Accidents related to dry cleaning activities

An oil lamp overturns due to inattention onto a stained tablecloth, now what could be dirtier! But what exactly happens once the tablecloth has dried? The stains disappear… Emboldened by this discovery, Jean-Baptiste Jolly opened the first dry cleaners in 1855 in Paris, and with it the dry cleaning industry was born.

Dry cleaning relies for the most part on introducing a solvent. Gasoline, petroleum and benzene were all used in this cleaning process until 1897. At the beginning of the 20th century, carbon tetrachloride was introduced, followed by trichloroethylene during the 1920's, finally giving way after the Second World War to tetrachloroethylene.

At present, though dry cleaning shops have become part of our daily lives, their operations still create a number of risks for human safety, property and the environment. As such, these activities are addressed within the scope of legislation regarding classified facilities.

The analysis of accident statistics presented herein concerns events that occurred in facilities that make use of dry cleaning machines. This analysis has been based on a total of 32 events in France and 3 elsewhere, as recorded in the ARIA database[1] between December 17, 1984 and August 21, 2007.

Due to a lack of information availability, the number of recorded accidents is, in all likelihood, less than the number of actual accidents, meaning that the output of this exercise cannot be considered a complete statistical study.

This analysis pertains to facilities that use dry cleaning machines operating with chlorine-based solvents (tetrachloroethylene in most cases). Given the absence of information on accidents ultimately due to experimental washing techniques relying on CO_2-based cleaning or "new generation" solvents, these alternative methods have not been included in the present study.

The list of illustrative accident summaries are contained in the Appendix to this report. Each summary is accompanied by 4 indices with reference to the 18 parameters composing the European scale of industrial accidents, which was officially adopted by the Member States' Competent Authority Committee to implement the *'SEVESO'* directive on handling hazardous substances. These indices correspond to the following:


Hazardous materials released


Human and social consequences


Environmental consequences


Economic consequences

Each index value, determined on a 6-point scale, is assigned in accordance with the rating rules available for consultation on the Website: **www.aria.developpement-durable.gouv.fr**.

[1] The database called ARIA (an acronym for Accident Analysis, Research and Information) is devoted to recording accidents and incidents that caused, or could have caused, damage to human health or public safety, agriculture, nature or the environment. For the most part, these events result from the activity of industrial or agricultural facilities either classified as hazardous or capable of being classified as such. Other events, such as those involving the transport of hazardous materials (whose lessons are nonetheless pertinent), have also been recorded in the base. This inventory, which does not claim to be exhaustive, along with the ensuing analyses has been processed since 1992.

A - Level of activity in France

In 2008, the dry cleaning sector in France encompassed 12,000 jobs, with on average 2.3 employees per activity (source: FFBP Trade Association).

Dry cleaning shops tend to be designed according to the same model, which comprises:

- a retail space
- a storage space for clothing
- a workshop area that includes ironing appliances
- a separate storage space for chemical products
- ironing boards
- one or more washing machines
- one or more dry cleaning machines.

In France, nearly all shops are equipped with dry cleaning machines that use tetrachloroethylene[2]. Total solvent consumption within this industrial sector was estimated in 2004 at approximately 5,900 tonnes. For indicative purposes, the consumption of tetrachloroethylene by French dry cleaning establishments equalled 3,000 tonnes in 2007. This drop can be explained by the lower number of establishments as well as modernisation in the dry cleaning machines placed in operations.

The May 2, 2002 decree issued relative to heading 2345 of the classified facilities legislation imposes the use of closed-circuit machines[3], in compliance with Standard NFG 45-011 or an equivalent recognised specification. Open-circuit machines were no longer authorised as of January 1st, 2003.

Operational guidelines for a dry cleaning machine:

Cleaning:
The clothing is placed in the machine drum and then mixed with the solvent.
After the spinning phase, the solvent is recovered and filtered, before being conveyed either to a still (if it is very dirty) or to a storage tank.
A dry cleaning machine with a 15-kg capacity typically contains from 200 to 400 litres of tetrachloroethylene divided between the tanks, filters and still.

Drying, deodorising:
Drying takes place in the machine subsequent to the cleaning phases and without operator involvement, by means of circulating a stream of hot air inside the machine. The residual solvent vapours drawn in this manner are then treated in an air filter.
The deodorisation step consists of having a stream of cold air circulate over the clothing.

Recovery of tetrachloroethylene:
The vapours released during the "drying - deodorisation" step are condensed.
The resultant liquid phase, featuring used tetrachloroethylene composed of approx. 99% tetrachloroethylene and 1% water (generated by the humidity contained on the clean clothes and the aqueous treatment products), is then channelled into a water separator.
Next, the dirty tetrachloroethylene gets distilled at 121°C. This distillation pro cess is halted if the boiler on the still reaches 140°C, in order to avoid thermal decomposition of the solvent.

The accumulated distillation residue lying at the bottom of the still can lastly be removed.

B - Accident typologies

Table 1 lists the various typologies derived for the 32 accidents that occurred at dry cleaning installations in France and recorded in the ARIA database.

	Number	%
Discharge of hazardous materials or pollutants	31	97
Fire	6	19
Explosion	3	9

Table 1: Accident typologies

(A single accident can, in some cases, fit into several typologies.)

2 INRS report: Technical checklist (ED 6025) on the dry cleaning sector, *Institut National de Recherche et de Sécurité*, 2008.

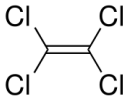
3 The notion of closed circuit has been defined in Standard NF G 45-011, specific to dry cleaning equipment.

Fires and explosions adversely affect dry cleaning machines, as just one database record of fire (ARIA 10442) left the machines intact, yet this case involved a storage room for dirty fabrics.

Tetrachloroethylene leaks

31 cases of hazardous material discharge were recorded. For the most part, these entailed tetrachloroethylene leaks in the liquid and/or gaseous phase. Since this product is volatile, leaks in the liquid phase generate vapours, which in turn diffuse easily within the dry cleaning shop and, in some cases, reach adjacent residences or commercial/retail space (ARIA 24026, 29917).

Tetrachloroethylene (also known as **perchloroethylene**) is a chemical compound possessing the formula: $Cl_2C=CCl_2$:



This substance is a colourless, volatile and practically non-water-soluble liquid that nonetheless remains miscible in most organic solvents. It is lipophilic (meaning attracted by grease); for this reason, it dissolves substances such as resins, oils and grease.

This compound is also considered to be non-flammable and non-explosive, both at room temperature and under normal use conditions.

The product's **vapour tensions** are respectively as follows:

1.9 kPa at 20°C
5.5 kPa at 40°C
30.1 kPa at 80°C
58.5 kPa at 100°C

Human health effects
Tetrachloroethylene can be absorbed into the body by inhalation, orally or through the skin.
During accidental exposure and depending on the degree of such exposure, the following symptoms may appear: irritation of the airways and eyes, vertigo, nausea, headaches and memory loss, and drowsiness. As an example, the lethality threshold determined by the American EPA is 1,600 ppm for a 10-minute exposure (AEGL 2 interim value - see the AEGL set of definitions); as for irreversible effects, the threshold value equals 230 ppm.
Prolonged exposure to tetrachloroethylene can cause deleterious effects on the human body, given the fact that this substance has been categorized 2A (likely carcinogen for humans) by the International Cancer Research Centre. In France, the threshold value for an 8-hour professional exposure to tetrachloroethylene amounts to 50 ppm.

Tetrachloroethylene is also toxic for aquatic organisms.

Note: 1 ppm = 6.78 mg/m^3

See INRS / INERIS safety data sheets
Website: http://www.epa.gov/oppt/aegl/pubs/results38.html

Table 2 displays the various machine components responsible for these leaks, along with the corresponding number of cases and event reference. Equipment malfunction is most often cited as the cause.

Component	Number of cases	ARIA accident ref. no.
Still	5	9514, 15062, 15612, 29917, 33949
Dry cleaning machine (no additional indication)	4	9701, 10820, 15843, 24026
Storage capacity or associated piping	2	13430, 26882
Solenoid valve	2	1056, 12732
Joint (no additional indication)	1	9877
Valve	1	15151

Table 2: List of components responsible for a tetrachloroethylene leak

Back view of a dry cleaning machine

Fires

Six cases of fire specific to dry cleaners are contained in the database (ARIA nos. 3178, 10442, 10881, 12893, 13920, 17558).

Tetrachloroethylene was not the direct cause of these accidents since the solvent offers the advantage of non-flammability (no flash point, no lower explosive limit - LEL). On the other hand, the machines, their electrical equipment, household linen and even some of the stain-removal substances that display non-flammability at room temperature (xylene, mixes of isoalkanes, isopropanol), despite their use in such small quantities during each operation (pre-cracking off, cracking-off), provide a good number of combustible materials and substances present in the process.

Besides the damage caused inside dry cleaning shops, fires spread to adjoining premises (ARIA 10442,17558), or in some cases to property located beyond the premises (ARIA 3178).

Releases of tetrachloroethylene vapours caused by heat from the fire might also complicate the work of rescue personnel and pollute the atmosphere (ARIA 13920, 10881). Emergency services are typically equipped with respiratory protection devices for this type of intervention.

Fire at a dry cleaning facility is also capable of polluting the water utility network (ARIA 10881).

Explosions

Despite the "non-explosive" nature of tetrachloroethylene under normal use conditions, explosions of dry cleaning machines have indeed been recorded[4].

[4] INRS report: Technical checklist (ED 6025) on the dry cleaning sector, *Institut National de Recherche et de Sécurité*, 2008.

The set of hypotheses forwarded[5] to explain such explosions include:

- the presence or use of an inflammable solvent instead of tetrachloroethylene, or an accidental mix with this substance;
- the thermal decomposition of tetrachloroethylene due to a malfunction of the temperature regulation systems;
- work performed at a hot spot on a gas-free machine during a programmed maintenance operation, with the heat generated capable of decomposing the tetrachloroethylene into inflammable by-products.

Three explosions at dry cleaning facilities have been entered into the ARIA base (nos. 5560, 13421, 17558), including one event in 1994 that involved an entire trichloroethylene tank (5560).

Waste treatment

Subsequent to a fire at a dry cleaners (ARIA no. 10881), instructions were given by the classified facilities inspection authorities to dispose of the waste materials resulting from the accident.

Even though not a single accident in the ARIA base involves wastes produced by the dry cleaning facilities themselves, it must still be recognised that this activity generates a considerable amount of hazardous waste: distillation residue, filtration cartridges and dirty jugs offer a few good examples. Poor handling of these wastes could lead to major nuisances as well as to chronic or accidental pollution of either water or the atmosphere.

Residue from the distillation of tetrachloroethylene discharged into the sewer system is capable of upsetting the operations of wastewater treatment plants. Moreover, such residue constitutes a risk for individuals working downstream in wastewater networks and for the aquatic environment receiving the discharged effluent.

For this reason, prior to their treatment, wastes must be stored in sealed, tagged packages placed in a ventilated room. The waste produced is to be collected and transported to certified treatment facilities. These steps must be effectively tracked using appropriate monitoring forms, a copy of which must always be kept by the waste producer.

C - Causes

The dry cleaning business is often performed by small enterprises with limited staffing (1- or 2-person operations). An inadequate organisation to incorporate risk prevention often proves critical in the causal chain of an accident.

The main inadequacies or anomalies identified pertain to the following:

- the condition, compliance and verification of electrical installations (ARIA 10881, 12893);
- machine conformity (ARIA 23216), whereby the verification of accessories (valves, still, etc.) often gets neglected (ARIA 9514, 15062, 12732, 29917, 33949, etc.);
- the absence / insufficiency of monitoring and detection resources, in addition to any human presence (ARIA 13761, 17558), hence facilitating malicious acts;
- professional training (ARIA 10820, 13430).

Attention should be drawn to the case of a leak occurring after the onsite work of a private subcontractor for a maintenance operation subsequent to a valve left open (ARIA 10820).

ARIA 10820 - 19/01/1997 - 78 - CHATOU

96.01 - Laundry - Dry cleaning

During start-up of one of the self-service dry cleaning machines, a customer smelled a strong odour and alerted the shop manager. Tetrachloroethylene was seeping onto the floor underneath the machine. The manager shut down the facility, soaked up the solvent with a sponge and died 10 min later. Fire-fighters arriving on the scene spread absorbent products and ventilated the premises. A quarter-turn bleed valve on the solvent tank had been accidentally left open during a maintenance service call performed by an outside professional. When the machine resumed operations, the circulation pump emptied the tank by projecting a pressurised stream of tetrachloroethylene (100 litres) outside the retention area. The accident was caused by design flaws on the installation as well as by inadequate personnel training.

5 INRS report: Technical checklist (ED 6025) on the dry cleaning sector, *Institut National de Recherche et de Sécurité*, 2008.

D - Consequences

Accidental discharges of tetrachloroethylene can produce serious human, social and economic consequences, namely:

- The manager of a dry cleaners died in 10 minutes while trying to absorb a puddle of tetrachloroethylene with a sponge while not wearing any respiratory protection (ARIA 10820);
- A 50-litre tetrachloroethylene leak on a machine intoxicated 14 individuals and necessitated the intervention of emergency personnel wearing sealed breathing masks along with the evacuation of an entire shopping mall for several hours (ARIA 15612);
- Another leak caused individuals to suffer intoxication, the closure of a supermarket and verification of foodstuffs exposed to fumes (ARIA 24026).

More generally, these accidents lie at the origin of injuries among personnel, fire-fighters and third parties (ARIA 5560, 9701, 13421, 13430, 13920, etc.). In most cases, victims suffer from intoxication and discomfort (ARIA 5560, 12829, 13920, 18425, etc.), requiring evacuation and hospitalisation of those in distress (ARIA 9514, 9701, 29917, etc.).

The intervention of rescue teams is typically accompanied by: the demarcation of a safety zone, access restrictions, and temporary store closures (ARIA 12732, 15612).

Property damage, which readily occurs during incidents of fire or explosion, most often relates to machinery or shop contents (ARIA 3178, 10442, 12893), yet such damage may also concern residences or other property (cars – ARIA 3178) located nearby.

Difficulties involved when fire-fighters are called to the scene of an accident

During the January 25, 1997 event in Montrouge (ARIA 10442), the press reported that fire-fighters were inconvenienced by a courtyard cluttered with cars and light-duty vehicles that needed to be quickly removed in order to prepare for installing turntable ladders. Despite the speedy arrival of fire-fighters (the station was located just a few metres away), the fire spread considerably, even threatening neighbouring residences. Building design and the presence of inflammable products were the hypotheses adopted to explain the extent of this incident.

In addition to the costs inherent in such damage (ARIA 10442, 10881), some cases necessitate employee redundancy periods of varying lengths.

E - Primary lessons learned

The principal recommendations stemming from feedback received will be presented in this section; they are intended to reduce both the occurrence and severity of solvent leaks by means of limiting human exposure and mitigating fire risks.

The context when locating dry cleaners in city centres, near residences or inside shopping malls serves to justify compliance with a number of major facility improvements.

Moreover, the release of a few litres of tetrachloroethylene is enough to cause headaches or irritations to a large segment of the population (ARIA 27264, 29917, etc.).

Decreasing the leak occurrence rate and human exposure

These objectives rely upon the implementation of various measures both inside the shop and applicable to dry cleaning operations. Machine design plays a vital role in this approach.

The shop

Dry cleaning machines along with all hazardous products **must be placed in a retention system**, which allows containing liquid leaks and minimizing both the evaporation surface area and solvent propagation throughout the premises (ARIA 9514). Since dry cleaning equipment is typically installed in the retention system, its design must take account of the volume occupied by the device.

In conjunction with this step, **an appropriate ventilation of the premises**, in order to permanently replenish the air, serves to limit health risks for employees, customers and third parties.

Machine design

The wide array of accidental gaseous tetrachloroethylene leaks encountered among the various types of dry cleaning equipment also provides confirmation of the importance of study and testing phases during the **design process** in preventing fumes from being released as a result of machine use. Standard NF G 45-011 imposes a high level of machine confinement based on maximum solvent concentration measurements in the atmosphere (335 mg/m^3, or 49.5 ppm), conducted at different points in the test room.

As a complement to Standard NF G 45011, the "dry cleaning machine" NF 107 mark calls for tests based on the protocol established in Standard NF G 45011, whose aim consists of verifying that the machine is not releasing at a rate higher than 100 mg/m^3 (15 ppm) as an 8-hour average. Other tests, still within the scope of this NF 107 mark, enable verifying that the rate of solvent emission (vapours) into the atmosphere remains below 7g/kg for treated clothing (the threshold set in the "COV" Directive for this activity stands at 20g/kg).

Component reliability and resistance over time along with the streamlined execution of maintenance tasks would also need to be incorporated during the dry cleaning machine design stages.

System operations

An **adapted maintenance programme** for the dry cleaning machine and its accessories, in addition to a **regular monitoring of solvent consumption**, contributes to preventing against tetrachloroethylene leaks.

Its application entails both introducing and **ensuring compliance with operational and safety guidelines** that have been commonly adopted by shop personnel and subcontractors; such guidelines serve to specify:

- nominal machine capacities not to be exceeded (to avoid overloading the drum);
- respect of cycle sequences, especially drying time;
- treatment of sludge type wastes and used chemical products;
- operations to be performed upon solvent delivery;
- measures to be adopted in the case of a leak or spill of halogenated solvents.

It is also beneficial to associate all actors involved in a preventive approach that must not exclusively rely on technical devices or the publication of guidelines. Increasing employee responsibility, including subcontractors, coupled with **regular** and **well-adapted training** in tetrachloroethylene-related risks, prove to be necessary steps.

Fire risk prevention

Electrical defects and malicious acts are counted among the identified causes of fires.

These factors must therefore incite a **preventive approach** that relies upon **verifications of electrical installations**, along with the implementation of **preventive and protective measures** (e.g. alarms, fire detectors).

Preventing fire from spreading to property outside the shop requires a minimum set of fire resistance characteristics for the walls and doors/windows on structures commonly integrated into the urban fabric.

The difficulties experienced by rescue units on the scene confirm the importance of accessibility to the shop and its various installations.

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Findings of the accident analysis have supported the need for machine manufacturers and operators to strengthen their prevention measures practiced, from both a technical and organisational standpoint.

The use of dry cleaning machines in a way that complies with current standards, respects manufacturer recommendations and includes their regular maintenance is essential to limiting accident-related risks.

Use of tetrachloroethylene is accompanied by potential serious risks that must be very closely managed.