



*Research article*

## **VOCs in cleaning products used in age care and social facilities: Identification of hazardous substances**

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**Abstract:** Prior to the nationwide survey on indoor air quality in 100 age care and social facilities across France, which is planned for 2019, a questionnaire was sent by email to the directors of all 18,432 institutions of these types to determine the potential emission sources of indoor pollutants. Among these, cleaning practices and cleaning products were targeted. The questionnaire included items regarding cleaning frequency and periods, cleaning techniques, storage areas, the use of air fresheners and the commercial names of the products used. A total of 2140 questionnaires were collected and processed, and 1109 cleaning products, along with their commercial names, were listed. From them, 341 different products were identified, for which 299 safety data sheets (SDSs) were available and analyzed. A total of 216 different chemical substances were identified in the SDSs. The boiling points were retrieved to classify the substances according to their volatility. Finally, information regarding their hazard classification was collected, and six categories of human health effects were considered. A total of 41 chemical substances were classified, among which 10 are carcinogenic, 6 are mutagenic, 1 has reproductive toxicity, 3 have specific target organ toxicity - repeat exposure, 19 are possible endocrine disruptors, 14 are skin sensitizers, and 2 are respiratory sensitizers. Of these 41 chemicals, 51% (n = 21) are volatile organic compounds (VOCs). Despite the limitations of using SDSs, which do not report the exact compositions of the products, this study shows that a large spectrum of volatile substances may be emitted from cleaning products used in age care and social facilities, which may have a potential impact on the indoor air quality.

**Keywords:** nursing homes; retirement homes; elderly care facilities; indoor air quality; volatile organic compound; safety data sheet; health effect; carcinogen; endocrine disruptor

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**Abbreviations:** VOC: volatile organic compound; SVOC: semi-volatile organic compound; VVOC: very volatile organic compound; CLP: Classification, Labelling and Packaging; IARC: International Agency for Research on Cancer; DHI/BKH: Consulting Engineers; US EPA: United States Environmental Protection Agency; NA: Not Available; SIN: Substitute It Now! TEDX: The Endocrine Disruption Exchange

## 1. Introduction

The French Indoor Air Quality Observatory has planned a national field campaign in 100 age care and social facilities across France for 2019 to characterize the indoor air quality (IAQ). To date, these facilities have been rarely studied, though vulnerable populations spend most of their time there. To identify which volatile organic compounds (VOCs) to look for in the indoor air, a survey was performed targeting all 18,432 French age care and social facilities to describe the buildings, activities, and cleaning tasks and cleaning products used, with the objective of identifying the VOC emission sources. A focus was put on cleaning products since they may be widely used in these buildings and emit VOCs, which have an impact on the IAQ [1].

Only six studies worldwide were identified to have investigated VOCs in the indoor air of age care facilities, while none were found for social facilities. In South Korea, Hwang et al. investigated the total volatile organic compounds (TVOCs) and formaldehyde in 62 facilities [2], and Lee et al. characterized the indoor and outdoor VOC and formaldehyde concentrations in 30 elderly care centers [3]. In Portugal, Almeida-Silva et al. measured the TVOCs in 10 elderly care centers [4]. Also in Portugal, under the framework of the Geriatric Study in Portugal on Health Effects of Air Quality in Elderly Care Centers (GERIA) project, the TVOC and formaldehyde concentrations were measured in 22 facilities [5]. Walgraeve et al. measured 25 VOCs in 6 elderly homes in Belgium [6]. Finally, within the European Geriatric study on health effects of air quality in nursing homes in Europe (GERIE) project, formaldehyde was measured in eight facilities in 7 countries [7]. In most of these studies, though, the individual VOCs were not measured.

An increasing number of studies have shown potential health effects due to chemical substances used in cleaning activities. Svanes et al. investigated the long-term effects of cleaning product exposure on lung function decline and airway obstruction in a cohort including occupational cleaners [8]. This study highlighted that cleaning sprays and other cleaning agents accelerate lung function decline in women cleaning at home or working as occupational cleaners. A study in California on 183 cleaning workers in an academic medical center investigated the association between acute symptoms and chemical exposure [9]. The study showed that symptoms of irritation due to chemical products are frequent for cleaning workers. Su et al. looked for the determinants of VOC exposures in healthcare settings and showed that exposure to various VOCs was associated with mixed cleaning tasks and the chemical ingredients of the products used [10]. Moreover, a recent review of epidemiological studies highlighted that the use of cleaning and disinfecting products is harmful to respiratory health and increases the risk of asthma [11]. Spray products were specifically targeted [12,13].

Meanwhile, the specific VOCs emitted by cleaning products remain poorly described. Gerster et al. identified the most used cleaning products by a survey of Swiss professional cleaning companies and, through a review of safety data sheets (SDSs), listed the hazardous substances, including VOCs, present in these products [14]. In five hospitals in the United States, Saito et al. assessed the exposure to cleaning and disinfecting chemicals among many occupations [15]. On the basis of the SDSs of the cleaning and disinfecting products, they concluded that different occupations in hospitals involved irritants or sensitizers. On the basis of the SDSs, Wei et al. identified the hazardous substances, including VOCs, present in cleaning products used in 310 nurseries and schools in France [16].

In this context, the aims of this study were to (1) describe the cleaning frequencies, techniques and products employed in French age care and social facilities, including the use of spray products and air fresheners; (2) identify the VOCs that may be emitted from these products in indoor air; and (3) compile a list of VOCs of concern based on their hazard classifications.

## **2. Materials and methods**

### *2.1. Questionnaire*

An online questionnaire was developed that included questions describing the frequency of floor and surface cleaning (several times a day, once a day, several times a week, or once a week or less), cleaning practices (i.e., without any product, with water, with liquid cleaning product and a mop, with pre-impregnated wet wipes, or with sprays), and storage areas (i.e., in shared living rooms or bedrooms or in a ventilated or unventilated adjacent or non-adjacent specific room). The use of air fresheners was also investigated. For each facility, a maximum of two buildings could be described, and for each building, the three most used cleaning products, along with their respective brand and commercial names, could be listed. The quantity of product used was also investigated. However, the low number of data points and disparities in the answers for this question required us to ignore this item.

### *2.2. Selection of facilities and data collection*

The survey was performed in facilities with a susceptible population, namely, dependent elderly people and disabled people. The target facilities were nursing homes and long-term care units for the elderly and specific facilities for disabled children or adults. The contact details (i.e., email, postal address, phone number) of the target facilities were identified from the National File of Sanitary and Social Institutions (FINESS) [17] managed by the French Ministry of Health, which included 18,432 facilities. The link to the online questionnaire was sent to all facilities by email on June 6, 2017. Three reminders were sent by email in June and July to non-responders. The web interface was closed on July 31, 2017.

### *2.3. Data analysis*

The first step was to clean up the database to group duplicate data and remove unusable data (i.e., dashes, question marks, only the brand or an incomplete name). Then, the SDSs of the reported cleaning products were collected from the internet, mostly from supplier websites. Some SDSs were obtained by emailing the supplier via an online contact form. When the SDS could not be found for a specific product, the product was excluded from further analysis.

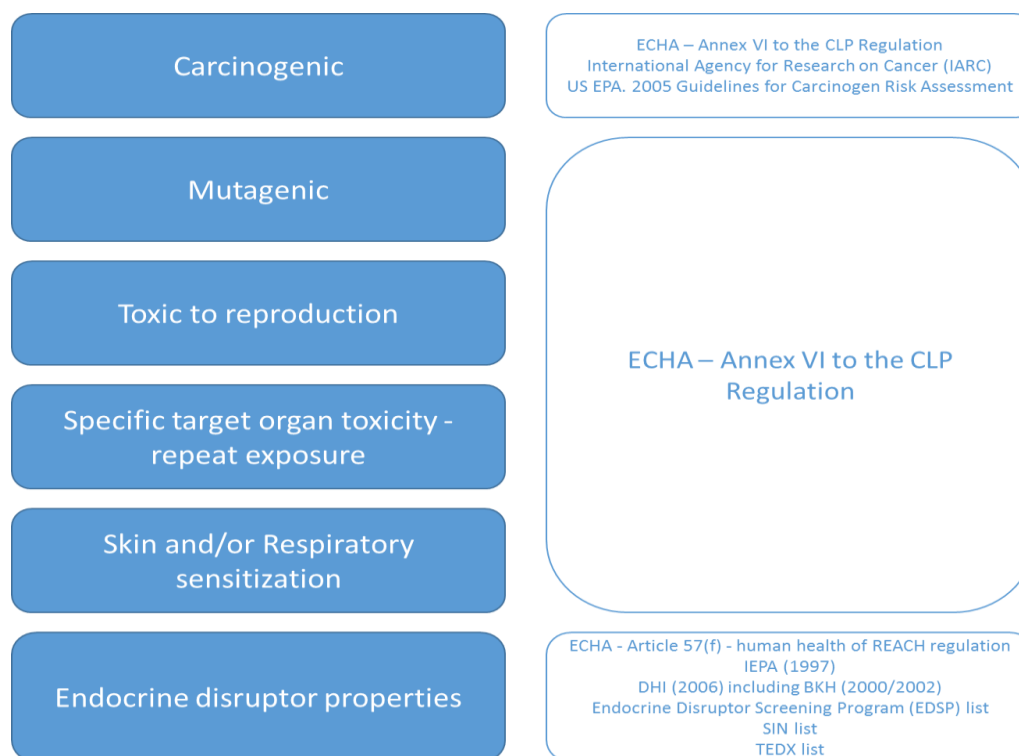
SDSs provide information about the health risks associated with the exposure to or use of hazardous products. Section 3 gives the names of the chemical substances contained in each product, along with their Chemical Abstracts Service (CAS) numbers, if available. Moreover, some substances, such as fragrance allergens, that can be found under section 15 “Regulatory Information” were collected. For each cleaning product, the names and CAS numbers of the chemical substances mentioned in the SDS were retrieved.

Six categories of health effects were investigated for each substance identified from the SDSs: carcinogenic, mutagenic, toxic to reproduction, specific target organ toxicity - repeat exposure (STOT-RE), endocrine-disrupting properties, and skin or respiratory sensitizing. When possible, different sources were checked to determine the health effects, and the most severe ranking was used.

Substances that are potentially carcinogenic, mutagenic, toxic to reproduction, STOT-RE, or skin or respiratory sensitizing were identified according to the European Chemicals Agency (ECHA) [18]. For those with carcinogenic potential, classifications by the US Environmental Protection Agency (US EPA) [19] and the International Agency for Research on Cancer (IARC) [20] were also considered. Similarly, multiple sources were consulted to evaluate the possible endocrine-disrupting properties of each substance. Using the candidate list of substances of very high concern for authorization available on the ECHA website and published in accordance with the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) Regulation, those classified to have endocrine-disrupting properties [21] were identified. Other projects, which were carried out for the European Commission DG ENV, the Illinois EPA (1997), and the US EPA were also taken into account [22–27]. Other non-regulatory lists were collected. First, the SIN list is a comprehensive database maintained by the non-governmental organization Chemsec, which identifies chemicals likely to be restricted or banned in the EU [28]. In this case, the list was restricted to substances included because of their potential endocrine-disrupting properties. Second, the Endocrine Disruption Exchange (TEDX) list of potential endocrine disruptors identifies chemicals that have demonstrated evidence of endocrine-disrupting properties in at least one study [29].

The health effects considered along with the different sources investigated are summarized in Figure 1.

Finally, the boiling points of the chemical substances were retrieved to classify them according to their volatility and to identify the VOCs. Four sources were considered as follows in order of priority: (1) the ECHA website [30], (2) the Hazardous Substances Data Bank (HSDB) [31], (3) the Chemspider website [32] and (4) the CompTox Dashboard by the US EPA [33]. Based on the definition provided by ISO 16000-6 [34], organic substances with a boiling point between 0 °C and 50–100 °C, are considered to be very volatile organic compounds (VVOCs). When the boiling point is between 50–100 °C and 240–260 °C, the organic substance belongs to the family of VOCs. Finally, between 240–260 °C and 380–400 °C, the substance belongs to the family of semi-volatile organic compounds (SVOCs). For practical reasons, the limits between VVOCs and VOCs, between VOCs and SVOCs, and between SVOCs and non-volatile compounds were set at 50 °C, 260 °C and 400 °C, respectively.



**Figure 1.** Studied health effects and associated information sources.

### 3. Results and discussion

Among the 18,432 questionnaires sent to the age care and social facilities, 4041 web questionnaires and 137 paper questionnaires were collected. After discarding incomplete or duplicate questionnaires, 2140 complete questionnaires were obtained, representing a response rate of 12% with good representativeness against the national base: among the final selected facilities, 58% are nursing homes, 25% are specific facilities for disabled adults, 14% are specific facilities for disabled young people, and 3% are long-term care units for elderly people. Because each questionnaire contained space for information regarding one or two buildings, the final Excel database contained 2739 recordings.

#### 3.1. Cleaning product storage

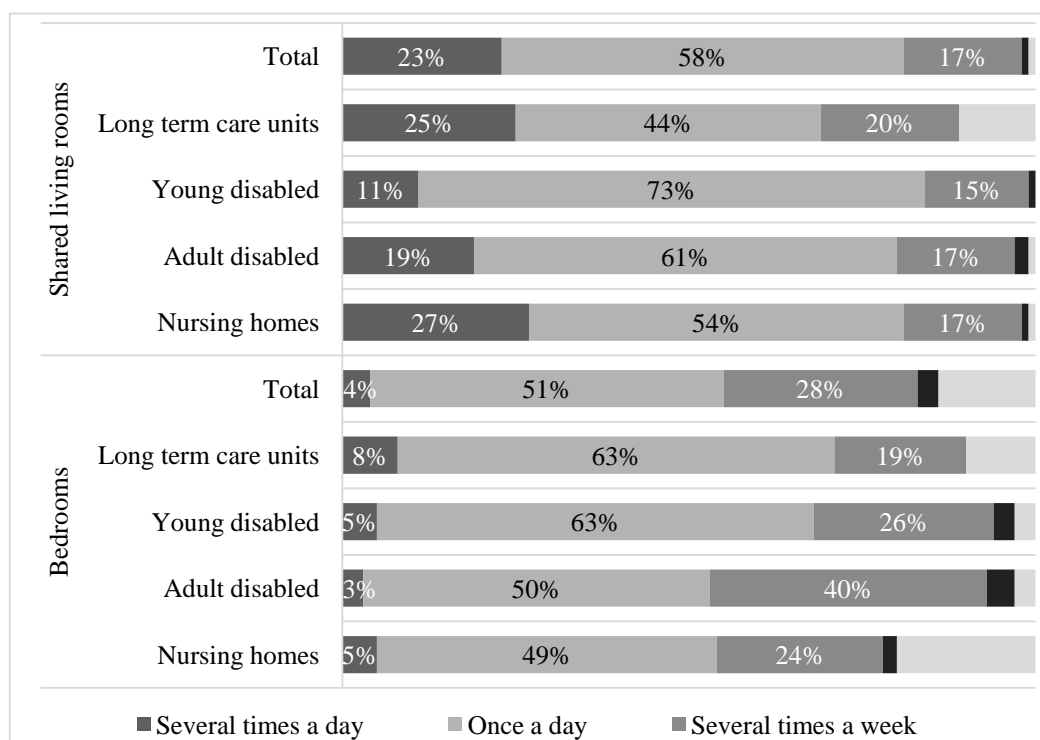
In more than half of the facilities, cleaning products are stored in a specific room that is non-adjacent to shared living rooms (53%) or to bedrooms (52%). The storage room is adjacent to the shared living rooms in 40% of facilities and adjacent to the bedrooms in about one-third of the facilities (29%). In both situations, the room is ventilated in most cases (72% and 79% for shared living rooms and bedrooms, respectively). In only 4% of the facilities, the cleaning products are stored in shared living rooms or in bedrooms. Information was not provided for 3% and 15% of the shared living rooms and bedrooms, respectively.

### 3.2. Cleaning frequencies and cleaning practices

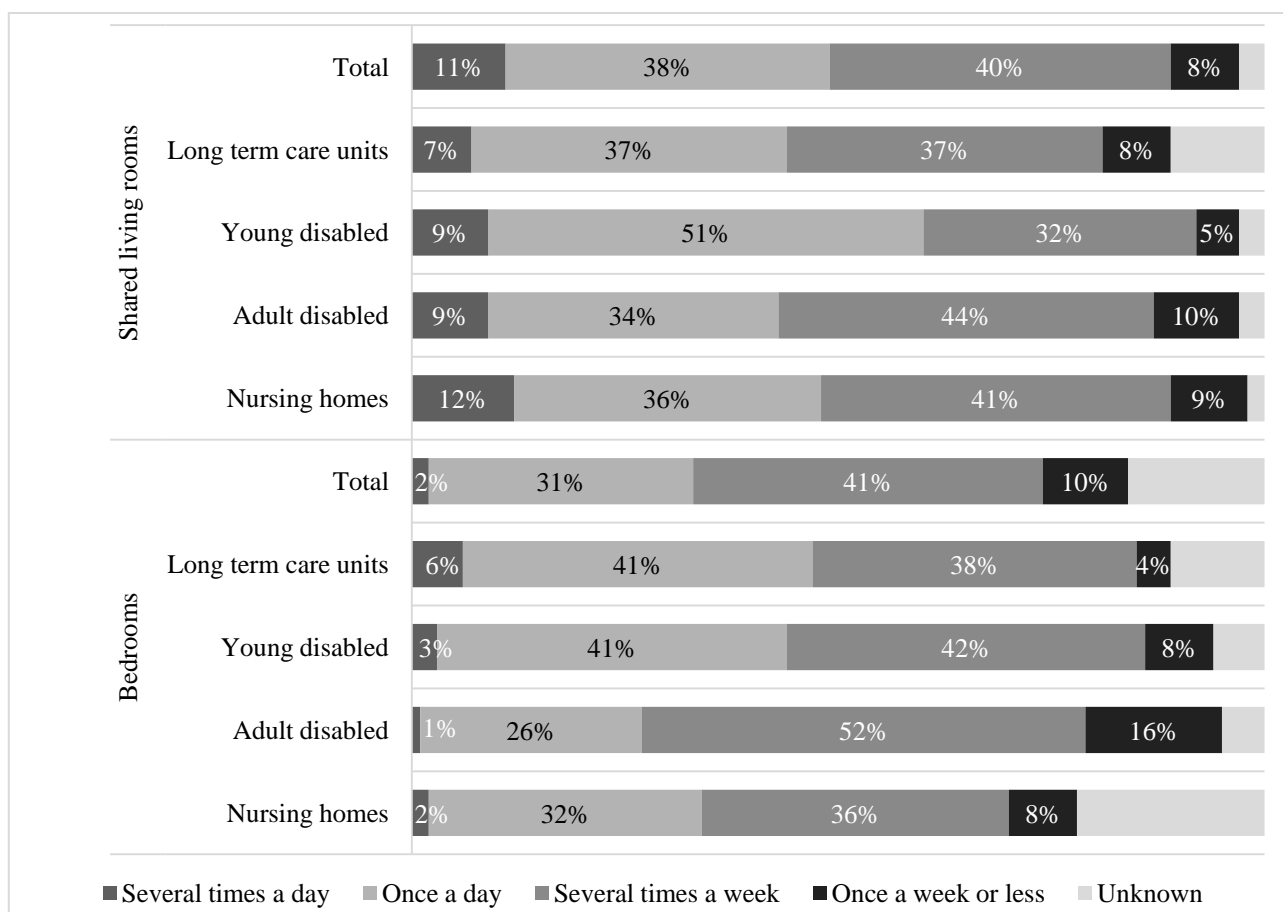
The cleaning frequencies vary according to the type of room. The floors of shared living rooms are cleaned once per day (58%) or several times per day (23%). In bedrooms, the floors are less frequently cleaned: once per day in 51% or several times per day in 4%. The surface cleaning frequencies are lower than the floor cleaning frequencies. Surface cleaning is mostly performed several times a week but not daily in both shared living rooms (40%) and bedrooms (41%). In approximately one-third of facilities, surfaces are cleaned several times per day (11%) or once per day (38%) in shared living rooms and several times per day (2%) or once per day (31%) in bedrooms. The cleaning frequencies are detailed according to the type of facility for floors in Figure 2 and for surfaces in Figure 3.

Two main techniques of floor cleaning are highlighted: liquid cleaning products are used in 61% of shared living rooms and 50% of bedrooms, and wet wipes in 19% of shared living rooms and 23% of bedrooms. For surfaces, sprays are the most used cleaning technique in shared living rooms (36%) and in bedrooms (31%). In shared living rooms, liquid products are used in 29% of the facilities, and wet wipes in 22%. In bedrooms, the percentages of use are 22% for both liquid cleaning products and for wet wipes.

The resuspension of settled dust may have a detrimental impact on IAQ [1,35]. Cleaning with a wet mop and wipes avoids the resuspension of settled dust from floors or surfaces. However, VOCs can be emitted from the cleaning products on the wipes or used with the mop.



**Figure 2.** Floor cleaning frequencies in French age care and social facilities (n = 2140).



**Figure 3.** Surface cleaning frequencies in French age care and social facilities (n = 2140).

### 3.3. Use of air fresheners

Air fresheners are commonly used (66%) and can be a major source of indoor air pollution. Air fresheners are more frequently used in nursing or elderly homes (75%), long-term care units (71%) and specific facilities for disabled adults (57%) than in specific facilities for young disabled people (41%). This frequent use of air fresheners may be related to the frequent bad smells in these types of facilities, as they are employed to mask these odors. Air fresheners emit many chemical substances and contribute to the production of secondary pollutants [36].

### 3.4. Chemical substances in the reported cleaning products

Overall, 2739 buildings were described, and for each, up to three cleaning products could be reported. In the end, 2348 answers were registered corresponding to 1403 different wordings. After sorting these wordings, 1109 answers containing the brand and name of the product were usable, corresponding to 341 distinct cleaning products. Among these 341 products, 285 SDSs were available on the internet, 14 were received from the supplier by email, and 38 could not be found or were not received. Four cleaning products without SDSs were retained for analysis because of their simple formulations, i.e., methylated spirit, rubbing alcohol, white vinegar and bleach.

**Table 1.** Top 10% most frequent chemical substances in the reported cleaning products.

CAS number	Substance name	Class	Use	Number of cleaning products	Occurrence across the 303 cleaning products (%)
67-63-0	Isopropanol	VOC	Solvent	80	26.4%
7173-51-5	Didecyldimethylammonium chloride	Salt	Disinfectant	72	23.8%
64-17-5	Ethanol	VOC	Solvent	58	19.1%
5989-27-5	D-Limonene	VOC	Scenting agent	56	18.5%
68424-85-1	C12-16-Alkyldimethylbenzylammonium chlorides	Salt	Detergent and surfactant	41	13.5%
78-70-6	Linalool	VOC	Scenting agent	37	12.2%
69011-36-5	Poly(oxy-1,2-ethanediyl), alpha-tridecyl-gamma-hydroxy-, branched	SVOC	Solvent	34	11.2%
64-02-8	Ethylenediaminetetraacetic acid tetrasodium salt	Salt	Chelating agent	30	9.9%
2372-82-9	1,3-Propanediamine, N-(3-aminopropyl)-N-dodecyl-	SVOC	Disinfectant	29	9.6%
68439-46-3	Alcohols, C9-11, ethoxylated	SVOC	Detergent and surfactant	27	8.9%
68891-38-3	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-hydroxy-, C12-14-alkyl ethers, sodium salts	Salt	Detergent and surfactant	26	8.6%
101-86-0	Hexyl cinnamic aldehyde	SVOC	Scenting agent	25	8.3%
1310-73-2	Sodium hydroxide	Salt	Detergent and surfactant	23	7.6%
106-22-9	Citronellol	VOC	Scenting agent	21	6.9%
5949-29-1	1,2,3-Propanetricarboxylic acid, 2-hydroxy-, hydrate (1:1)	SVOC	Disinfectant	20	6.6%
80-54-6	Lilial	SVOC	Scenting agent	18	5.9%
7664-38-2	Phosphoric acid	Inorganic	Detergent and surfactant	18	5.9%
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Non-volatile	Detergent and surfactant	18	5.9%
79-33-4	L-Lactic acid	VOC	Detergent and surfactant	17	5.6%
5392-40-5	3,7-Dimethyl-2,6-octadienal (Citral)	VOC	Scenting agent	17	5.6%
2634-33-5	1,2-Benzisothiazolin-3-one	SVOC	Disinfectant	16	5.3%
308062-28-4	Amines, C12-14 (even numbered)-alkyldimethyl, N-oxides	Non-volatile	Surfactant	16	5.3%



**Table 2.** Hazard classifications of the 41 chemical substances in cleaning products used in French age care and social facilities.

Substance name	CAS number	Class	Occurrence (%) <sup>(1)</sup>	Carcinogenicity	Mutagenicity	Reproductive toxicity	Endocrine disruption	STOT-R E	Sensitization	
									Skin	Respiratory
Didecyldimethylammonium chloride	7173-51-5	Salt	23.8	NA	NA	NA	TEDX	NA	NA	NA
D-Limonene	5989-27-5	VOC	18.5	NA	NA	NA	NA	NA	CLP 1	NA
Ethanol	64-17-5	VOC	19.1	*	NA	NA	TEDX	NA	NA	NA
Linalool	78-70-6	VOC	12.2	NA	NA	NA	NA	NA	CLP 1B	NA
Lilial	80-54-6	SVOC	5.9	NA	NA	NA	TEDX	NA	NA	NA
2-Methyl-3(2H)-isothiazolinone	2682-20-4	VOC	4,6	NA	NA	NA	TEDX	NA	NA	NA
Benzyl salicylate	118-58-1	SVOC	4.3	NA	NA	NA	TEDX	NA	NA	NA
1,6-Hexanediamine, polymer with N,N"-1,6-hexanediybis [N'-cyanoguanidine], hydrochloride	27083-27-8	Non-volatile	2.0	CLP 2	NA	NA	NA	CLP 1	CLP 1B	NA
1,2-Benzisothiazolin-3-one	2634-33-5	SVOC	5.3	NA	NA	NA	NA	NA	CLP 1	NA
3,7-Dimethyl-2,6-octadienal	5392-40-5	VOC	5.6	NA	NA	NA	NA	NA	CLP 1	NA
Ethanolamine	141-43-5	VOC	4.0	NA	NA	NA	TEDX	NA	NA	NA
2-(2-Butoxyethoxy)ethanol	112-34-5	VOC	3.0	NA	NA	NA	TEDX	NA	NA	NA
2-Phenylphenol	90-43-7	SVOC	0.3	NA	NA	NA	DHI/BKH 2	US EPA 1	TEDX	NA
Bio-Perge	55965-84-9	VOC	2.6	NA	NA	NA	NA	NA	CLP 1	NA

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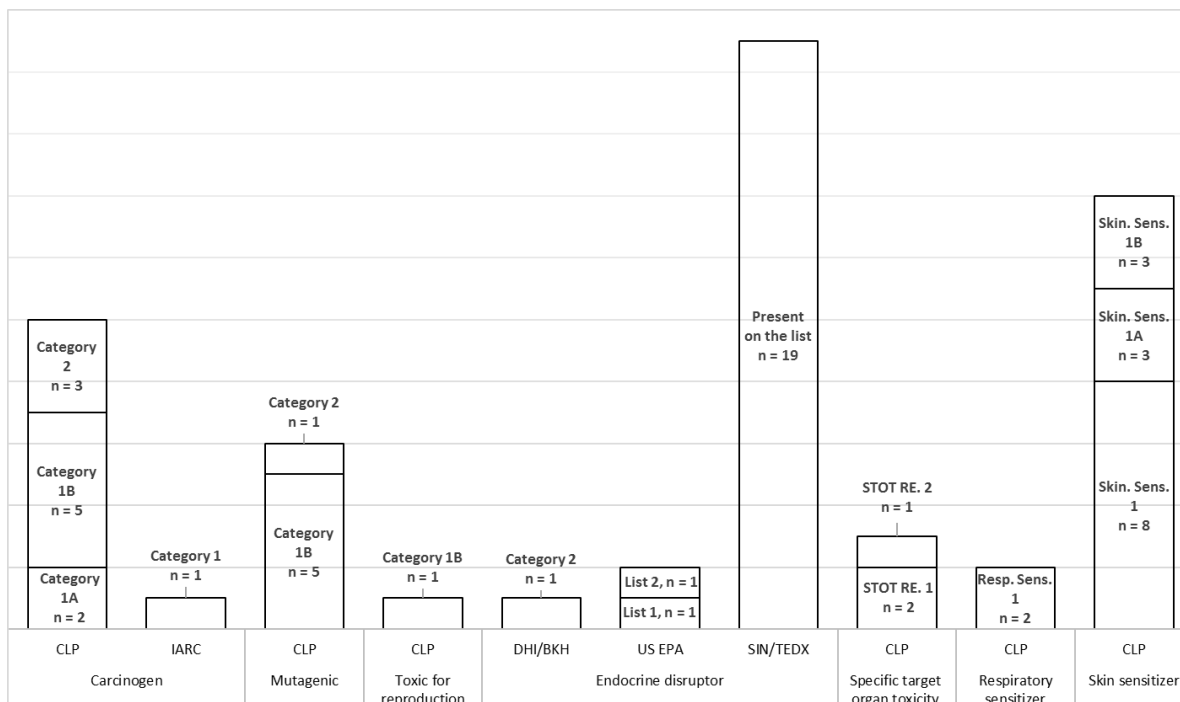
Substance name	CAS number	Class	Occurrence (%) <sup>(1)</sup>	Carcinogenicity	Mutagenicity	Reproductive toxicity	Endocrine disruption	STOT-RE	Sensitization	
									Skin	Respiratory
Bronopol	52-51-7	SVOC	2.3	NA	NA	NA	TEDX	NA	NA	NA
Glutaraldehyde	111-30-8	VOC	1.0	NA	NA	NA	TEDX	NA	CLP 1A	CLP 1
Limonene	138-86-3	VOC	1.0	NA	NA	NA	NA	NA	CLP 1	NA
1-Methoxy-2-propanol	107-98-2	VOC	1.3	NA	NA	NA	TEDX	NA	NA	NA
2-Butoxyethanol	111-76-2	VOC	1.3	NA	NA	NA	TEDX	NA	NA	NA
Octhilinone	26530-20-1	VOC	1.3	NA	NA	NA	NA	NA	CLP 1	NA
Methyl ethyl ketone	78-93-3	VOC	0.7	NA	NA	NA	TEDX	NA	NA	NA
Ethylene glycol	107-21-1	VOC	0.7	NA	NA	NA	US EPA 2	TEDX	NA	NA
Methanol	67-56-1	VOC	0.7	NA	NA	NA	TEDX	NA	NA	NA
(Z)-9-Octadecenylamine	112-90-3	SVOC	0.7	NA	NA	NA	NA	CLP 2	NA	NA
Butane	106-97-8	VVOC	0.7	CLP 1A	CLP 1B	NA	NA	NA	NA	NA
Poly (hexamethylene biguanide) hydrochloride	32289-58-0	SVOC	0.3	CLP 2	NA	NA	NA	CLP 1	CLP 1B	NA
Isobutane	75-28-5	VVOC	0.7	CLP 1A	CLP 1B	NA	NA	NA	NA	NA
Glycine, N,N-bis(carboxymethyl)-, trisodium salt	5064-31-3	SVOC	0.3	CLP 2	NA	NA	NA	NA	NA	NA
Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-	1222-05-5	SVOC	0.3	NA	NA	NA	SIN	TEDX	NA	NA
Distillates, petroleum, hydrotreated light paraffinic	64742-55-8	VOC	0.3	CLP 1B	NA	NA	NA	NA	NA	NA

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Substance name	CAS number	Class	Occurrence (%) <sup>(1)</sup>	Carcinogenicity		Mutagenicity	Reproductive toxicity	Endocrine disruption	STOT-RE	Sensitization	
										Skin	Respiratory
dl-Carvone	99-49-0	VOC	0.3	NA		NA	NA	NA	NA	CLP 1	NA
Formaldehyde	50-00-0	VVOC	0.3	CLP 1B	IARC 1	CLP 2	NA	TEDX	NA	CLP 1	NA
Naphtha, petroleum, hydrotreated light	64742-49-0	VOC	0.3	CLP 1B		CLP 1B	NA	NA	NA	NA	NA
Naphtha, (petroleum) hydrodesulfurized light, dearomatized	92045-53-9	VOC	0.3	CLP 1B		CLP 1B	NA	NA	NA	NA	NA
Heptane	142-82-5	VOC	0.3	NA		NA	NA	TEDX	NA	NA	NA
4-(4-Hydroxy-4-methylpentyl) cyclohex-3-ene-1-carbaldehyde	31906-04-4	SVOC	0.3	NA		NA	NA	NA	NA	CLP 1A	NA
3-(4-Hydroxy-4-methylpentyl) cyclohex-3-ene-1-carbaldehyde	51414-25-6	SVOC	0.3	NA		NA	NA	NA	NA	CLP 1A	NA
Naphtha, petroleum, hydrotreated heavy	64742-48-9	VVOC	0.3	CLP 1B		CLP 1B	NA	NA	NA	NA	NA
Octoxynol-9	9036-19-5	SVOC	0.3	NA		NA	NA	SIN   TEDX	NA	NA	NA
Sodium perborate tetrahydrate	10486-00-7	Inorganic salt	0.3	NA		NA	CLP 1B	NA	NA	NA	NA
Subtilisin	9014-01-1	Non-volatile	0.3	NA		NA	NA	NA	NA	NA	CLP 1

(1): occurrence across the 303 different cleaning products.

\*Specific classification: IARC Category 1 in alcoholic beverages only



**Carcinogen:** Category 1A – Substances known to have carcinogenic potential for humans; Category 1B – Substances presumed to have carcinogenic potential for humans; Category 2 – Suspected human carcinogens.

**Mutagenic:** Category 1B – Substances to be regarded as if they induce heritable mutations in the germ cells of humans; Category 2 – Substances that cause concern owing to the possibility that they may induce heritable mutations in the germ cells of humans.

**Toxic for reproduction:** Category 1B – Presumed human reproductive toxicant.

**Endocrine disruptor:** DHI/BKH category 2 – Potential for endocrine disruption. In vitro data indicating potential for endocrine disruption in intact organisms. Also includes effects in vivo that may or may not be ED-mediated. May include structural analyses and metabolic considerations. US EPA List 1 or List 2 – Presence on these lists means that the substance is suspected to demonstrate endocrine-disrupting properties.

**Specific target organ toxicity:** STOT-RE. 1 – Reliable evidence on the substance or mixture (including bridging) of an adverse effect on specific organs/systems or systemic toxicity in humans or animals; STOT-RE. 2 – Evidence on the substance or mixture (including bridging) of an adverse effect on specific organs/systems or systemic toxicity from animal or human studies.

**Respiratory sensitizer:** Resp. Sens. 1 – If there is human evidence that the individual substance induces specific respiratory hypersensitivity and/or positive results from an appropriate animal test and if any individual respiratory sensitizer in the mixture has a concentration of:  $\geq 1.0\%$  Solid/Liquid and  $\geq 0.2\%$  Gas.

**Skin sensitizer:** Skin. Sens. 1/1A/1B – If there is evidence in humans that the individual substance can induce sensitization by skin contact in a substantial number of persons or where there are positive results from an appropriate animal test and if any individual skin sensitizer in the mixture has a concentration of Subcategory 1B  $\geq 1.0\%$  Solid/Liquid/Gas or Subcategory 1A  $\geq 0.1\%$  Solid/Liquid/Gas.

**Figure 4.** Overview of the hazard classifications of the chemical substances present in the cleaning products used in age care and social facilities in France.

The analysis of the 299 SDSs and the four additional cleaning products (n = 303 products) allowed us to list 228 chemical substances. Among them, twelve refer to mixtures and could not be associated with a CAS number. Therefore, these twelve were not included in the final list. In the end, 216 chemical substances were considered. Among them, the 22 chemicals (10%) that were the most frequently present in the 303 products are listed in Table 1.

In comparison to previous studies, 14 substances (63%) of our top 10% most frequent chemical substances in the used cleaning products are also described in Gerster et al. (2014) [14], and 17 substances (77%) of our top 10% most frequent chemical substances in the used cleaning products were also reported by Wei et al. (2015) [16].

### 3.5. Hazard classification of the chemical substances in the reported cleaning products

Among the 216 substances, 41 are classified for their health effects. Ten substances are registered as carcinogenic by at least one of the sources: 9 by the ECHA and 1 by both the IARC and the ECHA. Six substances are classified as mutagenic by the ECHA. One substance is toxic to reproduction. Nineteen substances are considered to have endocrine-disrupting properties by at least one of the sources: the 19 substances are present on the TEDX list, 2 on the SIN list, 2 on the US EPA lists, and 1 in the second category of the DHI/BKH classification. Three substances are registered as STOT-RE by the ECHA: 2 in the first category and 1 in the second category. Finally, the ECHA classifies 2 substances as respiratory sensitizers and 14 as skin sensitizers. The detailed results are presented in Table 2 and Figure 4.

### 3.6. Limitations of the study

Among all the questionnaires registered (N = 2348), 1239 responses were not usable because of the lack of information provided by the interviewees. Most of the time, only the brand names were given, and some product names were often wrong or incomplete. The part of the questionnaire regarding the identification of the cleaning products used should have been more detailed to ensure a complete answer. Moreover, 38 SDSs were missing or were not received from the supplier after request.

The reported substances were determined from the SDSs, but the chemical compositions of the cleaning products are not fully listed in SDSs. The manufacturers must declare the compositions of hazardous substances only when their concentration is higher than 0.1% in the formulated products. Several substances with low concentrations in cleaning products were thus outside of the scope of this study. Moreover, the SDSs are declarative, and the reported information must be taken with caution (e.g., the wrong CAS number for eucalyptol was found in an SDS).

Despite these limitations, this work allowed us to list numerous substances in cleaning products with health effects and improved the knowledge of VOCs likely to be present in the indoor air of age care and social facilities.

## 4. Conclusion

This study showed that (1) the cleaning frequency is rather high in health care and social facilities, with floors being cleaned once or several times per day in most cases and (2) liquid cleaning products, wet wipes, and sprays are commonly used in all types of facilities and all types of rooms. The use of air fresheners is also very common. Among the cleaning products, 341 different

commercial references were identified, and information about the compositions of 303 could be retrieved. Among the 216 different chemical substances listed, 41 were classified for their potential health effects: 10 as carcinogenic, 6 as mutagenic, 1 as toxic for reproduction, 19 having possible endocrine-disrupting properties, 3 as toxic for a specific target organ under repeated exposure, 2 as respiratory sensitizers, and 14 as skin sensitizers. Of these 41 chemicals, 10% (n = 4) are VVOCs, 51% (n = 21) are VOCs, 29% (n = 12) are SVOCs, 5% (n = 2) are not volatile, 5% (n = 2) are salts. The VOCs emitted from the cleaning products used in these facilities will be considered for measurement during the upcoming nationwide monitoring campaign.

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## Conflicts of interest

The authors declare that they have no conflict of interest.

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