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Domestic chlorine gas exposures from household product mixing in France: characteristics, severity, and temporal trends, 2010–2025

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Research Article

Keywords: Chlorine, Accidental exposure, Poison control centers, Household cleaning products, Vinegar, Respiratory disease, Prevention

Posted Date: August 31st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10721319/v1

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Additional Declarations: Competing interest reported. JB and CG are employees of the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), which funded this work (see

Funding). Non-ANSES members of the working group contributed as independent experts, in accordance with standard rules governing scientific expertise. The authors declare no other competing interests.

Version of Record: A version of this preprint was published at Environmental Health on October 8th, 2026. See the published version at https://doi.org/10.1186/s12940-026-01345-0.

Abstract

Background

Domestic chlorine gas exposures, resulting from the mixing of hypochlorite-based products with acidic products, are a recognised public health issue. However, national evidence on factors associated with severity and long-term trends remains limited. We aimed to identify factors associated with severity of domestic chlorine gas exposures in France in 2023 and to analyse temporal trends over 16 years (2010–2025).

Methods

We conducted a national retrospective study combining an individual-level cross-sectional analysis of 2023 cases with an aggregate 16-year temporal trend analysis, using data from the French national poison control centre (PCC) database. Binary logistic regression identified factors independently associated with moderate-to-severe poisoning (Poisoning Severity Score ≥ 2) among symptomatic 2023 cases. Annual data for 2010–2025 were expressed as a standardised index (base 100, reference year 2010) and analysed using segmented regression to detect changes in trend.

Results

In 2023, 1,829 cases were recorded, of which 280 (17.1% of symptomatic cases) were moderate-to-severe, including 11 severe and 2 fatal poisonings. Obstructive airway disease (aOR 3.65, 95% CI 2.64–5.01), older age (aOR 1.25 per 10-year increment, 95% CI 1.15–1.35), and active smoking among individuals with no reported respiratory history (aOR 3.22, 95% CI 2.25–4.58) were associated with severity. The standardised index increased over the study period, with a breakpoint around 2018 after which the annual increase more than doubled (+ 12.25 vs + 4.97 points/year), coinciding with a marked rise in PCC-recorded cases involving vinegar rather than bleach.

Conclusions

Although uncommon, severe and fatal domestic chlorine gas poisonings from household product mixing occurred in 2023, highlighting the continuing public health relevance of these exposures. Obstructive airway disease, older age, and active smoking were independently associated with severity. PCC-recorded poisoning cases also increased substantially over 16 years, coinciding with a marked rise in cases involving vinegar rather than bleach. This pattern is consistent with growing use of vinegar alongside bleach as a perceived natural cleaning product. These findings support more visible, targeted prevention messaging and further investigation of the potential long-term respiratory consequences of recurrent, clinically minor exposures.

Background

Chlorine gas is a potent respiratory irritant that causes dose-dependent injury to the upper and lower airways, ranging from mucosal irritation to acute lung injury and reactive airways dysfunction syndrome (RADS) [1, 2]. Although chlorine has historically been associated with industrial accidents and chemical warfare, many contemporary exposures occur in domestic settings, resulting from the mixing of household cleaning products, most commonly sodium hypochlorite (bleach) with an acidic product [3]. The reaction generates chlorine gas (Cl_2), a highly reactive oxidant with well-established respiratory toxicity [1].

Poison control centres (PCC) provide a unique surveillance system for monitoring domestic chemical exposures at the population level. While most domestic chlorine gas exposures are self-limiting, a clinically significant minority result in moderate-to-severe poisoning requiring hospital care, and fatalities have been documented [4]. Pre-existing respiratory conditions and older age have been qualitatively associated with worse outcomes in small domestic case series [5, 6], and cigarette smoking has been suggested as a vulnerability factor in general reviews of chlorine toxicity [1, 7] and quantified in occupational cohorts with repeated exposure [8]; however, robust quantified estimates of these associations specific to acute domestic exposure remain lacking.

Beyond severity, the frequency of these exposures also appears to be changing. In the United States, the National Poison Data System documented over 85,000 chlorine and chloramine gas exposures between 2015 and 2022, with a 61% increase over the period [9]. A comparable increase has been reported in Canada [10], with the COVID-19 pandemic acting as a marked accelerant in several countries from March 2020 onwards [9, 10]. Despite this public health relevance, comprehensive national data on domestic chlorine gas exposures in Europe remain scarce: most published series originate from North America, are limited to short observation windows, or focus on the acute pandemic period specifically [9, 10]. Few European national studies have described such long-term trends, spanning more than a decade and capturing both the pre- and post-pandemic periods.

Using data from the French national poisoning database, covering all eight French poison control centres, we conducted a national study with two objectives: (i) to describe the characteristics and factors associated with severity of domestic chlorine gas exposures recorded in 2023, based on exhaustive individual case review; and (ii) to analyse temporal trends in domestic chlorine-related exposures over a 16-year period (2010–2025).

Methods

Study design and data source

We conducted a retrospective national study using data from the National Database of Poisoning Cases and Toxicological Information Requests (BNCIT), which aggregates anonymised records from all eight French PCC operating a 24/7 hotline for the public and healthcare professionals. Reporting a case to a

PCC is not mandatory, and the completeness of the information recorded therefore depends on what is volunteered during the call. For each case, information is recorded on patient characteristics, exposure circumstances, products involved, clinical severity, and recommended management. PCC seek to document subsequent clinical evolution through follow-up, when feasible, including telephone calls or text messages to the patient or healthcare professionals and requests for hospital discharge or medical reports. The BNCIT is administered by the French Ministry of Health and registered with the French Data Protection Authority (CNIL, Délibération n°2020 – 131 du 17 décembre 2020). As data processing within the BNCIT is carried out under a legal obligation for toxicovigilance purposes rather than on the basis of consent (see Declarations), individual informed consent was not required.

Study population and case selection

For the cross-sectional analysis, candidate cases of accidental domestic chlorine gas exposure recorded in 2023 were first identified from the BNCIT using queries via the decision-support service (SID) of the French PCC Information System (SICAP), then individually reviewed to confirm eligibility (defined as unintentional, non-suicidal exposures occurring at home and resulting from the mixing of a hypochlorite-based product with an acidic product) ensuring exhaustive ascertainment for the study year. No age restriction was applied at the eligibility stage: minors were eligible for inclusion whenever the above criteria were met.

For the temporal trend analysis, annual aggregated data were extracted from the BNCIT via SICAP-SID for the period 2010–2025, restricted to non-occupational, non-suicidal domestic exposures, using a standardised query selecting respiratory exposures compatible with chlorine inhalation occurring during domestic cleaning activities. Because exhaustive manual review of all historical cases was not feasible, this query was deliberately designed to maximise specificity rather than sensitivity, with the objective of tracking relative temporal changes using a stable surveillance indicator rather than estimating absolute incidence.

Variables

The unit of analysis differed by objective. Exposure incidents (single events potentially involving multiple co-exposed individuals) were used to describe circumstances and products involved. Individual cases were the unit of analysis for severity assessment. Clinical severity was graded using the Poisoning Severity Score (PSS) [11], a validated five-level scale ranging from 0 (no symptoms) to 4 (fatal). The primary outcome was moderate-to-severe poisoning, defined as PSS ≥ 2.

Hypochlorite products were categorised as: standard liquid bleach, hypochlorite-based spray, toilet bowl bleach gel, hypochlorite-based drain cleaner, and other or unspecified hypochlorite-based product. Acidic products were categorised as: vinegar, hydrochloric acid or drain cleaner, descaling/cleaning products, toilet cleaners, and other or unspecified acid.

Candidate predictors of severity were selected a priori on clinical grounds: age (continuous, per 10-year increment), sex, respiratory history, active smoking, type of hypochlorite product, and type of acidic product. Respiratory history was categorised into three groups based on information recorded in the case file: no reported respiratory history, obstructive airway disease, and other reported respiratory history. Obstructive airway disease included asthma, COPD, chronic bronchitis, and emphysema reported at the time of the PCC call. Other reported respiratory history included previous or childhood asthma, reported respiratory allergies without mention of an obstructive airway disease, and other respiratory or pulmonary conditions. In addition, cases for which no information on respiratory history was recorded in the case file were classified as respiratory history not recorded; this could reflect either a genuine absence of respiratory history or simply the absence of any enquiry or documentation on this point during the call.

Statistical analysis

Patient characteristics were described using median and interquartile range for continuous variables, and counts with percentages for categorical variables. The severity analysis was restricted to symptomatic cases (PSS ≥ 1), as asymptomatic individuals (PSS = 0) represent a behaviourally distinct population whose contact with PCC is driven by concern rather than clinical need. Binary logistic regression was used to identify factors associated with PSS ≥ 2 versus PSS 1. Both univariable and multivariable models were fitted; sex was included in all multivariable models as a forced covariate regardless of statistical significance. Given the relatively small size of some product categories, categories showing similar effect estimates in univariable analyses were combined into binary variables for multivariable modelling to improve model stability and precision. For respiratory history, cases classified as respiratory history not recorded were combined with cases with no reported respiratory history for the primary analysis; a sensitivity analysis excluded cases classified as respiratory history not recorded. Multivariable models used complete-case analysis for the remaining covariates. Active smoking was additionally assessed among cases with no reported respiratory history, including those classified as respiratory history not recorded. Results are expressed as adjusted odds ratios (aOR) with 95% confidence intervals (95% CI). The significance threshold was set at $p < 0.05$.

The annual standardised index of chlorine gas exposures (base 100, reference year 2010) was derived by dividing the annual number of chlorine gas exposure cases by the annual number of PCC cases meeting the same query criteria used to ascertain chlorine gas exposures, but without restriction to specific hypochlorite-based or acidic products, as an indicator of the volume of PCC cases captured by the underlying surveillance query, and rescaling to the 2010 value. Trends in this standardised index over 2010–2025 were modelled using linear regression with segmented (piecewise) regression to detect changes in the annual rate of increase, using the segmented package in R [12]. As a secondary, exploratory analysis, the annual rate of moderate-to-severe poisoning among symptomatic cases was modelled using quasi-Poisson regression, with the logarithm of the annual number of symptomatic cases as an offset, to account for overdispersion (dispersion parameter = 7.6), with the annual trend expressed as an incidence rate ratio (IRR); because severity coding was not manually verified across the

full 16-year period, unlike the exhaustive 2023 case review, this secondary result should be interpreted with caution. To further contextualise the temporal trends, we examined trends in PCC cases involving bleach and vinegar, as well as baking soda- and black soap-based products as proxies for newer “green” household cleaning products. Case counts were expressed as an index (base 100, reference year 2010); these queries were independent of, and broader than, the chlorine gas exposure query, and do not specifically indicate chlorine release. All analyses were performed using R (version 4.1.3). Generative AI tools were used to assist with translation of the manuscript into English, under the authors' supervision (see Declarations).

Results

In 2023, a total of 1,829 cases of accidental chlorine gas exposure were recorded across all eight French PCC, involving 1,767 distinct exposure incidents, of which 42 (2.4%) involved more than one exposed individual. These cases accounted for 0.9% of all calls for medical advice handled by French PCC in 2023 (1,829/207,305; approximately 1 in 113 cases). Two thirds of cases were female, and the median age was 34 years (IQR: 26–47). Respiratory history was reported in 16.7% of cases, including obstructive airway disease in 13.2% and other reported respiratory history in 3.5%. Active smoking was reported in 16.9% of cases. Standard liquid bleach was the predominant hypochlorite product (80.6% of incidents) and vinegar the most frequently implicated acidic product (55.1%). Exposures occurred predominantly in the bathroom or toilet, and the most common circumstance was general household cleaning. Of the 1,829 recorded cases, 193 (10.6%) were asymptomatic (PSS 0). Among the 1,636 symptomatic cases, 280 (17.1%) had moderate-to-severe poisoning (PSS ≥ 2), including 11 (0.6% of all cases) classified as severe (PSS 3) and 2 (0.1%) as fatal (PSS 4). Characteristics of exposed individuals and exposure incidents are presented in Table 1.

Table 1
Characteristics of accidental chlorine gas exposures from household product mixing, 2023.

Exposed individuals (n = 1,829)	**n (%) or median [IQR]**
Patient characteristics	
Age, years[a]	34 [26–47], range 0.2–89.8
Minors (< 18 years)	54 (3.0%)
Female sex[b]	1,221 (66.8%)
Pregnant women	47 (2.6%)
Active smoking	310 (16.9%)
Respiratory history	
No reported respiratory history	1,220 (66.7%)
Obstructive airway disease	242 (13.2%)
Other reported respiratory history	64 (3.5%)
Respiratory history not recorded	303 (16.6%)
Poisoning severity (PSS)	
PSS 0 - Asymptomatic	193 (10.6%)
PSS 1 - Minor	1,356 (74.1%)
PSS 2 - Moderate	267 (14.6%)
PSS 3 - Severe	11 (0.6%)
PSS 4 - Fatal	2 (0.1%)
Exposure incidents (n = 1,767)	
Hypochlorite-based product	
Standard liquid bleach	1,424 (80.6%)
Hypochlorite-based spray	146 (8.3%)
Toilet bowl bleach gel	74 (4.2%)
Hypochlorite-based drain cleaner	61 (3.5%)
Other or unspecified	62 (3.5%)

Exposed individuals (n = 1,829)	n (%) or median [IQR]
Patient characteristics	
Acidic product	
Vinegar	973 (55.1%)
Hydrochloric acid/drain cleaner	354 (20.0%)
Descaling/cleaning products	196 (11.1%)
Toilet cleaners	180 (10.2%)
Other or unspecified	64 (3.6%)
Exposure location	
Bathroom	507 (28.7%)
Toilet	275 (15.6%)
Kitchen	51 (2.9%)
Outdoor	47 (2.7%)
Other or multiple	35 (2.0%)
Unknown	852 (48.2%)
Circumstance	
General household cleaning	986 (55.8%)
Drain unblocking	70 (4.0%)
Animal care	24 (1.4%)
Laundry	17 (1.0%)
Pest control	14 (0.8%)
Washing machine use	11 (0.6%)
Unknown	645 (36.5%)

Data from the French poison control centres (national poisoning database, 2023). PSS: Poisoning Severity Score. IQR: interquartile range. An exposure incident is defined as a single exposure event, regardless of the number of individuals involved. a Missing for 33 cases (1.8%); b Missing for 8 cases (0.4%).

Factors associated with severity in univariable and multivariable analyses are presented in Table 2. In the multivariable model (n = 1,608), obstructive airway disease (aOR = 3.65; 95% CI 2.64–5.01; p < 0.001),

other reported respiratory history (aOR = 2.09; 95% CI 1.11–3.75; p = 0.017), and older age (aOR = 1.25 per 10-year increment; 95% CI 1.15–1.35; p < 0.001) were independently associated with moderate-to-severe poisoning (PSS ≥ 2). Exposure to an acidic product other than vinegar was also significantly associated with worse outcomes (aOR = 1.37; 95% CI 1.04–1.80; p = 0.025). The sensitivity analysis restricted to cases with recorded respiratory history (n = 1,387) yielded consistent results, with aORs of 1.94 (95% CI 1.03–3.49; p = 0.033) for other reported respiratory history and 3.37 (95% CI 2.43–4.67; p < 0.001) for obstructive airway disease; 1,375 cases were included in the multivariable model. Among cases with no reported respiratory history (including not recorded, n = 1,346), active smoking was independently associated with moderate-to-severe poisoning (aOR = 3.22; 95% CI 2.25–4.58; p < 0.001), with consistent effects of age (aOR = 1.28; 95% CI 1.16–1.42; p < 0.001) and acid product type (aOR = 1.49; 95% CI 1.07–2.08; p = 0.019).

Table 2
Factors associated with moderate-to-severe chlorine gas poisoning (PSS ≥ 2 vs PSS 1) from household product mixing, 2023.

	Univariable OR [95% CI], p	Multivariable OR [95% CI], p
Analysis A: Factors associated with moderate-to-severe chlorine gas poisoning (n = 1,636)		
Age (per 10-year increment)		
Continuous	1.28 [1.18–1.38], p < 0.001	1.25 [1.15–1.35], p < 0.001
Sex		
Female	*Reference*	*Reference*
Male	0.95 [0.72–1.25], p = 0.729	0.84 [0.63–1.12], p = 0.249
Respiratory history		
No reported respiratory history[†]	*Reference*	*Reference*
Other reported respiratory history	2.25 [1.21–3.98], p = 0.007	2.09 [1.11–3.75], p = 0.017
Obstructive airway disease	3.78 [2.76–5.15], p < 0.001	3.65 [2.64–5.01], p < 0.001
Hypochlorite-based product		
Standard liquid bleach	*Reference*	—
Hypochlorite-based spray	1.15 [0.71–1.81], p = 0.552	—
Toilet bowl bleach gel	0.73 [0.32–1.47], p = 0.421	—
Other or unspecified hypochlorite-based product	1.26 [0.61–2.39], p = 0.503	—
Hypochlorite-based drain cleaner	1.99 [1.09–3.50], p = 0.020	1.77 [0.93–3.26], p = 0.073
All hypochlorite-based products other than drain cleaner (combined)	—	*Reference*
Acidic product		
Vinegar	*Reference*	*Reference*
Hydrochloric acid/drain cleaner	1.49 [1.08–2.04], p = 0.014	—

	Univariable OR [95% CI], p	Multivariable OR [95% CI], p
Analysis A: Factors associated with moderate-to-severe chlorine gas poisoning (n = 1,636)		
Age (per 10-year increment)		
Descaling/cleaning products	1.22 [0.78–1.86], p = 0.373	—
Toilet cleaners	1.34 [0.87–2.02], p = 0.173	—
Other or unspecified acid	1.48 [0.73–2.79], p = 0.242	—
All acidic products other than vinegar (combined)	—	1.37 [1.04–1.80], p = 0.025
Analysis B: Active smoking and moderate-to-severe poisoning among cases with no reported respiratory history[†] (n = 1,346)		
Active smoking		
No	*Reference*	*Reference*
Yes	2.93 [2.07–4.11], p < 0.001	3.22 [2.25–4.58], p < 0.001

Data from the French poison control centres (national poisoning database, 2023). PSS: Poisoning Severity Score; OR: odds ratio; CI: confidence interval; [†] Includes cases classified as respiratory history not recorded; —: not included in the model. Analysis A includes all symptomatic cases (PSS ≥ 1); the multivariable model was restricted to complete cases (n = 1,608); hypochlorite-based and acidic product categories showing similar univariable effect estimates were combined into binary variables for multivariable modelling (see Methods). Analysis B is restricted to cases with no reported respiratory history; the multivariable model was restricted to complete cases (n = 1,318) and additionally included age, sex, hypochlorite product, and acidic product as adjustment covariates.

Over the 2010–2025 period, the standardised index of domestic chlorine gas exposures increased significantly, with a breakpoint estimated at 2018.45 (95% CI 2014.86–2022.03), after which the rate of increase accelerated markedly (+ 4.97 index points per year before the breakpoint vs + 12.25 after; Fig. 1A). Concurrently, the annual indices of poison control cases associated with vinegar-based, baking soda-based, and black soap-based products increased substantially, while the bleach-associated index remained stable, with a transient peak across all product-associated indices in 2020 coinciding with the COVID-19 pandemic (Fig. 1B). In an exploratory analysis, the annual rate of moderate-to-severe poisoning showed no significant trend over the study period (IRR = 1.002; 95% CI 0.978–1.027; p = 0.888).

Figure 1. Temporal trends in domestic chlorine gas exposures and household product cases, 2010–2025.

1. (A) Annual standardised index of accidental domestic chlorine gas exposures from household product mixing (base 100, reference year: 2010), adjusted for poison control centre activity. Shaded area: 95% confidence interval of the segmented regression model.
2. (B) Annual crude index of poison centre cases involving selected household products (base 100, reference year: 2010, log scale).

Data source: French poison control centres (national poisoning database, 2010–2025).

Discussion

This national study of accidental domestic chlorine gas exposures in France, combining exhaustive case-level analysis for 2023 with a 16-year temporal assessment, yields several key findings. Among the 1,829 cases recorded in 2023, two-thirds were female, consistent with previous observations of a predominance of women among household cleaning-product exposures [13, 14]. Severe and fatal outcomes remained proportionally rare (11 severe and 2 fatal cases), but given the sustained high volume of exposures, they represent a recurring and non-negligible public health burden. Both obstructive airway disease and other reported respiratory history, as well as older age and active smoking, were independently associated with moderate-to-severe poisoning. Over the 16-year study period, the standardised index of domestic chlorine gas exposures increased markedly, with a breakpoint identified around 2018 after which the rate of increase accelerated substantially.

The main finding of this study is the marked acceleration in domestic chlorine gas exposures identified from 2018 onwards, with the rate of increase more than doubling compared with the preceding period (+ 12.25 versus + 4.97 index points per year). This pattern was not anticipated at the outset of the study and only emerged from the temporal analysis. These findings extend recent North American observations of rising chlorine and chloramine exposures [9, 10] by capturing a longer pre-pandemic baseline and a sustained post-pandemic trajectory suggesting that the increase cannot be explained solely by the COVID-19 pandemic. Closer examination of trends by product category reveals a clear divergence between products: while the bleach-associated index remained essentially stable throughout the 16-year period, the vinegar-associated index rose sharply over the same timeframe, in parallel with a similar rise for baking soda- and black soap-based products, often perceived as natural alternatives, which may reflect broader changes in the types of household cleaning products involved in PCC cases.

Taken together, these findings are consistent with a broader shift in household cleaning practices in which vinegar is increasingly used alongside bleach, rather than with a change in bleach use itself, often without awareness of the resulting chemical reaction. This is consistent with broader evidence that consumers often assume "natural" or eco-labelled products are inherently free of harmful properties [15], a belief that may extend to common household items such as vinegar and lower perceived vigilance when combining them with bleach. This points to a potential gap in current prevention messaging:

warnings, which have historically focused on avoiding the deliberate or careless mixing of "chemical" cleaning products, may not adequately address a population increasingly turning to products marketed and perceived as natural alternatives. This perception gap is not limited to acute exposure: a French cohort study similarly found that regular household use of green and homemade cleaning products was associated with higher asthma symptom scores, despite being perceived as safer alternatives [16].

Beyond these temporal trends, our case-level analysis identifies obstructive airway disease, other reported respiratory history, older age, and active smoking as factors independently associated with moderate-to-severe poisoning. While a role for respiratory comorbidity and age in domestic chlorine exposure has been qualitatively suggested by small case series [5, 6], and a quantified effect of smoking has previously been reported only in occupational cohorts with repeated exposure [8], this study provides, to our knowledge, among the first quantified estimates of these associations in a large, non-occupational domestic population (aOR = 3.65 [2.64–5.01] for obstructive airway disease; aOR = 2.09 [1.11–3.75] for other reported respiratory history; aOR = 1.25 [1.15–1.35] per 10-year increment for age; aOR = 3.22 [2.25–4.58] for active smoking). The magnitude of the smoking association is particularly notable: it identifies an additional potentially vulnerable population that would not be captured by respiratory-history-based risk stratification alone, since active smokers with no reported respiratory history are not typically flagged as at-risk in general prevention messaging. These findings are consistent with recognised mechanisms of increased airway vulnerability to acute irritant injury: chronic airway inflammation and remodelling in individuals with obstructive airway disease may lower the baseline threshold for clinically significant bronchoconstriction and mucosal injury, while smoking-induced epithelial damage and impaired mucociliary clearance similarly reduce the airway's capacity to buffer an acute oxidant insult [1, 2, 7].

Beyond deliberate bleach-acid mixing, exposure circumstances were diverse (including sequential product use on the same surface, reuse of containers, and unexpected uses of bleach as a drain opener, insecticide, or textile cleaner), reflecting gaps in consumer understanding rather than deliberate misuse, and suggesting that "do not mix bleach with other products" messaging alone may not cover the full range of real-world scenarios. This diversity may partly explain part of the lower severity observed with vinegar relative to other acids (aOR = 1.37 for other acidic products vs vinegar): possible contributors include a lower acetic acid concentration in vinegar, differences in the hypochlorite product typically involved, or exposure occurring less often in confined spaces such as toilets or during drain-unblocking. This should not be read as evidence that vinegar is a safe substitute when combined with bleach.

Beyond the acute episode, a single severe chlorine exposure can produce lasting respiratory sequelae, as shown by follow-up of workers exposed in the 2005 Graniteville train derailment (reduced FEV_1 up to 18 months later [17]) and by broader evidence of persistent airway inflammation and remodelling after severe exposure [18]. Whether this extends to the much more common minor exposures in our series (PSS 1: 1,356/1,829, 74.1%) is, to our knowledge, unexplored: studies of domestic cleaning product use and asthma have focused on cumulative regular use [16, 19], not discrete high-concentration accidental episodes. Future studies on cleaning-product exposure and respiratory health could usefully record prior

accidental gas exposures, regardless of severity, to help clarify their independent contribution to long-term risk.

Beyond identifying at-risk individuals, our findings point to a more concrete lever for prevention: existing GHS hazard pictograms (adopted in the EU under the CLP Regulation) are generic (e.g., corrosive, irritant), and the specific warning against mixing with other products (EUH206) already carried by bleach is a small-print textual statement that is, in practice, often overlooked by consumers [15]. A distinct, highly visible warning symbol indicating the risk of toxic gas release from mixing could plausibly alert consumers more effectively than current generic labelling, although this remains to be evaluated; to be effective, such a symbol would need to appear not only on hypochlorite-based products but also on the acidic household products most frequently involved, such as vinegar and descaling products.

The content of prevention messaging may also need to evolve alongside its visibility. In our series, mixing was not confined to general surface cleaning: drain unblocking (70/1,767 incidents, 4.0%) and pest or rodent control (14/1,767, 0.8%) together accounted for a small but consistent share of exposure circumstances. In these situations, combining products may plausibly reflect, in some cases, an expectation that mixing enhances potency rather than simple unawareness of the reaction risk; toxicovigilance data do not capture callers' stated motivation, so this interpretation remains hypothetical. Prevention messages framed solely as "do not mix bleach with other products" may fail to reach individuals acting on this belief; communication that explicitly names and addresses the misconception that combining cleaning or pest-control products makes them more effective, rather than relying only on a generic mixing prohibition, could usefully complement pictogram-based warnings.

This study has several strengths, including the use of a national toxicovigilance system covering all eight French poison control centres, combined with exhaustive individual case review for 2023, and a 16-year observation period spanning both pre- and post-pandemic periods. However, several limitations should be acknowledged. First, the 16-year temporal analysis relies on standardised aggregate queries rather than individual case review, and its temporal resolution is inherently limited by the number of annual data points (n = 16); the estimated breakpoint should therefore be interpreted as approximate rather than precisely dated. The parallel, exploratory severity-trend analysis in particular was not manually verified and should be interpreted with caution. Second, respiratory history and smoking status were based on information recorded in PCC case files and may therefore be subject to incomplete documentation. For respiratory history, cases classified as respiratory history not recorded were combined with cases with no reported respiratory history for the primary analysis; a sensitivity analysis excluding these cases yielded consistent results. Residual misclassification and confounding cannot be excluded. Third, PCC data capture only cases for which a call was placed; the likelihood of contacting a PCC may itself differ by symptom severity, health literacy, and access to healthcare, potentially affecting both the observed severity distribution and temporal trends, and the true incidence of domestic chlorine exposures is likely substantially higher than recorded. Fourth, our dataset lacks direct measures of exposure intensity (air concentration, quantities mixed, duration, ventilation), plausible factors associated with severity that toxicovigilance data cannot capture [1, 2].

The extent to which these findings can be generalised beyond France also warrants consideration. Although conducted in France, our severity findings are unlikely to be country-specific, given that domestic chlorine gas exposures from bleach-acid mixing are documented across multiple high-income countries with comparable cleaning habits [5, 6, 9, 10]; the pace and magnitude of the temporal trend, however, likely reflect France-specific consumer patterns (notably the rise in vinegar use) and should not be assumed to generalise directly. As cleaning practices continue to evolve elsewhere too, prevention messaging will require ongoing collaboration between poison control centres, regulatory authorities, and manufacturers to keep pace with emerging risk patterns.

Conclusions

Domestic chlorine gas exposures from household product mixing, reported to French PCC, increased markedly over the past 16 years. This coincided with a marked increase in cases involving vinegar and other selected products, while bleach-associated cases remained relatively stable, consistent with growing household use of vinegar as a perceived natural cleaning product, used alongside rather than instead of bleach. Although rare in proportion, severe and fatal cases occurred in 2023, confirming this remains an active public health concern. Obstructive airway disease, older age, and active smoking were independently associated with poisoning severity and may help identify individuals at higher risk. The diversity of circumstances in which mixing occurs further supports strengthening both the visibility and the content of prevention messaging, including clearer mixture-specific warnings and communication that directly addresses misconceptions about the effectiveness of combining products. Whether the large number of clinically minor exposures recorded in this study carries any lasting, moderate impact on respiratory function remains unknown and could usefully be incorporated into future epidemiological research on domestic cleaning product exposure and respiratory health.

Abbreviations

PCC
Poison control centre
BNCIT
National Database of Poisoning Cases and Toxicological Information Requests
SICAP
Système d'Information des Centres Antipoison et de toxicovigilance
SICAP-SID
SICAP decision-support system
COPD
chronic obstructive pulmonary disease
PSS
Poisoning Severity Score
aOR
adjusted odds ratio

OR
odds ratio
CI
confidence interval
IQR
interquartile range
IRR
incidence rate ratio
RADS
reactive airways dysfunction syndrome
FEV_1
forced expiratory volume in one second
GHS
Globally Harmonized System of Classification and Labelling of Chemicals
EU
European Union
CLP
Classification, Labelling and Packaging (EU regulation)
ANSES
French Agency for Food, Environmental and Occupational Health & Safety
CNIL
French Data Protection Authority.

Declarations

Ethics approval and consent to participate

This study is based on data from the French national poison control and toxicovigilance information system (SICAP), whose personal data processing is governed by the arrêté du 21 février 2022 relatif au fonctionnement du système d'information des centres antipoison et de toxicovigilance, Décret n°2014-128 du 14 février 2014 relatif à la toxicovigilance, and Décret n°2016-1744 du 15 décembre 2016, following review by the French data protection authority (CNIL, Délibération n°2020-131 du 17 décembre 2020). Data used for toxicovigilance purposes, including for this study, are pseudonymised in accordance with these regulations; individual informed consent was not required under this legal framework.

Consent for publication

Not applicable.

Clinical trial number

Not applicable.

Availability of data and materials

The pseudonymised individual-level data underlying this study cannot be made publicly available due to French regulatory restrictions governing the national poison control and toxicovigilance information system. Aggregated data may be made available by the corresponding author upon reasonable request, subject to approval by the relevant authorities.

Competing interests

JB and CG are employees of the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), which funded this work (see Funding). Non-ANSES members of the working group contributed as independent experts, in accordance with standard rules governing scientific expertise. The authors declare no other competing interests.

Funding

This work was partially funded by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), which contributed to the running and coordination of the working group within which this study was conducted, and to the participation of external experts and rapporteurs. Beyond the contributions of JB and CG as co-authors, the funder had no role in the study design, data analysis, interpretation of results, or decision to submit for publication.

Authors' contributions

HLC, CG, PN, AMP, GM, GC, and JB contributed to the design of the study and to the interpretation of the results, and critically revised the manuscript for important intellectual content. HLC, CG, PN, and AMP additionally performed the review of individual cases. HLC additionally conducted the statistical analysis and drafted the manuscript. The French PCC Research Group contributed to data collection. All named authors read and approved the final manuscript.

Acknowledgements

The authors thank Ester Dias for case review and data collection.
The authors also thank the members of the French PCC Research Group for their contribution to data collection: Nathalie Paret, Cécile Chevallier, Anthony Facile (Lyon Poison Control Centre, France), Ramy Azzouz, Anne Garat (Lille Poison Control Centre, France), Jérémy Lecot, Morgane Cellier, Philippe Chauveau (Angers Poison Control Centre, France), Nicolas Delcourt, Fanny Pelissier, Alix-Marie Pouget (Toulouse Poison Control Centre, France), Camille Paradis, Coralie Braganca, Magali Labadie (Bordeaux Poison Control Centre, France), Romain Torrents, Julien Reynoard, Nicolas Simon (Marseille Poison Control Centre, France), Céline Moulut, Marion Evrard, Emmanuel Puskarczyk (Nancy Poison Control Centre, France), Hélène Sempéré, Jérôme Langrand, Weniko Caré (Paris Poison Control Centre, France)

Use of AI tools

Generative AI tools (Claude Sonnet 5, Anthropic) were used to assist with translation of the manuscript into English. All AI-assisted text was reviewed and validated by the authors, who remain fully responsible for the content of the manuscript.

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Figures

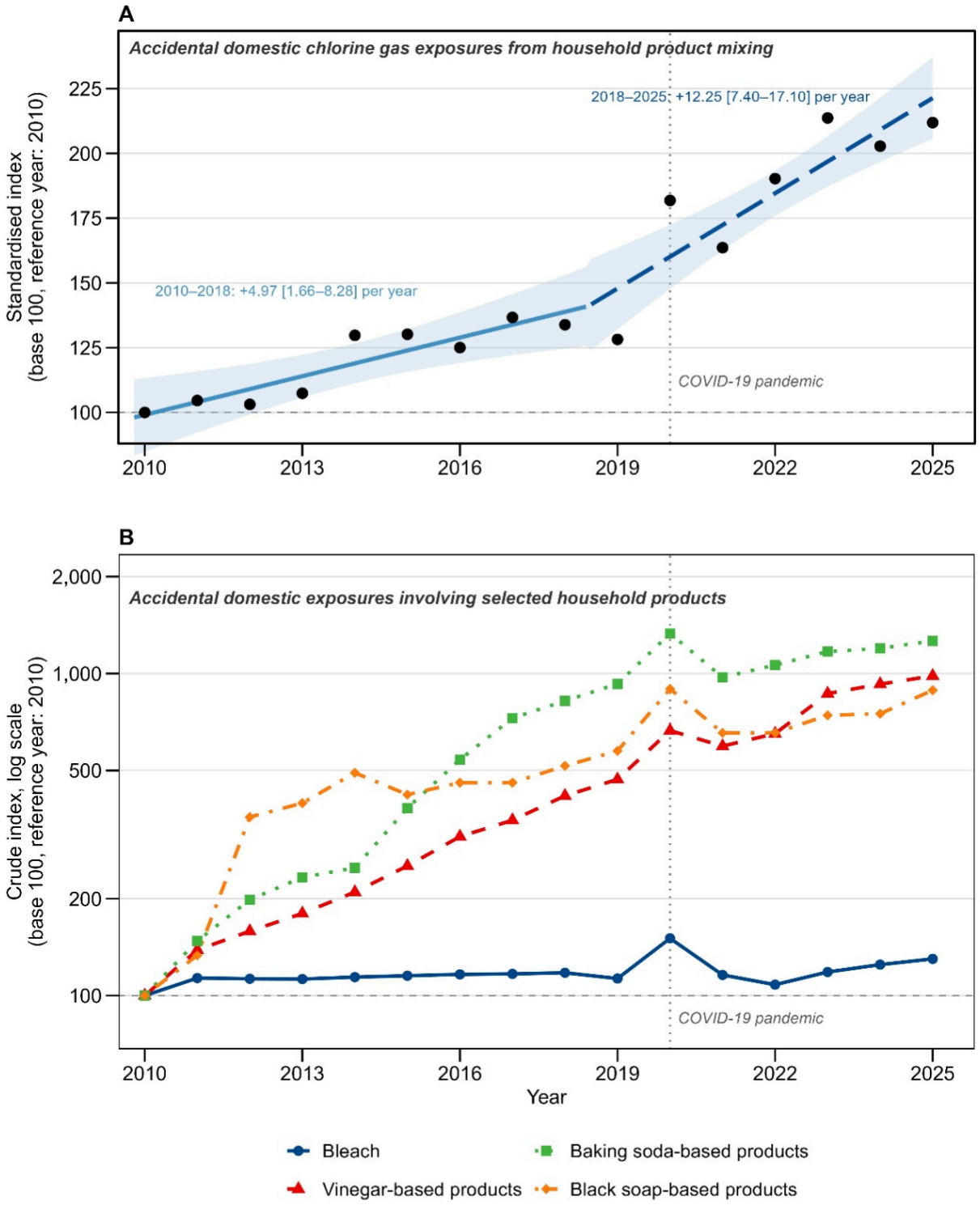

Figure 1

Temporal trends in domestic chlorine gas exposures and household product cases, 2010–2025.

(A) Annual standardised index of accidental domestic chlorine gas exposures from household product mixing (base 100, reference year: 2010), adjusted for poison control centre activity. Shaded area: 95% confidence interval of the segmented regression model.

(B) Annual crude index of poison centre cases involving selected household products (base 100, reference year: 2010, log scale).

Data source: French poison control centres (national poisoning database, 2010–2025).