Safety and Health at Work 15 (2024) 192–199

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Original article

Safety Data Sheets as a Hazard Communication Tool: An Assessment of Suitability and Readability

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A R T I C L E I N F O

Article history:
Received 16 June 2023
Received in revised form
28 January 2024
Accepted 29 January 2024
Available online 3 February 2024

Keywords:
Hazard communication
Literacy
Readability
Safety data sheets
Suitability

A B S T R A C T

Background: Safety data sheets (SDSs) are hazard communication materials that accompany chemicals/hazardous products in the workplace. Many SDSs contain dense, technical text, which places considerable comprehension demands on workers, especially those with lower literacy skills. The goal of this study was to assess SDSs for readability, comprehensibility, and suitability (i.e., fit to the target audience).
Methods: The Suitability Assessment of Materials (SAM) tool assessed SDSs for suitability and readability. We then amended the SAM tool to further assess SDSs for comprehensibility factors. Both the original and amended SAM tool were used to score 45 randomly selected SDSs for content, literacy demand, graphics, and layout/typography.
Results: SDSs performed poorly in terms of readability, suitability, and comprehensibility. The mean readability scores were Flesch–Kincaid Grade Level (9.6), Gunning Fog index (11.0), Coleman–Liau index (13.7), and Simple Measure of Gobbledygook index (10.7), all above the recommended reading level. The original SAM graded SDSs as "not suitable" for suitability and readability. When the amended SAM was used, the mean total SAM score increased, but the SDSs were still considered "not suitable" when adding comprehensibility considerations. The amended SAM tool better identified content-related issues specific to SDSs that make it difficult for a reader to understand the material.
Conclusions: In terms of readability, comprehensibility, and suitability, SDSs perform poorly in their primary role as a hazard communication tool, therefore, putting workers at risk. The amended SAM tool could be used when writing SDSs to ensure that the information is more easily understandable for all audiences.

1. Introduction

Safety data sheets (SDSs) are an important element of hazard communication in workplaces in many countries [1]. SDSs ensure that workers have access to important information about hazardous products they are exposed to in the workplace. SDSs help communicate information about products, including but not limited to hazardous effects to health; precautionary measures for handling; and first-aid response. Chemical manufacturers are responsible for producing and distributing SDSs to employers, who are then required to ensure that workers can easily access the SDSs in the workplace and are trained on how to understand and interpret the SDSs [2].

Prior to 2015 in Canada, the SDS was previously known as the material safety data sheet (MSDS). MSDSs were required to have 9 section headings under the 1988 Workplace Hazardous Materials Information System (WHMIS 1988) [1]. In 2015, WHMIS 1988 was aligned with the Globally Harmonized System of Classification and Labeling of Chemicals, with the former now being known as WHMIS 2015. Subsequently, Canadian SDSs have adopted the new 16-section format and standardized "hazard statements" to align with global SDS requirements [2].

Communicating health and safety information to workers with low literacy has been recognized as an ongoing challenge [1,3]. MSDSs have been previously criticized as being overly technical, poorly organized, inaccurate, and often incomplete [1,4].

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2093-7911/$ — see front matter
https://doi.org/10.1016/j.shaw.2024.01.006

Additionally, they are written for multiple audiences, making it difficult for the average worker to understand. In one study, MSDSs were presented to 160 trade workers, and approximately 39% of the workers found the sheets difficult to understand [5]. In another study, workers were found to retain and understand only 60% of the health and safety information on an MSDS [6]. With the implementation of the Globally Harmonized System and WHMIS 2015, it is unknown whether the changes to SDSs have helped to improve the communication of hazards to workers, particularly those with low literacy.

Occupational health literacy is essential to ensuring that workers are safe on the job as it provides them with the skill to obtain, process, and understand the basic health information found on hazard communication materials, such as SDSs [3,7]. To accommodate workers with low health literacy levels, hazard communication materials such as SDSs should therefore be written in a manner that is easily understood [3].

Health literacy is often assessed using a standardized questionnaire to measure the reading and numerical skills of individuals [8,9]. Examples of health literacy survey instruments include the Health Literacy Questionnaire [10] and the European Health Literacy Survey Questionnaire [11]. The International Adult Literacy Survey (IALS) and the Adult Literacy and Life Skills Survey [12] use a five-point scale of functional literacy/competency (level one being the lowest and level three being the minimum threshold for being able to cope with the everyday demands of life and work). For someone to understand an SDS, it has been estimated that literacy skills equivalent to IALS level four or five is required, equating to the highest degree of literacy possessed by only 19.5% of working-age Canadians [13]. This high level of literacy required to understand SDSs therefore poses a serious challenge for hazard communication in workplaces.

In contrast to directly assessing health literacy by surveying individuals, the effectiveness of health communication materials for individuals with low health literacy can also be inferred from tests that measure the overall “literacy burden” of the materials (i.e., how difficult the materials are to understand at a certain literacy level) [14]. Two common tools used to measure the health literacy burden of materials are readability tests and ‘Suitability Assessment of Materials’ (SAM) tests.

Readability tests are objective assessments that use mathematical formulas to measure word length, number of syllables per word, number of words per sentence, and number of sentences per paragraph [15]. The outcome is a score that is roughly equivalent to the school grade needed for an individual to read and understand the text. Popular reading-grade formulas include the Flesch–Kincaid Reading Ease test, Gunning Fog index, Coleman–Liau index, and Simple Measure of Gobbledygook (SMOG) Index [16]. However, each formula is not directly equivalent as they measure different aspects of sentence structure [16]. Although there is no direct conversion between reading-grade levels and functional competency levels, it has been suggested that a 5th-grade reading level is roughly equivalent to literacy skills at level one (the lowest level) of functional competency [17]. Therefore, materials written at or below the 5th-grade level would be considered “superior”, whereas those written between the 6th and 8th grade level are considered “suitable”, or “minimally acceptable” [17].

The SAM tool includes readability but takes additional factors into consideration when assessing the health literacy burden of materials. These factors include content, literacy demand, graphics, layout, font style, motivational cues, and culturally appropriate references to determine the overall “suitability” of a written material [17]. Suitability in this context is therefore defined as a measure of how well the materials “fit” the target audience. The SAM tool consists of a checklist of 22 items that yields a score of 1–100 for each material assessed. The SAM tests, although subjective, have been extensively validated across different cultures to support their use and reflect how low-literacy individuals would judge materials [17]. The original SAM tool has been amended by others to better account for additional factors such as “comprehensibility,” with comprehensibility defined as factors that make written material more understandable (particularly for specific audiences) [18]. The goal of this study was to assess the readability and suitability (including comprehensibility) of SDSs as a hazard communication tool for workers with low health literacy.

2. Methods

2.1. Sampling of safety data sheets

A sample of SDSs were extracted from the Canadian Centre for Occupational Health and Safety SDS Database [19]. For the years 2019 and 2020, all SDSs were retrieved, and a random-number generator was used to select 25 for each year, totaling 50 SDSs. Only SDSs with a date of 2019 or later were selected for evaluation to ensure that they were developed following the new legislated content requirements under WHMIS 2015. In instances where multiple SDSs from a single manufacturer were selected, only the SDS with the latest date was selected for review as SDSs authored by the same manufacturer are likely to share similar characteristics with regards to its accuracy and writing style. Only 50 SDSs were initially selected due to resource limitations. Out of the 50 SDSs originally extracted, 45 unique SDSs were selected from 45 manufacturers for evaluation.

2.2. Assessing health literacy burden in materials

Two types of health literacy tools were used to evaluate SDSs: readability tests and SAM tests. Both tools were selected to evaluate SDSs for the following reasons. First, both readability and SAM tests have been commonly used to assess the health literacy burden of printed and/or digital health communication materials [18,20]. Second, both tools are relatively inexpensive and easy-to-use: important considerations for occupational health and safety professionals when developing hazard communication materials [17]. Finally, they are both well-established tools that can systematically evaluate materials for health literacy burdens in written and visual materials [21].

2.3. Reviewing safety data sheets for readability

A standard online readability calculator [22] was used to evaluate the SDSs for readability. The English versions of the SDSs were assessed by copying and pasting the text within each SDS into the online readability calculator for evaluation, generating grade-level equivalents using four common indices: Flesch–Kincaid, Gunning Fog, Coleman–Liau, and SMOG. Each of these indices uses a different approach to assess the reading-grade level; however, common attributes include average sentence length, number of syllables per word, and number of polysyllabic words.

Certain characteristics of SDSs such as the frequent use of sentence fragments and numerical data to describe chemical and physical properties are not easily recognized by readability-testing programs as they are not complete sentences. However, sections 4–7 of the SDS (first-aid measures; fire-fighting measures; accidental release measures; and handling and storage, respectively) provide written instructions in the form of complete sentences to guide the reader on best-practices and how to complete specific tasks. Moreover, there are no restrictions on how much technical jargon a manufacturer may choose to include in

Table 1
Summary of SDS Evaluation ($n = 45$) using the original SAM tool

SAM item		Materials rated superior (%)	Materials rated adequate (%)	Materials rated not suitable (%)	Materials rated not applicable (%)
Content	Purpose	0%	93%	7%	0%
	Content topics	0%	0%	100%	0%
	Scope	0%	0%	100%	0%
	Summary and review	0%	0%	100%	0%
Literacy Demand	Reading-grade level	0%	0%	100%	0%
	Writing style	4%	29%	67%	0%
	Vocabulary	0%	33%	67%	0%
	In sentence construction, the context is given before new information.	4%	31%	64%	0%
	Learning enhancement by advance organizers (road signs)	98%	2%	0%	0%
Graphics	Cover graphic	9%	0%	0%	91%
	Type of illustrations	2%	2%	64%	31%
	Relevance of illustrations	91%	7%	2%	0%
	Graphics: lists, tables, graphs, charts, geometric forms	0%	13%	58%	29%
	Captions are used to “announce"/explain graphics	2%	13%	62%	22%
Layout and Typography	Layout	7%	82%	11%	0%
	Typography	100%	0%	0%	0%
	Subheadings or chunking	0%	22%	78%	0%
Learning Stimulation and Motivation	Interaction included in the text and/or graphic	0%	0%	100%	0%
	Desired behavior patterns are modeled, shown in specific terms	0%	0%	0%	100%
	Motivation	0%	0%	0%	100%
	Culture match: logic, language, and experience	0%	0%	0%	100%
	Cultural image and examples	0%	0%	0%	100%

Abbreviations: SAM, Suitability Assessment of Materials; SDS, safety data sheet.

these sections, which may further impact reader’s understanding. Therefore, in addition to readability scores for the entire SDS, readability scores for sections 4–7 were separately generated.

2.4. Reviewing safety data sheets for suitability

SAM testing was independently performed on each SDS by two different evaluators. The SDSs were independently scored by the coauthors (one graduate student and one professor in occupational health and safety) progressively in groups of 10 SDSs, with results compared after each group. If there was disagreement in ratings, then a consensus was utilized to create the final score. Initially, one rater produced consistently higher ratings, but after the first few rounds, the level of disagreement was minimal. This method was adapted from a similar procedure to evaluate engineered nanomaterial SDSs [23].

Initially, the original SAM tool was used, which required evaluators to score SDS elements as either superior, adequate, not suitable, or not applicable, based on elements within five categories [17]. Each element within a category is given two points for a “superior” rating, one point for “adequate”, and zero points for “not suitable”. If the element is deemed to be not applicable to the material, then the maximum value of that element (two points) was subtracted from the total SAM score. The overall SAM scores were summed and divided by the total possible SAM score to create a percentage. The percentages were interpreted as follows: 70–100% referred to “superior material” that is suitable for all individuals with low literacy, 40–69% was for “adequate material” that may or may not be understood by all individuals with low literacy, and 0–39% was for “not suitable material” and would not be understood by individuals with low literacy [14,17].

Since the SAM tool was originally developed to evaluate patient education materials, not all of its categories are appropriate to assess SDSs. For example, when using the original SAM tool, nearly all the SDSs scored “not suitable” under subcategories of the “Content” category (including “Content Topics,” “Scope,” and “Summary and Review”). Given the fact that SDSs are highly technical in nature and that they are primarily a hazard communication tool for multiple audiences, we developed a modified SAM tool for the purpose of assessing SDSs. Based on a similar method [18], the SAM tool was amended and subsequently used to re-evaluate all SDSs in this study. This included removing nonapplicable elements and adding new elements under the “Content” category to better address content requirements of SDSs and help identify deficiencies specific to SDSs that reduce the overall suitability. The new and deleted elements were based on best-practice “tips” outlined in the SDS Compliance Tool by WHMIS.org [24]. The SAM tool was therefore amended by adding several “tips” to help identify SDS-specific factors, which may make it more difficult for a reader to understand the material, therefore affecting its “comprehensibility” [18]. However, specific legislative requirements outlined by the compliance tool that did not influence readability, suitability, or comprehensibility were not incorporated into the modified SAM tool. Overall, a “superior” rating would indicate that the SDS is both suitable for all individuals with low literacy and places less demand on the reader to understand the material (i.e., aids comprehensibility). The items assessed by the original SAM tool are listed in Table 1, with the items assessed by the modified SAM tool shown in Table 2.

3. Results

3.1. Readability tests

The average readability scores, in reading-grade levels, for the SDSs are reported in Fig. 1. Calculation of reading-grade levels (Flesch–Kincaid, Gunning Fog, Coleman–Liau, and SMOG) showed reading grade levels from the 9.6th to the 13.7th grade, when the entire document was analyzed (Fig. 1). For the individual sections four, five, six, and seven of the SDS, the reading-grade levels ranged from the 8.9th grade to the 12.1th grade; the 10.7th grade to the 15.3th grade; the 10.9th to the 15.4th grade; and the 9th to the 13.2nd grade, respectively. The majority of the SDSs were above the 9th-grade reading level, regardless of the section analyzed or the readability formula used.

Table 2
Summary of SDS evaluation ($n = 45$) using the modified SAM tool

	SAM item	Materials rated superior (%)	Materials rated adequate (%)	Materials rated not suitable (%)	Materials rated not applicable (%)
Content	In Section 1—Identification—are the recommended use and restrictions on use for the product clearly identified and specified?	36%	7%	58%	0%
	Does the SDS refer to a full table of the H-statements and P-statements with their corresponding codes in Section 16?	2%	27%	51%	20%
	In Section 2—Hazard Identification of the SDS—are specific references made to 1) the GHS classifications, 2) the Hazardous Products Regulation?	40%	27%	33%	0%
	In section 3—Composition/Information on Ingredients of the SDS—are the units used to calculate concentrations of the chemical or mixture available?	40%	20%	36%	4%
	In Section 3—Composition/Information on Ingredients—if the chemical information is classified as a trade secret, is proof of claim under the Hazardous Materials Information Review Act p …	0%	2%	33%	64%
	In Section 4—First Aid—are the instructions listed consistent with the hazard statements in Section 2—Hazards Identification?	29%	16%	56%	0%
	In Section 4—First Aid—are the instructions listed consistent with the information in Section 11—Toxicological Information?	47%	4%	49%	0%
	Does Section 6—Accidental Release Measures—make reference to Section 13—Disposal Considerations?	22%	64%	13%	0%
	Is the information provided in Section 7—Handling and Storage—specific and consistent with the precautionary statements outlined in Section 2—Hazard Identification?	42%	13%	44%	0%
	Where PPE is referenced in any section (e.g., sections 5–7), is the reader directed to Section 8—Exposure Control/PPE?	11%	36%	53%	0%
	Does Section 8—PPE appropriately address the hazard statements outlined by Section 2—Hazards Identification?	38%	13%	49%	0%
	For Section 8—Exposure Control/PPE—are the control parameters (e.g., occupational exposure limits) clearly explained and defined?	0%	69%	24%	7%
	Does Section 9—Physical and Chemical Properties—contain all of the appropriate information and values?	76%	16%	9%	0%
Literacy Demand	Reading-grade level	0%	0%	100%	0%
	(Writing Style) Where applicable—are instructions written in a conversational style and in the active voice to be easily understood?	4%	29%	67%	0%
	(Vocabulary) Where applicable—are instructions written using common words with limited technical jargon?	0%	33%	67%	0%
	In sentence construction, the context is given before new information.	4%	31%	64%	0%
	Learning enhancement by advance organizers (road signs)	98%	2%	0%	0%
Graphics	Cover Graphic	0%	0%	9%	91%
	Type of illustrations	2%	2%	67%	29%
	Relevance of illustrations	91%	7%	2%	0%
	Captions are used to “announce"/explain graphics	2%	13%	62%	22%
	Graphics: lists, tables, graphs, charts, geometric forms	0%	13%	58%	29%
Layout	Layout	7%	82%	11%	0%
	SDS cover page	29%	40%	31%	0%
	Typography	100%	0%	0%	0%
	Subheadings and/or chunking	0%	22%	78	0%

Abbreviations: SAM, Suitability Assessment of Materials; SDS, safety data sheet; GHS; PPE, personal protective equipment.

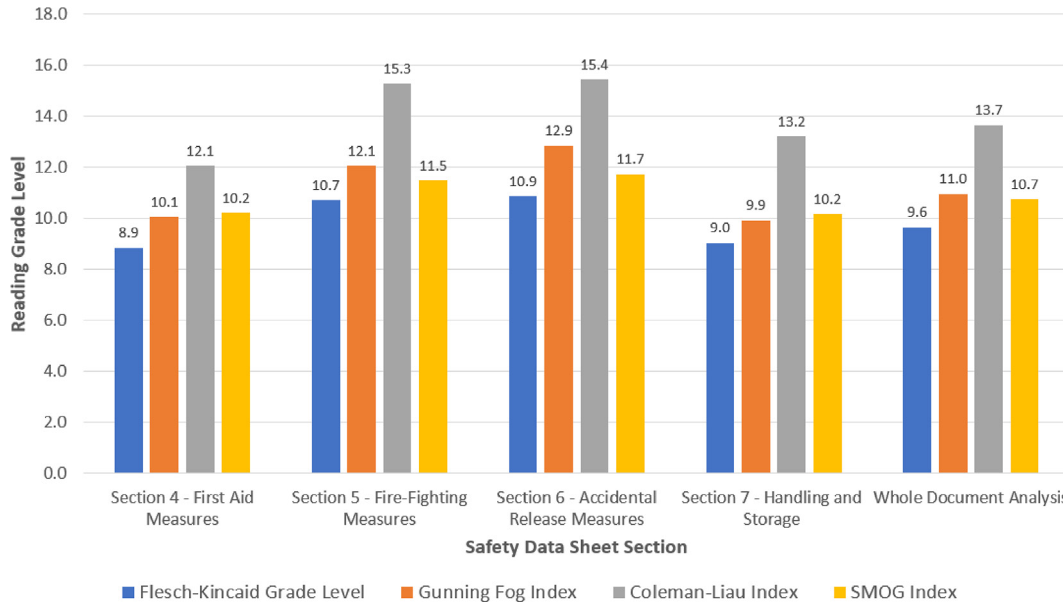

Fig. 1. Mean readability scores by SDS section ($n = 45$) using four different readability indices. Abbreviation: SDS, safety data sheet.

3.2. *Suitability test—original tool*

When using the original SAM tool, the average score of the SDSs was "not suitable" at 30.2% (Fig. 2). More specifically, 6 SDSs (13%) scored in the "adequate" range, whereas 39 SDSs (87%) scored in the "not-suitable" range. No SDSs were rated as "superior." The individual categories in the original SAM tool were also analyzed (see Fig. 2), with the average SAM score of SDSs being 23% (not suitable) when assessing content; 31% (not suitable) for literacy demand; 46% (adequate) for graphics; and 53% (adequate) for layout and typography.

The categories of the original SAM tool were also broken down into their subcategories for analysis (refer to Table 1). For the 'Content' category, 93% of SDSs were rated as 'adequate' when assessing their 'purpose'. However, 100% of SDSs were rated as 'not suitable' for 'content topics' since nearly all the topics covered by SDSs focus on nonbehavior facts. All of the SDSs also rated 'not suitable' for 'scope' as their content is meant to be communicated to more than one audience. All of the SDSs also scored as 'not suitable' when providing 'summaries or reviews' of key messages or points.

In analyzing the 'Literacy Demand' subcategories, all the SDSs scored as 'not suitable' for 'reading grade' level; 67% scored 'not suitable' for 'writing style' and 'vocabulary'; and 64% scored 'not suitable' for 'sentence construction' (Table 1). However, 98% of SDSs scored as superior when providing 'learning enhancement by advance organizers' since they are required by legislation to provide specific headings to cover elements 1–16.

Under the 'Graphics' category, the majority of SDSs did not provide a 'cover graphic' (nor is it required by legislation) and therefore scored as 'not applicable'. Up to 64% of SDSs were rated as 'not suitable' in the 'types of illustrations' they provided as many of the medical drawings and WHMIS symbols may not be understood

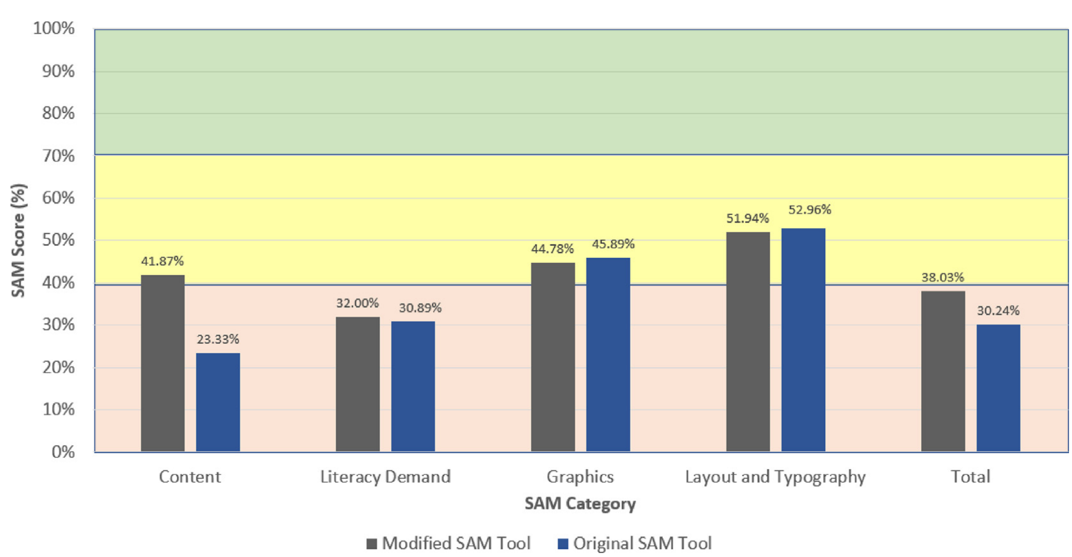

Fig. 2. Mean percentage SAM scores of SDSs ($n = 45$) using the original SAM tool vs. modified SAM tool. Interpretation of SAM scores are as follows: 70-100% is superior material; 40-69% is adequate material; and 0-39% is not suitable material [17]. Abbreviations: SAM, Suitability Assessment of Materials; SDS, safety data sheet.

by the audience without prior training. Moreover, 58% of SDSs were rated as 'not suitable' under the 'types of graphics' provided as many were presented without proper explanation and/or a caption to follow.

Under the 'Layout and Typography' category, 82% of SDSs had good overall layout (adequate), and all SDSs had 'superior' typography. However, 78% of SDSs were rated as 'not suitable' under the 'subheadings or chunking' subcategory as they failed use subheadings to help provide context and guide the reader about the numerous items and topics presented throughout the document.

The 'Learning stimulation and Motivation' category was rated as 'nonapplicable' for most of the subcategories, as many of the criteria for assessment such as reader motivation, culture match, etc. were deemed to be beyond the scope of SDSs.

3.3. *Suitability test—modified tool*

When using the modified SAM tool, the average SAM score of the SDSs increased, but they were still rated as 'not suitable' at 38% (Fig. 2). More specifically, 22 (48.9%) scored in the "adequate" range, and 23 (51.1%) scored in the "not-suitable" range. Again, none of the SDSs were rated as "superior." The individual categories in the modified SAM tool were also analyzed, with the average SAM score of SDSs being 41.9% (adequate) when assessing content; 32% (not suitable) for literacy demand; 44.8% (adequate) for graphics; and 51.9% (adequate) for layout and typography (see Fig. 2).

Many of the changes to the modified tool were primarily applied toward amending the criteria used to assess the "content" of the SDSs (Table 2). In assessing the new content areas, it was found that 58% of the SDSs were 'not suitable' for identifying the 'recommended use and restrictions on use' of the hazardous product. With regards to first-aid instructions (Section 4 of the SDS), 56% were 'not suitable' as they failed to address the hazard statements that were previously presented in Section 2—Hazard Identification. Similarly, 44% of the SDSs were 'not suitable' for their handling and storage instructions (Section 7) as the information was again inconsistent with the hazard statements presented in Section 2. Additionally, 49% of the SDSs were 'not suitable' for the information contained in Section 8—Personal Protective Equipment (PPE) as the information again did not appropriately address the hazard statements in Section 2. Furthermore, 53% of the SDSs were 'not suitable' in directing the reader to Section 8—PPE whenever PPE is referenced in any other section of the SDS.

4. Discussion

In our study, the majority of SDSs were above the 9th-grade reading level. To our knowledge, only one other study has assessed the reading-grade level of SDSs [25]. In that study, three SDSs were analyzed using the SMOG and Flesch—Kincaid readability formulas, and average reading-grade levels of 8.8 and 10 were found, respectively. Our findings confirm that the majority of SDSs are written at too high a reading level, especially for those with low literacy levels (where a reading grade level of grade 6 to 8 is considered minimally acceptable). Therefore, SDSs, especially sections 4—7, should focus more on using plain language and limit the use of technical jargon to ensure that the safety messaging is accessible to workers with lower literacy levels.

In terms of "suitability" testing, if SDSs are to be an effective hazard communication tool, ideally they should rate as "superior" (i.e., suitable for all individuals with low literacy). However, a "superior" rating is probably not realistic, given the technical nature of SDSs and the range of audiences they are servicing. As such, a rating of "adequate" (i.e., may or may not be understood by all individuals with low literacy) is probably more achievable, particularly if the SDSs are supplemented by additional materials or training at workplaces. Using the original SAM tool, we found that SDSs were "not suitable" (i.e., average suitability score was 30.2%). These findings are consistent with a previous study where three SDSs assessed using the original SAM tool averaged 36.3% [25]. In that study, similar trends were observed where the SDSs often used unfamiliar terms, focused on multiple audiences and purposes, and provided little in the way of context for numbers, concepts, behaviors, and graphics [25].

When using the modified SAM tool, the average overall SAM score of the SDSs increased from 30.2% (original tool) to 38% (modified tool); however, this is still considered 'not suitable.' The main SDS-related modifications to the original SAM tool were under the Content category, where the average SAM score increased from 23.3% (i.e., not suitable) with the original tool to 41.9% (i.e., the lower range of acceptable) with the modified tool. Through these modifications to the SAM tool, we were better able to better assess the technical nature of SDSs, capture specific differences between SDSs, and identify areas to improve their overall suitability and comprehensibility. For example, there was a distinct lack of consistency between Section 2 (hazard identification) and other sections of the SDS, primarily relating to identification of the product (Section 1), first-aid information (Section 4), handling and storage (Section 7), and first aid (Section 8). This is a major factor impacting comprehensibility making it more difficult for a reader to understand the SDS. Such lack of consistency between sections is also referred to as a lack of text coherence, which refers to the connectedness of ideas in a text, influencing comprehension of the materials [26,27]. The logical structure of the text and its cohesion (how well the parts stick together) is an important factor that contributes to the fit, or suitability, between a reader and text [28].

Similar findings regarding a lack of consistency among SDSs sections were also reported in the gray literature. In an SDS audit project by Health Canada, 188 publicly available SDSs were assessed for noncompliance under the Hazardous Products Act [29]. It was determined that 17.49% of the SDSs lacked consistency in Section 4: First-Aid measures, where the instructions were not consistent with the hazard and precautionary statements outlined in Section 2—Hazard Identification. Additionally, 13.94% of the SDSs in that study contained contradictory information in Section 11—Toxicological Information—which did not appropriately address the hazard and precautionary statements outlined in Section 2. In another study by the European Chemicals Agency, 197 SDSs were assessed for compliance with the Registration, Evaluation, Authorisation and restriction of chemicals legislation [30]. They determined that in 20% of the SDSs assessed, information on recommended/identified uses was missing; and in 66% of the SDSs, information on 'uses advised against' was missing. Additionally, in Section 7—Handling and Storage—34% of the SDSs contained vague and generic information that failed to address the hazard and precautionary statements outlined in Section 2—Hazard Identification. These compliance studies therefore confirm the results of our suitability study and provide prominent examples of specific barriers that affect the overall readability, comprehensibility, and suitability of SDSs.

The barriers that we and others have identified (e.g., inconsistency between sections; highly technical jargon; and unfamiliar terms) contribute to the overall literacy burden of SDSs. This presents a significant safety challenge as several studies have observed that poor literacy skills, such as a lack of understanding of occupational health and safety regulations and safe work procedures present safety risks [31—34] that can lead to workplace accidents [13,35]. Moreover, past studies assessing MSDSs observed that the majority of workers found MSDSs to be difficult to understand and read and that they were confusing [5,6]. Taken together, these studies imply that improving the readability of SDSs may be helpful in reducing the safety risks associated with low literacy in the workplace.

These results also indicate that publishers of SDSs should use readability and suitability testing to identify opportunities to make their materials more accessible and understandable to workers with low literacy levels. Furthermore, given their high comprehension demands on workers, it is critically important that SDSs are supplemented with job-specific/site-specific training and materials [36]. Such training can help better contextualize and communicate workplace-specific hazards more effectively to workers and particularly for those who may not fully understand the hazards communicated by SDSs in the written form.

4.1. Strengths and limitations

This study combined a recognized and validated health literacy approach (the SAM tool) with best practices developed by WHMIS.org to develop a modified SAM tool that accounts for the specific nature of SDSs as a hazard communication tool. This is the only tool that we are aware of, which has been designed to assess readability and suitability of SDSs. However, in developing the modified SAM tool, aspects of judgment and subjectiveness were required. A weakness with our modified SAM tool was that the original authors of the SAM tool [17] were not contacted for validation as occurred in a previous study that modified the tool [18].

Furthermore, the SAM test is subjective by nature and can bias the results of the study if the differences between evaluators are not controlled for (i.e., inter-rater reliability). In our study, the SDSs were independently scored by the coauthors, and if there were differences, then a consensus was used to create the final score. This scoring method was adapted by following a similar procedure to evaluate engineered nanomaterial SDSs [23]. However, to reduce the potential for bias among evaluators, where possible, the number of evaluators should be maximized [37].

Given the large number of chemicals (with SDSs) commercially available, this study should be considered an indication of the issues associated with the SDSs reviewed and may not be representative of SDSs in general. Finally, the SDSs were mainly assessed for their suitability and readability. The current investigation did not assess SDSs for their compliance with the Canadian hazard communication legislation (e.g., WHMIS 2015) and was only partially assessed for 'compliance factors' that would influence readability (e.g., inconsistency of information across sections). Future investigations should conduct a full assessment to include suitability, readability, and legislative compliance.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

We are grateful for the support and funding provided by the Undergraduate Research Opportunities Programs funded by Toronto Metropolitan University.

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