified use basis seem to be available in the literature. According to the Health and Safety Executive (HSE), cement is one of the most relevant non-carcinogenic hazardous products in the construction industry [24]. Based on our findings, cement is one of the most represented identified uses, and it is by far the most prevalent ingredient.

Ho et al. [25] analyzed 45 Safety Data Sheets in order to assess their readability and suitability for the target audience. They found that the Safety Data Sheets were ineffective in their main function as a hazard communication tool, thus exposing workers to risk. Although the authors did not thoroughly examine the potential role of the updated status with regard to the identified poor suitability, it could be considered a contributing factor. The REACH regulation [6] mandates the manufacturers or the suppliers to provide an update to the safety data sheet when new information becomes available regarding risk management measures or hazards, when an authorization is granted or refused, or a

restriction is imposed. Thus, the updated status is a relevant characteristic that may impact the availability and the quality of the other information contained in the SDS. No peer-reviewed scientific studies assessing its impact were found in the construction sector or in other sectors.

4.2. Hazards of the Construction Materials and Occupational Exposure Limits

Our study highlights that differences exist between diverse identified uses with regard to the hazards of the construction products and occupational exposure limits. The most frequently observed risk classification is irritating and sensitizing, whereas mortar and plaster appear to be less hazardous, being classified only as irritants. However, the differences between the H-scores are less significant. Stucco shows the lowest risk classification, the lowest H-score, and the highest TLV. It can be speculated that stucco/putty is the least health-threatening product among the products analyzed in this study.

The most frequent lowest TLVs are 0.025 mg/m³ and 1 mg/m³. They are associated with quartz and cement, respectively [8]; indeed, these ingredients are highly prevalent in the chemical products under study. The identified use that is strongly associated with the 0.025 TLV is adhesive/glue, while coating does not seem to be associated with it. Our analysis also highlights that the 1 mg/m³ TLV is not frequent in adhesive/glues.

Regarding the hazards of the construction materials, Rey-Alvarez et al. [26] highlighted that several differences exist between different construction chemical products. The authors assessed non-cancer and cancer risk assessment through the Life Cycle Impact Assessment (LCIA) model USEtox, developed by Rosenbaum et al. [27]. Although their methodological assessment is significantly different from ours, they found that among the materials used for wall covering, plaster shows a lower toxicity. However, in their comparison, cement and cement-based construction materials showed lower toxicity than materials like wood, steel, polyurethane, and many others. From a life-cycle perspective, materials' dangerousness does not appear to be linked to usage-related hazards.

A recent study by Mishra et al. [28] highlighted that construction workers report moderate to severe eye, skin, and respiratory irritation linked to cementitious products, both during direct use and during construction activities involving building structures. This information is strongly linked to our dangerousness-related data; indeed, our analysis reveals a predominance of irritant and skin-sensitizing characteristics.

Pollutants generated by on-site construction activities are a relevant occupational health issue that is widely studied all over the world. A cross-sectional study [29] reported that cement dust is strongly linked to impaired pulmonary function among male cement plant workers.

With regard to exposure limits on construction sites, a study by Broström et al. [30] revealed that during apartment renovation, occupational exposure limits for inhalable and respirable dusts were exceeded [31]. Based on occupational exposure limits reported in the safety data sheets, most of the ingredients contained in the studied mixtures show a respirable dust profile. For this reason, the lowest TLVs that are very frequent in our construction products are equal to 1 or 0.025 mg/m³. According to ACGIH [8], these TLVs belong to cement and crystalline silica dust. Although the presence of cement in the powdery products analyzed is evident, we should point out that quartz was always found to be lower than 1% in concentration. In EU countries, crystalline silica and other Category 1 carcinogens placed on the market, either in pure form or as components of mixtures, must be classified accordingly, unless their concentration is below 0.1% (w/w) [7]. It is important to note that respirable quartz can cause silicosis and other organ damage. Therefore, products containing these substances should carry the following warnings: "May cause lung cancer by inhalation" and "Causes damage to lungs." Natural materials such as

minerals, ores, gravel, and sand containing quartz are exempt from REACH regulation [6], provided that they are chemically unmodified. Nevertheless, the European Industrial Minerals Association (IMA), based on a hazard assessment, has recommended that even unmodified products containing crystalline silica (fine fraction) must be classified according to their crystalline silica content [32]. Accordingly, products with respirable crystalline silica concentrations of 10 wt.% or higher should be labeled STOT RE 1 (Specific Target Organ Toxicity upon Repeated Exposure, Category 1, H372). For respirable crystalline silica concentrations between 1.0 and 10 wt.%, the labeling should be STOT RE 2 (Category 2, H373). Mixtures and substances with respirable crystalline silica (fine fraction) below 1.0 wt.% do not require classification according to IMA guidelines.

In a previous study published in 2021 [33], we assessed the occupational exposure to inhalable and respirable crystalline silica dusts in the post-earthquake reconstruction context. Inhalable dust showed higher levels, especially for demolition workers. Overall, we found low respirable and inhalable dust concentrations, but dust arising from work activities, as opposed to that originating from powdered chemical products, is not quantifiable. Respirable crystalline silica showed very low concentrations, and this may be explained by the very scarce presence of quartz in the examined products (always lower than 1% by weight).

4.3. Ingredients and Sustainability Assessment

Our findings indicate that the composition of powdery construction materials is closely linked to their intended use, with certain ingredients or combinations preferentially associated with specific product types. Adhesives and glues are frequently formulated with cement and quartz, while coatings and plasters often contain cement, hydraulic lime, and hydrated lime. Mortars, grouts, screeds, and skim coats display distinct combinations of cement, lime, calcium carbonate, and quartz, reflecting functional requirements such as bonding strength, workability, or setting time. Stucco and putty products tend to contain either calcium carbonate alone or no additional cementitious components, consistent with their lightweight finishing function.

These patterns align with previous studies highlighting that ingredient composition in construction powders is tailored to optimize performance. Importantly, the presence of cement and quartz underscores the potential for respirable crystalline silica exposure, while lime-rich formulations pose risks of skin and eye irritation [34,35].

Solid pollutants such as calcium carbonate, quartz, and cement may contribute to acute or chronic diseases in construction employees [36]. Respirable-sized particles may reach the lower respiratory tract and contribute to occupational-related diseases.

An experimental study conducted on powdery construction materials [37] revealed the airborne behavior of several constituents that we found in our chemical products. Regardless of toxicological characteristics, substances like cement, calcium carbonate, hydrated lime, and grout contribute equally to respirable-sized airborne contamination, due to their physical properties. Conversely, quartz sand shows a minor contribution to airborne particle contamination under the same conditions despite Brostrom et al.'s demonstration that airborne respirable silica is a concerning xenobiotic in indoor construction activities [30].

With regard to the sustainability characteristics of the products, our data highlight that among the eleven identified uses, less sustainable materials are cement, binders, grout, and adhesives. Moreover, the analysis indicates that Portland clinker content is moderately associated with product hazard indicators, thus suggesting a link between sustainability and chemical risk. Products with the lowest TLV (0.025 mg/m^3) tend to contain higher clinker percentages than those with higher TLVs, even though TLV alone is a weak predictor of clinker content. Although we found this link, as can be seen in Table 3, TLVs frequency

distribution is markedly skewed toward values of 1 and 0.025 (95.2% of the total). This characteristic and the number of possible predictors for the variable “TLV” may influence the weakness of the relationship between TLV and clinker percentage.

Conversely, risk classification emerges as a stronger determinant, with less hazardous products consistently exhibiting lower clinker percentages. This pattern aligns with linear regression results, showing that each unit increase in H-score corresponds to an average 7.4 percentage point rise in clinker content, further reinforcing the inverse association between sustainability and product hazardousness. Health-related hazard profiles and environmental impact indicators do not always align across different construction materials. Overall, these findings demonstrate that “more sustainable” materials are not necessarily “safer” materials, underscoring the importance of integrating occupational health risk assessment into sustainability-driven material substitution strategies. Finally, with regard to the environmental burden of chemicals, it must be said that chemical regulations [6,7] mandate the manufacturer to identify the environmental hazards (H-400 series); however, information about CO₂ emissions and ecological footprint is not specifically required.

The literature provides extensive information about the Portland clinker burden on CO₂ emissions [38]. As a result, we chose clinker percentage as a sustainability indicator. The findings indicate that clinker and cement substitution may significantly reduce greenhouse gas emissions from cement production, with theoretical reductions of up to 44% achievable through the global maximization of secondary cementitious material use. Ige et al. [39] estimated that several mitigation pathways are technically viable, yet each is constrained by significant practical limitations. Clinker substitution enables immediate emission reductions, but it is restricted by the availability and quality of supplementary cementitious materials, durability requirements, and conservative regulatory standards.

This study has some limitations. First, no comparable studies addressing the specific objectives of the present work were identified. More specifically, studies using SDSs to evaluate health-related risks according to the identified uses are currently lacking, making direct comparisons with previously published results not feasible. With respect to sustainability, only one study proposes the “Greenness Index” [40], a method based on SDS data to assess the sustainability of chemical substances; however, this approach differs from the methodology applied in our study. Although the large amount of data collected would have allowed for additional analyses (e.g., associations between mixture composition and other investigated characteristics; an assessment of inconsistencies between updated and not-updated versions), we deliberately limited our focus to the relationship between identified use and the other variables considered in this study. The fact that not all safety data sheets were recently updated may have influenced the study results.

Finally, the involvement of a larger number of construction companies could reveal additional identified uses or highlight the presence of products with different hazard profiles, potentially including more hazardous characteristics.

5. Conclusions

To the best of our knowledge, this is the first study that focuses on the identified use of powdery construction materials. It highlighted some differences in the hazards of the construction products in terms of risk classification, occupational exposure limits, and hazard score, especially indicating stucco/putty as an acceptable-hazard product. Cement is substantially a widespread ingredient, and Portland clinker plays a role in mixture dangerousness and ecological burden.

Our results may play a key role in the design of safety training programs for construction workers, as well as in the risk assessment processes carried out by stakeholders. Although SDSs may be an imperfect tool, we believe that they can be effectively used for

preliminary investigations and to determine which information should be conveyed to workers during occupational safety training.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/su18052331/s1>: Table S1: Frequency distribution of the SDSs with regard to the nominal variable “Composition/ingredients”; Table S2: Adjusted-residuals post hoc analysis for the variable “composition/ingredients”; Table S3: Pairwise comparisons of H-scores between identified uses. *p*-values are adjusted for multiple comparisons; only statistically significant comparisons are discussed in the main text; Table S4: Pairwise comparisons of Portland clinker percentage with regard to identified use. *p*-values are adjusted for multiple comparisons; only statistically significant comparisons are discussed in the main text.

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Abbreviations

The following abbreviations are used in this manuscript:

OHS	occupational health and safety
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
CLP	Classification, Labelling and Packaging
SDS	Safety Data Sheet
TLV	Threshold Limit Value
TWA	Time-Weighted Average
PPE	personal protective equipment
CAS	Chemical Abstract Service
H-score	hazard score
ACGIH	American Conference of Governmental Industrial Hygienists
OSHA	Occupational Safety and Health Authority
SD	standard deviation
HSE	Health and Safety Executive
LCIA	Life Cycle Impact Assessment
IMA	Industrial Minerals Association
EU	European Union

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