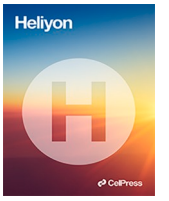
Heliyon 10 (2024) e35763

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Inconsistent health hazard information across safety data sheets for substances in cleaning products used in healthcare centres

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ARTICLE INFO

Keywords:
Safety data sheet
Cleaning product
Hazard
Harmonised classification and labelling

ABSTRACT

Safety Data Sheets (SDSs) are used to inform downstream users of any hazardous substances in chemical products and advise on how to manage the risks from using these products. It is therefore important that information on the SDS is accurate and consistent. This study investigates the accuracy and consistency of hazard information included in the SDSs of cleaning products used in the healthcare sector in England and Wales.

Data on cleaning products used in the National Health Service (NHS) in England and Wales and their chemical composition and any hazard information (as H-statements) were collected from the products' SDSs obtained from the NHS supply online catalogue. By each hazard, mainly respiratory hazards, the number of hazardous substances specified as hazardous in all SDSs was identified. Moreover, we investigated hazard characteristics of substances identified by only SDS (at least one SDS) or only through Harmonised Classifications and Labeling (CLH) or by SDS and through CLH simultaneously.

In total, 229 unique chemical substances were found in 473 cleaning products' SDSs. All 4 respiratory sensitisiers were identified in all SDSs and through CLH. However, only 14 of the 25 respiratory irritants (56.0 %) were consistently labelled across all SDSs. Although respiratory irritation characteristics of 3 substances were classified through CLH, it was not identified by any of the relevant SDSs.

Substantially incorrect and inconsistent health hazard information for the same substances was identified across SDSs. Therefore, healthcare workers and their managers may not receive accurate information on the presence of and potential for exposure to hazardous substances in the cleaning products they are using.

1. Introduction

Healthcare workers have an elevated risk of occupational disorders, for instance, asthma and rhinitis [1–3] and dermatitis [4,5]. Given their frequent use of cleaning and disinfection products [6], healthcare workers can be exposed to potentially high levels of various hazardous substances contained in these cleaning products [7,8]. Lately, due to the pandemic, frequent use of cleaning and disinfection products to remove SARS-CoV-2 in healthcare settings was recommended by the World Health Organization [9]. This potentially resulted in higher exposure to these products compared to before the pandemic [10].

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https://doi.org/10.1016/j.heliyon.2024.e35763
Received 22 November 2023; Received in revised form 30 July 2024; Accepted 2 August 2024
Available online 3 August 2024

In Europe and the UK Safety Data Sheets (SDS) are obligatory documents to provide users of chemicals and products that contain chemicals information on hazards associated with these chemicals. The SDS are completed by manufacturers, importers, and downstream users according to UK Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) [11] that align with the key principles of EU REACH [12]. SDSs include fundamental information about the products and chemical substances, encompassing their composition and their human and environmental hazard characteristics [13]. The European Chemicals Agency (ECHA) employs standardized codes known as H-statements to indicate potential health or environmental hazards of substances or mixtures based on specified criteria. The presence of hazardous substances and mixtures in cleaning products and appropriate risk management measures are communicated to the users through the SDS of the product [14,15].

The list in Annex VI of the CLP regulation includes hazard characteristics (as H-statements) based on Harmonised Classification and Labelling (CLH) [16]. These hazards have been assessed by a committee for the risk assessment process in ECHA and should be included on the SDS if these substances are present [17]. In addition the H-statements listed in Annex VI, the manufacturers, importers, or suppliers of chemical substances or products containing chemicals should include self-classified H-statements on the based on adequacy and reliability of all available information [18].

However, it has been suggested that the SDSs often contain inaccurate information and that information on hazardous substances is not always consistent between different SDSs [19,20]. For example, although the athmagenic effect of isocyanates is well known, two studies found that the hazards were not always described in all the SDSs of products that contained these substances [21,22]. The potential adverse health effects from exposure to substances in the product, according to SDS, may therefore not always be representative of the consensus for such health effects [23,24]. Another study found that among 91 substances found in 320 SDSs of cleaning products, the hazard characteristics identified by ECHA of 57 substances (63 %) were not present across SDSs [25]. However, the levels of incorrect and inconsistent hazard information contained in the SDSs for cleaning products used in the UK and healthcare sectors have not yet been comprehensively studied.

The aim of this study is to determine, in the SDSs of cleaning products used in healthcare system in England and Wales, the extent of missing and inconsistent hazard information, especially respiratory hazards, by H-statement, SDS, and SDS provider.

2. Methods

2.1. Data extraction

Initially, we developed a list of substances in cleaning products used in healthcare centres in England and Wales. These substances and their hazard characteristics were obtained from section 3 of the SDSs of the cleaning products listed in the "Cleaning hygiene and infection control" category on the NHS supply chain online catalogue website, accessed initially in April 2019, and again in April 2021. This website includes information on all products used in NHS organisations across England and Wales [26]. This list of cleaning products comprises constituent substances, their hazard characteristics (H-statements) from section 3 of the SDS, SDS providers (companies) and other information [27].

2.2. Data analysis

This study's main focus is respiratory hazards (H334- respiratory sensitisation, H335- respiratory irritation), but other hazards posed by the substances according to their classifications were also included. By each hazard, the number of hazardous substances specified as hazardous in all SDSs was identified. Moreover, we investigated hazard characteristics of substances identified by only SDS (at least one SDS) or by SDS and through CLH simulatenously, or only through CLH.

Among hazardous substances whose hazards classfied through CLH, since SDSs or SDS providers may not identify all hazards of each substance classified through CLH, we found the number of SDSs and SDS providers did not present all the hazards. Furthermore, since a single SDS provider can publish multiple SDSs for products containing the same substance, we found the SDS provider who did

Table 1
By H-statement, the number of SDSs that presented the given hazard across SDSs.

Respiratory or other hazards	H-statement	Total number of hazardous substances that at least one SDS presented this hazard	Number of hazardous substances for which their given H-statement presented in all SDSs (%)	The number of SDSs that described this hazard (% of 473 SDSs of total products)	Number of SDSs per hazardous substance Mean ± SD (range)
Respiratory hazards	H334 (Rs)	4	4 (100)	13 (2.7)	3.8 ± 2.4 (2–7)
	H335 (Rr)	25	14 (56.0)	117 (24.7)	8.8 ± 9.4 (1–33)
Other hazards	H302 (Ato)	88	64 (72.7)	334 (70.6)	7.5 ± 9.1 (1–45)
	H315 (Sr)	89	70 (78.7)	235 (49.7)	5.3 ± 6.4 (1–35)
	H317 (Ss)	15	13 (86.7)	79 (16.7)	6.5 ± 8.6 (1–35)
	H318 (Ed)	92	63 (68.5)	279 (59)	7.8 ± 10.4 (1–52)
	H319 (Er)	77	51 (66.2)	276 (58.4)	7.6 ± 11.0 (1–65)

*Only respiratory hazard and other hazard groups having over fifteen hazardous substances are included in this table.
Rs: Respiratory sensitisation, Rr: Respiratory irritation, Ato: Acute toxicity (oral), Sr: Skin irritation, Ss: Skin sensitisation, Ed: Eye damage, Er: Eye irritation.

not always label the hazards classified through CLH on its own SDSs.

In hazardous substances whose hazards were not classified through CLH, their hazards SDS may be shown differently across SDSs. We identified the most common H-statement combination appearing across the SDSs. Next, the number of SDSs with a deviating combination of H-statements (compared to the most common combination) was determined.

3. Results

3.1. All substances found in at least one SDS

We found a total of 473 cleaning products and 229 unique chemicals substances in SDSs. For 27 substances none of the SDSs presented any hazard characteristics.

Table 1 provides information on the number of chemical agents by hazard statement, including CHL and self-assessed H-statements. There were only 4 chemicals classified as respiratory sensitisers (H334), which were present in 13 products, all of which included this H-statement in the SDS. There were more chemical substances classified as respiratory irritants (H335) (n = 25), which were contained in 117 products. Only 14 of the25 respiratory irritants (H335: 56.0 %) were consistently labelled across all SDSs.

Concerning other hazardous substances, there were chemicals labelled as H318 (Eye damage), 89 substances as H315 (Skin irritation), and 88 substances as H302 (Oral acute hazard),. Among substances labelled H319 (Eye irritation) and H318, 66.2 % and 68.5 %, respectively, were consistently labelled in all SDSs. The information of the rest of hazard categories had fewer than 15 hazardous substances was described in S1.

3.2. Substances whose hazards were classified through CLH

One or more than one on hazard characteristics of 64 substances were included in Annex VI of the CLP Regulation. Out of 165 substances not included in Annex VI of the CLP, but with one or more self-assessed H-statements, 109 substances were mentioned in more than one SDS (Fig. 1).

Compared to the hazard classification through CLH, all of the respiratory sensitisers (H334) identified in at least one SDS were correctly labelled in all the relevant SDSs. However, 9 respiratory irritants (H335) were found by at least one SDS and through CLH simultaneously and rest of 16 irritants were identified by only SDSs. 11 among 92 substances labelled H318 (Eye damage) based on information within at least one SDS were classified through CLH (Fig. 2). The rest of hazards was presented in S2.

None of the chemicals in any of the cleaning products considered here, were labelled as a respiratory sensitiser in Annex VI of the CLP. Although respiratory irritation characteristic of 3 substances, sodium perborate tetrahydrate, glutaraldehyde (descried as a respiratory sensitiser on SDSs), and methyloxirane were classified through CLH, it was not identified by any of the relevant SDSs. Also,

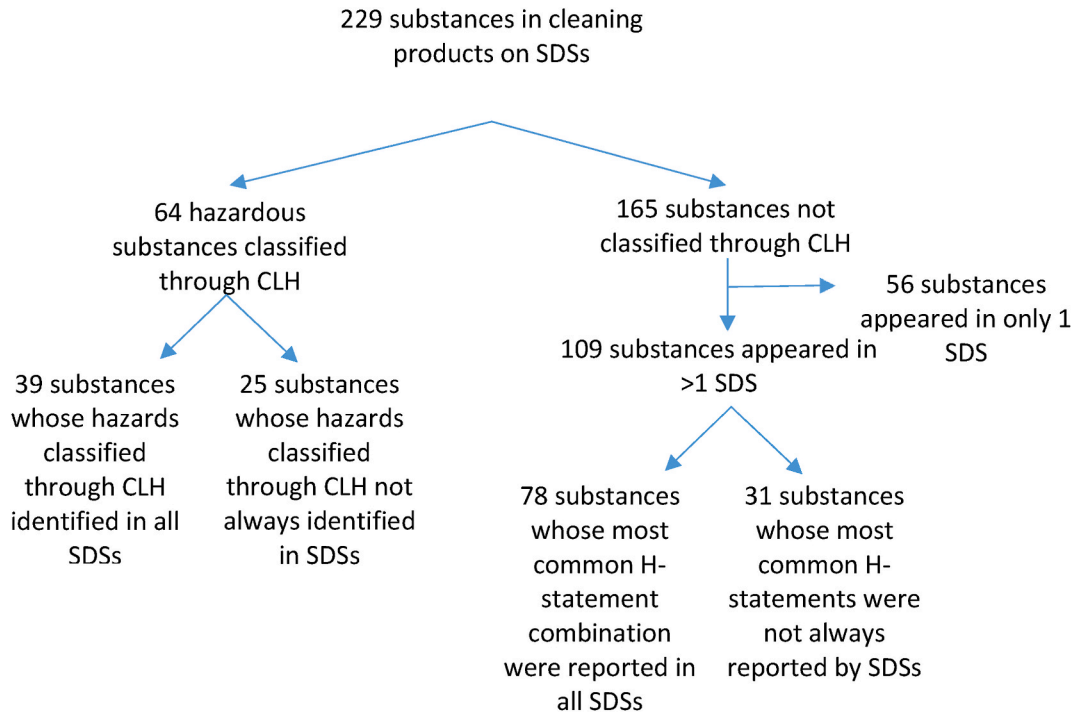

Fig. 1. The number of hazardous substances classified through CLH and not classified through CLH for analysis.

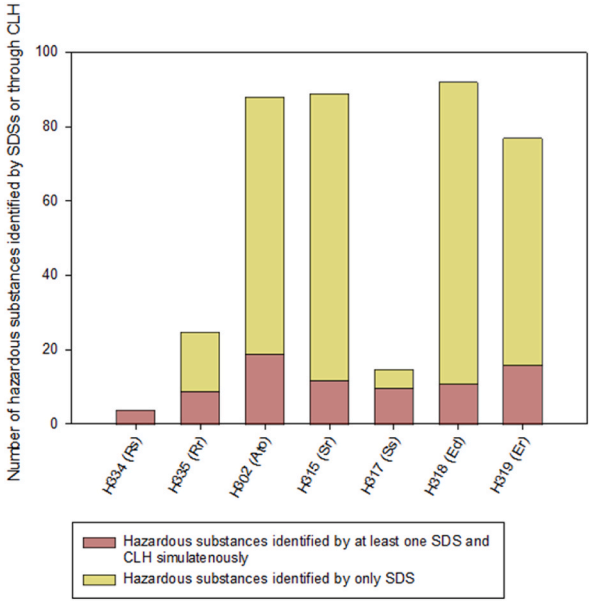

Fig. 2. The number of hazardous substances identified through Harmonised Classification and Labelling (CLH) or by SDS by H-statement.

4 hazardous substances classified H302 (Acute toxicity - oral) and H318 (Eye damage) through CLH were identified by none of SDSs (Table 2). The list of substances and their other hazards identified through CLH but, not included in any SDS was illustrated in S3.

Out of the 64 substances included in Annex VI, 18 had one H-statement, and the other 46 substances had multiple H-statements. For 25 of 64 substances included in Annex VI (39.1 %), not all the H-statements classified through CLH were included in all the relevant SDSs. For 2 substances (5-chloro-2-methyl-2H-isothiazol-3-one and 2-methyl-2H-isothiazol-3-one (3:1) and hydrochloric acid), none of the SDSs were correctly labelled with all the H-statements. The SDSs provided by the same supplier did not properly label the hazard characteristics classified through CLH for the five hazardous substances: isopropyl alcohol, 2-butoxyethanol, adipic acid, sodium hydroxide, and 2-Methyl-4-isothiazolin-3-one (Table 3).

Table 2
The list of substances and their hazards identified through CLH but, not included in any SDS.

Respiratory or other hazards	H-statement	CAS RN	Name of hazardous substance	Formula
Respiratory	H335 (Rr)	10486-00-7	Sodium perborate tetrahydrate	$BNaO_3$ * 4 H_2O (mixture)
hazards		111-30-8	Glutaraldehyde	$C_5H_8O_2$
		75-56-9	Methyloxirane	C_3H_6O
Other hazards	H302 (Ato)	122-99-6	2-phenoxyethanol	$C_8H_{10}O_2$
		520-45-6	3-acetyl-6-methyl-2H-pyran-2,4(3H)-dione	$C_8H_8O_4$
		55406-53-6	3-Iodo-2-propynyl butylcarbamate	$C_8H_{12}INO_2$
		75-56-9	Methyloxirane	C_3H_6O
	H315 (Sr)	65-85-0	Benzoic acid	$C_7H_6O_2$
	H317 (Ss)	55406-53-6	3-Iodo-2-propynyl butylcarbamate	$C_8H_{12}INO_2$
	H318 (Ed)	10486-00-7	Sodium perborate tetrahydrate	$BNaO_3$ * 4 H_2O (mixture)
		55406-53-6	3-Iodo-2-propynyl butylcarbamate	$C_8H_{12}INO_2$
		55965-84-9	5-chloro-2-methyl-2H-isothiazol-3-one and 2-methyl-2H-isothiazol-3-one (3:1)	$C_4H_5NOS.C_4H_4ClNOS$ (mixture)
		65-85-0	Benzoic acid	$C_7H_6O_2$
	H319 (Er)	122-99-6	2-phenoxyethanol	$C_8H_{10}O_2$
		75-56-9	Methyloxirane	C_3H_6O

Rs: Respiratory sensitisation, Rr: Respiratory irritation, Ato: Acute toxicity (oral), Sr: Skin irritation, Ss: Skin sensitisation, Ed: Eye damage, Er: Eye irritation.

Table 3
List of hazardous substances classified through CLH, for which SDS/SDS providers did not always label all H-statements classified through CLH.

Multiple/ Single SDS provider published SDSs including this substance	CAS RN	Name of hazardous substance	H-statements classified through CLH	Total SDSs with this substance	SDSs with this substance not labelling one of the H-statements classified through CLH (%)	Total SDS providers that published SDSs with this substance	Number of SDS providers that published at least one SDS that did not include all H-statements classified through CLH, among total SDS providers (%)
Multiple SDS providers	55965-84-9	Mixture of 5-chloro-2-methyl-2H-isothiazol-3-one and 2-methyl-2H-isothiazol-3-one (3:1)	H301,H314, H317,H318, H330	9	9 (100)	3	3 (100)
	7647-01-0	Hydrochloric Acid	H314,H331	2	2 (100)	2	2 (100)
	27083-27-8	Polyhexamethylene biguanide hydrochloride	H302,H317, H318, H330, H351,H372	12	10 (83.3)	4	1 (25)
	79-21-0	Peracetic acid	H302,H312, H314, H332	6	4 (66.7)	3	1 (33.3)
	7681-52-9	Sodium hypochlorite	H314,H318	11	7 (63.6)	7	5 (71.4)
	9014-01-01	Subtilisin	H315,H318, H334, H335	2	1 (50)	2	1 (50)
	7173-51-5	Didecyldimethylammonium chloride	H302,H314	26	9 (34.6)	9	3 (33.3)
	52-51-7	Bronopol	H302,H312, H315, H318, H335	7	2 (28.6)	3	2 (66.7)
	63449-41-2	Benzalkonium chloride	H302,H312, H314	5	1 (20)	4	1 (25)
	60-00-4	Edetic acid	H319	6	1 (16.7)	3	1 (33.3)
	67-63-0	**Isopropyl alcohol**	**H319,H336**	**52**	**6 (11.5)**	**14**	**2 (14.3)**
	111-76-2	**2-Butoxyethanol**	**H302,H312, H315, H319, H332**	**10**	**1 (10)**	**4**	**1 (25)**
	141-43-5	2-aminoethanol	H302,H312, H314, H332	33	3 (9.1)	12	2 (16.7)
	124-04-9	**Adipic acid**	**H319**	**28**	**2 (7.1)**	**8**	**1 (12.5)**
	1310-73-2	**Sodium hydroxide**	**H314**	**41**	**2 (4.9)**	**14**	**1 (7.1)**
Single SDS provider	111-30-8	Glutaraldehyde	H301,H314, H317,H330, H334, H335	7	7 (100)		
	69-72-7	Salicylic acid	H302,H318, H361d	4	4 (100)		
	122-99-6	2-phenoxyethanol	H302,H319	2	2 (100)		
	520-45-6	3-acetyl-6-methyl-2H-pyran-2,4 (3H)-dione	H302	2	2 (100)		
	55406-53-6	3-Iodo-2-propynyl butylcarbamate	H302,H317, H318, H331, H372	2	2 (100)		
	65-85-0	Benzoic acid	H315,H318, H372	2	2 (100)		
	10486-00-7	Perboric acid, monosodium salt trihydrate	H318,H332, H335, H360Df	1	1 (100)		
	64742-48-9	Naphtha (petroleum), hydrotreated heavy	H304,H340, H350	1	1 (100)		
	75-56-9	Methyloxirane	H302,H311, H319,H331, H335,H340, H350	1	1 (100)		
	2682-20-4	**2-Methyl-4-isothiazolin-3-one**	**H301,H311, H314, H317, H318,H330**	**2**	**1 (50)**		

In bold: hazardous substances whose H-statements classified through CLH were provided differently across SDSs made by the same provider.

3.3. Substances whose hazards were not classified through CLH

From the 165 substances that were not included in Annex VI, 109 substances were present in more than 1 SDS (with a range of 2–45 different SDSs). For 31 of these substances (28.4 %) the combination of H-statements was not consistent across all the relevant SDSs. The same SDS providers reported hazards for 18 substances differently compared to the most common combination of H-statements on the SDSs including the given substances (Table 4).

4. Discussion

For managing risks of occupational illnesses such as asthma or dermatitis, complete and correct hazard information about substances in cleaning products to healthcare workers is essential and the information should be delivered to healthcare workers consistently. While the list in Annex VI to the CLP regulation by ECHA offers harmonised hazard information, some SDSs do not include all the H-statements based on the CLH. Specifically, although glutaraldehyde, sodium perborate tetrahydrate, and methyloxirane have all been identified as respiratory irritants through the CLH, these substances were not identified as respiratory irritants on any of the SDSs reviewed in this study. Incorrect and inconsistent H-statements of hazardous substances were found across SDS and SDS providers compared to H-statements classified through CLH. Furthermore, H-statements of the same substances were not consistent across SDSs and within/between different SDS providers, which may be due to subjective self (provider)-classification. This implies that product users may receive inaccurate hazard information for identical substances from different SDSs, and the extent of inconsistency could vary depending on the specific H-statement used. Such inconsistency in hazard information presents a challenge to efficient communication and risk management, with potential implications for healthcare workers' health.

As asthma and rhinitis [1–3] and dermatitis [4,5] in healthcare staff can occur due to exposure to cleaning products, respiratory hazards should be identified appropriately. There is a list of non-professional cleaning products in the USA [28]. However, the hazards of ingredients were not presented. Comprehensive hazards of substances in cleaning products used by cleaners but not healthcare workers were identified based on H-statements [15]. We found hazards based on at least one SDS in our recent work [27]. However, we found inconsistent hazard information across SDSs, this study investigated the inconsistency of hazard information across SDSs.

The SDS serves as the primary source of information for the user of hazard characteristics of chemical substances [29]. Given that the SDS are mandatory [12], the users of chemical products can find all hazard information of constituents. Therefore, it is a convenient and useful tool for identifying hazards. The SDS has been employed for identifying the hazard characteristics of cleaning product constituents in several studies [15,30].

However, inconsistent hazard information of substances has been observed previously as this study shows. In the studies from the United States, greater than 60 % of 687 material SDSs (MSDSs), the adverse reproductive effects of lead and ethylene glycol ethers were not specified [23]. Only approximately 40 % of MSDSs showed adverse health effects correctly compared with relevant references in the other study [24]. For toluene diisocyanate, 50 % of 30 MSDS providers did not include asthmagenic effects, that have been observed by physicians, in 61 MSDSs [22].

There are several difficulties to present hazards consistently. Fundamentally, hazard information on SDSs is written based on the provider's self-classification. Indeed, the observed inconsistency and inaccuracy in SDSs may arise from the fact that manufacturers or suppliers, who are tasked with submitting SDSs, might choose not to include potential hazards. This could be a deliberate choice driven by the intention to present more favourable or positive information [25]. Additionally, SDSs only include those substances whose concentrations in the product are greater than 0.1 % or 1 % depending on the hazard [13].

Additionally, hazard characteristics can be assessed inappropriately due to the lack of toxicological or hazard evaluation data. For example, in ECHA guidance [31], respiratory sensitisation and irritation could be assessed based on reliable human studies such as case reports, epidemiological studies, or animal experiments. However, relevant human data for assessing respiratory hazards barely exists. Generally, human data do not show clear evidence for toxicity classification.

Furthermore, a gold standard for the hazard characteristics of substances is often not available, since the providers of SDS have challenges in evaluating the hazards of individual substances accurately. In this study, the list in Annex VI to the CLP regulation was employed as the gold standard as the hazard information classified through CLH is reviewed by a team of independent experts in ECHA's committee for risk Assessment [17]. However, additional hazards of substances suggested by manufacturers, importers, and downstream users can be included in the Annex VI to the CLP regulation after a review based on the latest scientific findings and advancements, re-evaluation of current data, and updates in classification criteria by the ECHA committee [17]. Due to the review process, potentially some hazards may not be added in the latest version of the Annex VI. Nevertheless, we believe that hazards classified through CLH are highly reliable data. Recently, respiratory and skin hazards classified through CLH were compared to the hazards on SDSs and SDSs that did not present respiratory hazards classified through CLH were observed [30].

Similarly, in this study, SDSs lacked or partially presented the hazards classified through CLH. For instance, glutaraldehyde, present in cleaning products, is a substance to which healthcare workers are frequently exposed [32]. The respiratory hazard related to asthma from this substance has been recognised [33], and was also specified on the list in Annex VI to the CLP regulation and the two methods used in the other study [34]. Furthermore, glutaraldehyde was only identified as a respiratory sensitiser, on none of the relevant SDSs was this labelled as a respiratory irritant.

In addition, further hazards not identified either by SDS or through CLH can be found by additional methods. Alternative methods, such as QSAR, grouping, and read-across assessment, to enhance the accuracy of hazard identification have been suggested when SDS providers publish SDSs [35]. As an example, in a previous study [34], a QSAR model and list of asthmagens, as complementary methods, identified a substantially greater number of cleaning products containing further potential sensitisers that were not reported

Table 4
List of hazardous substances not classified through CLH and evaluated by over one SDS, but at least one SDS/SDS provider did not label one of the H-statements in the most common H-statement combination.

Multiple/ Single SDS provider published SDSs including this substance	CAS RN	Name of hazardous substance	Most common H-statement combination	Total SDSs with this substance	SDSs with this substance which include all the most common H-statements (%)	Total providers that published SDSs with this substance	Number of providers that did not publish at least one SDS with all the most common H-statements among total providers (%)
Multiple SDS providers	**1344-09-8**	**Sodium silicate**	**H315,H318, H335**	**18**	**8 (44.4)**	**6**	**3 (50)**
	1643-20-5	Lauramine oxide	H302,H315, H318	6	3 (50)	3	1 (33.3)
	166736-08-9	Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) ether	H302,H315, H319	6	3 (50)	3	1 (33.3)
	68551-13-3	Alcohols, C12-15, ethoxylated propoxylated	H315	4	2 (50)	2	1 (50)
	69227-21-0	Alcohols, C12-18, ethoxylated and propoxylated	H315	2	1 (50)	2	1 (50)
	18472-51-0	**Chlorhexidine gluconate**	**H318**	**9**	**5 (55.6)**	**6**	**4 (66.7)**
	68439-50-9	Alcohols, C12-14, ethoxylated	H302,H318	5	3 (60)	3	2 (66.7)
	68424-85-1	**Quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides**	**H302,H312, H314**	**45**	**30 (66.7)**	**11**	**4 (36.4)**
	91995-81-2	Fatty acids, C10-20 and C16-18-unsatd., reaction products with triethanolamine, di-Me sulfate-quaternized	H315,H319	6	4 (66.7)	4	2 (50)
	26635-93-8	Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[[(9Z)-9-octadecen-1-ylimino]di-2,1-ethanediyl]bis[.omega.-hydroxy-	H302,H315, H318	3	2 (66.7)	2	1 (50)
	60-12-08.	2-Phenylethanol	H302,H311, H319	3	2 (66.7)	2	1 (50)
	61788-90-7	Cocamine oxide	H302,H315, H318	3	2 (66.7)	2	1 (50)
	85409-23-0	**Quaternary ammonium compounds, C12-14-alkyl [(ethylphenyl)methyl] dimethyl, chlorides**	**H302,H314**	**3**	**2 (66.7)**	**2**	**1 (50)**
	68002-97-1	Alcohols, C10-16, ethoxylated	H302,H315, H318	5	4 (80)	3	2 (66.7)
	137-16-6	Sodium N-lauroylsarcosinate	H315,H318	5	4 (80)	4	3 (75)
	68391-01-5	**Quaternary ammonium compounds, benzyl-C12-18-alkyldimethyl, chlorides**	**H302,H314**	**6**	**5 (83.3)**	**2**	**1 (50)**
	68411-30-3	**Benzenesulfonic acid, C10-13-alkyl derivs., sodium salts**	**H302,H315, H318**	**18**	**15 (83.3)**	**7**	**5 (71.4)**
	8001-54-5	Alkyldimethylbenzylammonium chloride	H302,H312, H314	6	5 (83.3)	2	1 (50)
	2372-82-9	**N-(3-Aminopropyl)-N-dodecylpropane-1,3-diamine**	**H301,H314, H373**	**13**	**11 (84.6)**	**4**	**2 (50)**
	68585-34-2	Alcohols, C10-16, ethoxylated, sulfates, sodium salts	H315,H318	7	6 (85.7)	4	3 (75)
	68439-46-3	**Alcohols, C9-11, ethoxylated**	**H302,H318**	**23**	**20 (87)**	**6**	**4 (66.7)**
	69011-36-5	**Isotridecanol, ethoxylated**	**H302,H318**	**32**	**28 (87.5)**	**5**	**3 (60)**
	77-92-9	**Citric acid**	**H319**	**28**	**25 (89.3)**	**11**	**9 (81.8)**
	25155-30-0	**Benzenesulfonic acid, C10-14-alkyl derivs., sodium salts**	**H302,H315, H318**	**12**	**11 (91.7)**	**5**	**4 (80)**
	68131-39-5	**Alcohols, C12-15, ethoxylated**	**H302,H318**	**19**	**18 (94.7)**	**3**	**2 (66.7)**

(*continued on next page*)

Table 4 (*continued*)

Multiple/ Single SDS provider published SDSs including this substance	CAS RN	Name of hazardous substance	Most common H-statement combination	Total SDSs with this substance	SDSs with this substance which include all the most common H-statements (%)	Total providers that published SDSs with this substance	Number of providers that did not publish at least one SDS with all the most common H-statements among total providers (%)
Single SDS provider	**29329-71-3**	**Phosphonic acid, (1-hydroxyethylidene)bis-, sodium salt**	**H302 or H319**	**2**	**1 (50)**		
	57-13-6	**Urea**	**H319**	**3**	**2 (66.7)**		
	151-21-3	**Sodium dodecyl sulfate**	**H302,H315, H318**	**4**	**3 (75)**		
	7758-19-2	**Sodium chlorite**	**H301,H310, H330,H373**	**4**	**3 (75)**		
	90194-45-9	**Benzenesulfonic acid, mono-C10-13-alkyl derivs., sodium salts**	**H302,H315, H318**	**10**	**8 (80)**		
	61789-40-0	**Cocamidopropyl betaine**	**H318**	**11**	**10 (90.9)**		

In bold: hazardous substances whose most common H-statements were provided differently across SDSs the same provider made.

on SDSs [34]. Potential respiratory hazards of 28 substances in spray cleaning products were screened by the Danish QSAR database using more than 200 QSAR models [36] and respiratory hazards of ethylenediaminetetraacetic acid, 2-aminoethanol, and salicylic acid were identified by the QSAR models in this study and the Danish study but not by SDSs in this study. This suggests the presence of potential sensitisers/irritants in cleaning products which were not identified on the SDSs.

This study showed inconsistent hazard characteristics of many cleaning product substances on SDSs in different ways by the comparison between SDSs/SDS providers and the comparison between SDSs and through CLH. Also, this study found inconsistency even between SDSs published by the same SDS provider. To our knowledge, this is the first study to identify inconsistent health information across SDSs and SDS providers, especially with the comprehensive cleaning agents. Recently, in Sweden [30], skin and respiratory hazards identified by SDSs were compared to the hazards classified through CLH. However, hazard information between different SDSs was not compared. Nevertheless, It was not possible to determine the degree of inconsistent hazard information for identical chemicals between SDSs or SDS providers as the number of SDSs including each chemical differed.

In order to reconcile the inconsistency of hazards on SDSs, a standard resource such as ECHA's C&L Inventory or platform that includes all the hazard characteristics of chemicals from different sources such as Agency for Toxic Substances and Disease Registry (ATSDR), Occupational Safety and Health Administration (OSHA) from different countries, Reprotox established by The Reproductive Toxicology Center, AOEC list in our research, etc., may be required. Subsequently, SDS providers could review this platform and be encouraged to report hazards and add new hazards on SDSs consistently.

5. Conclusion

In conclusion, this study found that disparate health hazard information for identical substances was observed between SDSs and the hazardous substance list established through CLH and among SDSs. Hence, it could result in difficulties in setting health risk management strategies for managers and also communicating the risks between managers and healthcare professionals. SDSs should be improved to deliver hazard information consistently to healthcare professionals. Then, SDSs could play an appropriate role as a primary source of hazard information.

Data availability statement

The main description of the database for this study was introduced in another journal article. Data will be made available on request.

Ethics statement

As this research did not use any health information, prior review by an ethics committee was not necessary.

CRediT authorship contribution statement

Sewon Lee: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Andrew Povey:** Writing – review & editing, Validation, Supervision, Methodology. **Martin Seed:** Supervision, Methodology, Investigation. **Martie van Tongeren:** Writing – review & editing, Supervision, Project administration,

Methodology, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35763.

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