Efficiency of inductively torch plasma operating at atmospheric pressure on destruction of chlorinated liquid wastes- A path to the treatment of radioactive organic halogen liquid wastes.

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Abstract: The performance of a plasma reactor for the degradation of chlorinated hydrocarbon waste is reported. Chloroform was used as a target for a recently patented destruction process based using an inductive plasma torch. Liquid waste was directly injected axially into the argon plasma with a supplied power of ~4 kW in the presence of oxygen as oxidant and carrier gas. Decomposition was performed at CHCl₃ feed rates up to 400 g·h⁻¹ with different oxygen/waste molar ratios, chloroform destruction was obtained with at least 99% efficiency and the energy efficiency reached 100 g·kWh⁻¹. The conversion end products were identified and assayed by online FTIR spectroscopy (CO₂, HCl and H₂O) and redox titration (Cl₂). Considering phosgene as representative of toxic compounds, only very small quantities of toxics were released (< 1 g·h⁻¹) even with high waste feed rates. The experimental results were very close to the equilibrium composition predicted by thermodynamic calculations. At the bottom of the reactor, the chlorinated acids were successfully trapped in a scrubber and transformed into mineral salts, hence, only CO₂ and H₂O have been found in the final off-gases composition.

1. Introduction

Organohalogens are often cited as responsible for climate change and occupational diseases. These compounds are used in many processes in the chemical, nuclear, and processing industries and the quantity of waste generated is a problem requiring a solution at industrial scale. Conventional thermal destruction is often used industrially to decompose, but if not sufficiently controlled it raises the risk of emissions that can be even more toxic than the initial waste. During combustion, chlorinated hydrocarbons are also known to interfere and modify the process, if only by the presence of chlorine which prevents the oxidation of CO to CO₂ [1] and favors the production of harmful products such as dioxins, furans, phosgene, etc. Organohalogens are also very poorly biodegradable, and their chemical stability requires destruction by energy-intensive processes.

Thermal plasma can be used; several studies have proposed the thermal plasma process for the destruction of organo-halogenated wastes [2-4]. In order to reduce the waste volumes, radioactive or
not, the CEA recently patented an “Installation for the Destruction of Organo-Halogenated Liquids” (IDOHL: French patent FR 0450303) using inductively coupled thermal plasma. This type of plasma has several advantages as the geometry of the torch which allows the treatment not only of gases but also of liquids without prior evaporation (it is not always easy to place liquid directly in the plasma because of the viscosity of plasma medium), the absence of electrodes, the kinetics and the extended residence time. The initial tests with this device, at a higher power level (41–45 kW) than in the present work, demonstrated the chloroform destruction using water as the oxidant to minimize the production of toxic byproducts [5]. Pure liquid CHCl3 was completely degraded with a calculated energy efficiency (waste mass decomposed per hour / torch power) of 19 g.kWh⁻¹ and converted to HCl and CO₂. Unfortunately, however, simultaneously supplying water and waste can lead to major overconsumption of the initial plasma energy because of the high energy necessary to heat and vaporize the water. This drawback can limit the waste input and thus affect the energy efficiency. In addition, not all waste compounds are fully miscible with water, and their destruction can occur under pyrolytic conditions, although the importance of destroying chloromethanes under oxidative rather than pyrolytic conditions is well known [6]. These limitations led us to choose a new procedure using oxygen instead of water. A smaller (~4 kW) plasma reactor was built to demonstrate the feasibility of processing radioactive liquid organochlorine waste. Chloroform was also selected as the organochlorine model. With its Cl:H ratio of 3:1, there is a strong possibility of forming toxic gases such as Cl₂ and COCl₂ during its destruction. Then, CHCl₃ represents a good model to study the complete and safe degradation. As the destruction of halocarbons is more likely to form toxic halogenated byproducts in the presence of O₂ [1,7,8] than in the presence of H₂O [9,10], the objective of the present work is not only to demonstrate the degradation and complete mineralization of chloroform to harmless CO₂ and H₂O by IDOHL process with oxygen as the oxidizing gas, but also to decompose without formation of toxic, thereby ensuring acceptable gas release as in the previous work [5]. Another objective is to improve the energy efficiency by substituting O₂ for H₂O. The influence of initial waste concentration and the oxidant/ratio molar ratio on the qualitative and quantitative nature of the off-gas will also be discussed.

2. Thermodynamic considerations

In order to predict the equilibrium composition, thermodynamic calculations based on minimizing the Gibbs free energy were performed with the software package, FactSage®. The calculations were also intended to predict the optimum quenching temperature for decomposition. The calculations assume the use of ideal gases and given the high temperatures of the plasma, equilibrium is assumed to have been reached. Calculations were performed for temperatures between 300 K and 4000 K at atmospheric pressure. For C-H-Cl-O system, more than 70 species were taken into account. The calculated equilibrium results for thermal destruction of chloroform are shown in figure 1.

![Figure 1](image.png)

**Figure 1.** Equilibrium composition of system of 1 mol of CHCl₃ in Ar plasma (n₄Ar/n₄CHCl₃ = 100).

N.B: The graph of Ar is not represented because of the scale.
At 4000 K, CHCl$_3$ is entirely degraded; gaseous Cl, H, C radicals together with HCl are found in the system. C(s) appears below 3500 K. HCl, Cl, Cl$_2$ and C(s) are the main thermal decomposition products of chloroform between 2500 K and 3500 K. The apparition of CCl$_4$, which is formed in large amounts below 900 K, must be avoided. Indeed, it is preferable to avoid the formation of other haloalkanes (for example, the Global Warming Potential of CCl$_4$ is 1400 times greater than that of CO$_2$ and 10 times higher than that of CHCl$_3$). Moreover, C(s) must be converted to CO$_2$. For all these reasons, it is necessary to supply oxygenated specie to the system. **Figure 2** shows the equilibrium calculations in the presence of oxygen in equimolar quantity with the waste.

![Equilibrium composition of CHCl$_3$ + O$_2$ + Ar](image1)

**Figure 2.** Equilibrium composition of CHCl$_3$ + O$_2$ + Ar ($n_{O_2} = n_{CHCl_3} = 1$ mol, $n_{Ar}/n_{CHCl_3} = 100$) (Left) Major species; (Right) Minor species. N.B: The graph of Ar is not represented.

At high temperatures, the initial carbon is present in the form of CO, and soot is theoretically no longer formed. Between 2500 K and 3500 K the equilibrium composition is dominated by Cl, HCl, CO, CO$_2$, O$_2$ and H$_2$O. No new organic product with a molar fraction exceeding $10^{-3}$ is formed. The decomposition of chloroform becomes complete. The oxidation kinetics of CO to CO$_2$ is known not to be fast when the temperature decreases; in practice, moreover, this oxidation is complicated by the presence of chlorine [1]. Excess O$_2$ is used to minimize these drawbacks.

The calculated results for a simulation with O$_2$/CHCl$_3$ molar ratio = 20:1 are presented in **figure 3**.

![Equilibrium composition of CHCl$_3$ + O$_2$ + Ar](image2)

**Figure 3.** Equilibrium composition of CHCl$_3$ + O$_2$ + Ar with excess of oxygen ($n_{CHCl_3} = 1$ mol; $n_{O_2}/n_{CHCl_3} = 20$, $n_{Ar}/n_{CHCl_3} = 100$). N.B: The graph of Ar is not represented.
Compared with stoichiometric conditions (figure 2), figure 3 shows that excess oxygen favors the formation of $\text{H}_2\text{O}$ over $\text{HCl}$. This would result in increased quantities of molecular chlorine ($\text{Cl}_2$) in the cold off-gas stream. When dealing with chlorinated compounds it is preferable to favor the formation of $\text{HCl}$ (more readily neutralizable and more soluble in aqueous solution) rather than $\text{Cl}_2$ which may also combine with $\text{CO}$ to form toxic compounds such as phosgene. The peak of formation of $\text{HCl}$ is around $1200 \text{ K}$. It is thus advisable to work with excess oxygen, but to ensure rapid quenching of the gas to prevent the formation of undesirable and enhance the formation of $\text{HCl}$, $\text{CO}_2$ and $\text{H}_2\text{O}$.

In order to suitably control the off-gas release, we also examined the formation of toxic. The phosgene was targeted in this study as a representative of the off-gas quality to limit its toxicity. Its formation, which has no economic advantage in this work, must be minimized. According to the literature, the formation of phosgene is relatively stable between $500 \text{ K}$ and $2100 \text{ K}$ during combustion of organohalogens [11-13].

For a mixture with an $\text{O}_2$ deficiency the calculations predicted a large formation of phosgene with a peak near $780 \text{ K}$ (figure 4, curves $A = 0.5$ and $A = 0.75$). Simply starting with a stoichiometric mixture or with excess oxygen has a beneficial effect on reducing the quantity of phosgene formed (figure 4, curves $A = 1$, $A > 1$). Excess $\text{O}_2$ appears to have a positive effect on reducing the quantities of $\text{COCl}_2$ liable to form. Figure 4 shows that from $\text{O}_2:\text{CHCl}_3 = 10:1$, the $\text{COCl}_2$ concentration is $< 1 \text{ ppm}$.

The thermodynamic analysis led to the following conclusions:

- oxygen must be added to the system in order to oxidize carbon to $\text{CO}$ and $\text{CO}_2$, it must be in excess to accelerate the conversion to $\text{CO}_2$ and especially to minimize the risk of producing toxic gases such as phosgene and incomplete combustion products such as $\text{CO}$;
- the off-gas must be cooled rapidly after the reaction to prevent undesirable recombinations.

3. Experimental

3.1 Inductively coupled plasma and reactor

The experimental device is presented in figure 5.
The plasma source is an induction plasma torch (Tekna PL-50) with high-purity argon as the plasma and sheath gas. It is supplied by a high-voltage power supply coupled with a high-frequency (64 MHz) transmitter supplying a 7-turn copper induction coil to generate the plasma. The maximum power rating is 4.5 kW. The plasma is confined in a quartz tube with an inside diameter of 35 mm. The torch is coupled with a reactor consisting of three main parts (Figure 5A):

- The first (341 mm long, 43 mm inside diameter) presents an appropriate design to avoid cold areas, with a refractory wall. When only argon plasma is working, the reactor design allows gas temperatures of about 1200 K to be reached at the output of this stage.
- The second part is the afterburner stage consisting of a Venturi system. There is injection of airstreams to enrich the medium in oxygen in order to fully oxidize the residual carbon to CO₂ and hydrogen to H₂O, as well as to sharply reduce the temperature of the gas mixture from the first stage. A temperature of around 500 K is measured at the end of this zone.
- The third stage of the reactor is a stainless steel tube 300 mm long and 43 mm in inside diameter. The reaction products are further quenched in this column.

The entire process operates under slight negative pressure (≤ 30 mbar) to prevent leakage.

3.2 Waste injection

The oxygen is injected in the reactor via an alumina tube (4 mm inside diameter). Then, liquid chloroform (> 99% purity, Sigma-Aldrich, France) is introduced via an alumina tube (1.5 mm inside diameter); the two tubes form a coaxial cylindrical injection system (Figure 5B). As the chloroform passes through the tube already containing oxygen, the two reactants are mixed well before they enter into the plasma. The injection tube can be placed in several positions in the plasma. In this study the tube was positioned between the 5th and 6th coils from the top. As the system is hot, combustion begins in the lower part of the injection tube. We tested various flow rates for both CHCl₃ and O₂; Table 1 indicates the test conditions.
Table 1. Operating conditions.

| Parameters                  | Values                  |
|-----------------------------|-------------------------|
| Supplied plasma power       | 4 – 4.2 kW              |
| Pressure                    | $1 \times 10^5$ Pa      |
| Total argon flow            | 40 NL-min$^{-1}$        |
| Oxygen flow                 | 7 – 28 NL-min$^{-1}$    |
| Chloroform                  | 100 – 400 g·h$^{-1}$    |
| $O_2/CHCl_3$ molar ratio    | 15–30                   |
| Additional air flow         | 60 NL-min$^{-1}$        |

3.3 Gas analysis

Analysis was performed at two locations: i) just at the bottom of the reactor to measure the efficiency of plasma-reactor alone, ii) after the scrubber, in order to have the performance of the entire process.

A gas sample is analyzed continuously by a Fourier transform infrared spectrometer (Gasmet™ DX4000, Finland). The spectrometer output signal is updated every 20 seconds. It is capable of simultaneously analyzing more than 30 gaseous species, notably the following in our study: CHCl$_3$, HCl, CO$_2$, H$_2$O, CO, COCl$_2$. The instrument was calibrated with certified chloroform concentrations ranging from 0 to 200 ppm. The same method was used to calibrate the other species analyzed.

Cl$_2$ was identified by bubbling a fraction of the reactor off-gas stream through a NaOH solution, followed by a reaction with KI. The iodine generated was titrated with an aqueous solution of sodium thiosulfate, Na$_2$S$_2$O$_3$.

Just at the bottom of the reactor, the off-gas is trapped in an aqueous NaOH solution. The main reason for caustic scrubbing is to absorb and thus neutralize the acidity due to the major chlorinated species (Cl$_2$ and HCl) generated. The scrubbing solution pH is automatically adjusted when it drops below 9.

4. Results and discussions

Throughout the tests, the argon flow rate was maintained constant at 40 NL-min$^{-1}$. The plasma operating power was obtained by multiplying the instantaneous voltage and current readings; the power remained around 4.2 kW at all times (figure 6, curve A).

4.1 Gas temperature in the reactor

Gas temperature is the first parameter describes the good working of the process. figure 6 shows typical operating conditions, with the temperatures variations measured in the first stage of the reactor (curve B) and those recorded after the injection of cooling air (curve C). Table 2 describes the procedure. The air injection rapidly cooled the gas stream, as shown by a temperature difference of about 650°C between curves B and C.

After starting the plasma, the temperature rapidly increased as the electrical energy supplied to the plasma is converted into thermal energy. When thermal equilibrium is reached, the temperature at the bottom of the first stage is about 950°C (curve B, sequence 1). This temperature, measured relatively far from the plasma torch (29 cm from the tail of the plasma), is a good indicator of process performance.
4.2 Decomposition in the presence of oxygen and effect of molar ratio

Decomposition is clearly illustrated in figure 7, which compares the FTIR spectra before and after the destruction of CHCl₃. After injection in the plasma-reactor torch, the spectral properties of CHCl₃ clearly disappear. Peaks are observed for CO₂, HCl and H₂O.

![Figure 6](image6.png)

**Figure 6.** Plasma power (curve A) and gas temperatures (curve B: at the bottom of the first stage of reactor; Curve C: after air cooling) versus experiment time.

![Figure 7](image7.png)

**Figure 7.** FTIR spectra of CHCl₃ (A) before and (B) after plasma processing (the figure inset represents an enlargement of the lower part of B). CHCl₃ feed rate: 100 g·h⁻¹, O₂: 10 NL·min⁻¹.

The decomposition efficiency is calculated by equation (1):

\[
\text{Decomposition of chloroform (\%)} = \frac{\text{moles of CHCl₃ converted}}{\text{moles of initial CHCl₃}} \times 100
\]  

(1)

The results obtained under the different test conditions are indicated in the following table (table 3).

| Sequence Number | Time (min) | Description                                      |
|-----------------|------------|--------------------------------------------------|
| 1               | 0-36       | Heating with Ar plasma                           |
| 2               | 36-81      | 1st injection of O₂ (7 NL·min⁻¹)                 |
| 3               | 81-124     | Introduction of waste (100 g·h⁻¹)                |
| 4               | 124-164    | Increasing O₂ (10 NL·min⁻¹)                      |
| 5               | 164-212    | Increasing waste (150 g·h⁻¹)                     |
| 6               | 212-273    | Increasing waste (200 g·h⁻¹)                     |
| 7               | 273-304    | Increasing O₂ (14 NL·min⁻¹)                      |
| 8               | 304-320    | Increasing O₂ (20 NL·min⁻¹)                      |
| 9               | 320-350    | Process shutdown                                 |

Table 2. Experiment description.

The results obtained under the different test conditions are indicated in the following table (table 3).
Table 3. Conversion of CHCl₃ in inductively plasma reactor.

| CHCl₃ feed rate (g·h⁻¹) | O₂ (NL·min⁻¹) | CHCl₃ destruction (%) | Conversion to CO₂ (%) | Initial Cl conversion to HCl (%) | Conversion to Cl₂ (%) |
|-------------------------|--------------|-----------------------|-----------------------|---------------------------------|----------------------|
|                         | 7            | 99.95                 | 99.16                 | 32.70                           | 62.98                |
|                         | 10           | 99.96                 | 99.34                 | 31.55                           | 64.04                |
| 100                     | 7            | 99.09                 | 88.59                 | 31.14                           | ND                   |
|                         | 10           | 99.71                 | 99.67                 | 29.44                           | 66.75                |
|                         | 14           | 99.95                 | >99.99                | 28.72                           | 69.14                |
| 150                     | 14           | 99.70                 | 98.45                 | 27.40                           | 64.50                |
|                         | 17           | 99.95                 | >99.99                | 28.44                           | 70.00                |
|                         | 20           | 99.98                 | >99.99                | 26.38                           | 73.35                |
| 200                     | 20           | 99.96                 | 97.20                 | 24.88                           | ND                   |
|                         | 24           | 99.94                 | >99.99                | 24.32                           | ND                   |
|                         | 28           | 99.98                 | 96.18                 | 25.74                           | ND                   |
| 300                     | 20           | 99.96                 | 97.20                 | 24.88                           | ND                   |
|                         | 24           | 99.94                 | >99.99                | 24.32                           | ND                   |
|                         | 28           | 99.98                 | 94.33                 | 26.30                           | ND                   |
| 400                     | 20           | 99.96                 | 97.20                 | 24.88                           | ND                   |
|                         | 24           | 99.94                 | >99.99                | 24.32                           | ND                   |
|                         | 28           | 99.98                 | 94.33                 | 26.30                           | ND                   |

ND: Not determined

Near 100% destruction of the initial chloroform was obtained regardless of the chloroform injection rate (100–400 g·h⁻¹). When sufficient oxygen is injected, complete destruction of the initial chloroform is guaranteed. The energy efficiency increases with the chloroform injection rate up to a relatively high value of 100 g·kWh⁻¹ (i.e. 400 g·h⁻¹ CHCl₃ entirely degraded in a 4 kW plasma). For the same degraded compound, the energy efficiency is significantly improved in comparison with the previous study with liquid H₂O as the oxidant where the calculated value was 19 g.kWh⁻¹ [5]. The energy efficiency obtained here is also higher than reported by Föglen et al. [3] for thermal destruction of CHCl₃ by inductively coupled plasma, or by Krawczyk et al. [14] and Song et al. [4] for gliding plasma arc decomposition of chloroform.

Another parameter investigated was the oxidation factor or CO₂ conversion, corresponding to the final step of oxidation of the initial carbon based on the equilibrium curves in excess oxygen (figure 3). Negligible CO concentrations were present in the reaction off-gas; CO₂ was thus the main carbon specie measured by FTIR. The measured CO₂ production can therefore be a suitable performance indicator for this process. The CO₂ conversion factor was calculated with the following relation:

\[
\text{Fraction converted to CO}_2 (%) = \frac{\text{mole of CO}_2 \text{ produced}}{\text{mole of CHCl}_3 \text{ converted}} \times 100
\]  

Column 4 in table 3 shows very satisfactory conversion of the initial carbon. The conversion results are generally better than 90%, indicating that the initial carbon is effectively converted to CO₂. Although increasing the oxygen flow rate (and thus the molar ratio) reduces the temperature in the reactor under certain conditions (figure 6), the overall performance of the process was not affected by this temperature drop.

In addition to the conversion of the initial carbon to CO₂, it was very interesting to observe the fate of the initial chlorine. The fraction of initial Cl converted to HCl was calculated using the following relation:

\[
\text{Fraction converted to HCl (%) = } \frac{\text{mole of HCl produced}}{3 \times \text{mole of CHCl}_3 \text{ converted}} \times 100
\]  

Between 25% and 33% of the initial chlorine was converted to HCl (table 3, column 5). For each chloroform injection rate, the overall percentage of Cl converted to HCl tends to diminish when the oxygen flow rate increases (i.e. for increasing excess oxygen). The same behavior was reported by Huang et al. [8] for plasma decomposition of C₂HCl₃ in the presence of oxygen. Our findings are consistent with calculations at thermodynamic equilibrium (figure 2 Left and figure 3) showing that
excess oxygen is unfavorable to the formation of HCl: the oxygen atoms capture hydrogen atoms to form H2O molecules instead. Most of the Cl atoms thus remain in the form of Cl2 molecules.

To confirm this hypothesis, Cl2 was measured. The test results are shown in the last column of table 3. Cl2 is indeed formed; the chlorine balance shows that, regardless of the test conditions, more than 95% of the initial chlorine is finally present as HCl and Cl2.

4.3 Influence of the initial chloroform concentration

To assess the possible influence of the initial waste concentration, the O2/CHCl3 molar ratio was maintained at 20, while the initial chloroform concentration in the initial mixture (CHCl3 + O2 + Ar) varied from 0.7 mol% to 2 mol% and the oxygen concentration was adjusted to maintain a constant molar ratio. The results are shown in figure 8 for the decomposition rate of CHCl3 and its conversion to CO2 and HCl.

![Figure 8](image)

The overall decomposition of CHCl3 exceeds 99% and varies only slightly in the range studied. The initial concentration has a minor effect on the conversion to CO2. The curve decreases slightly as the initial CHCl3 concentration increases. For example, the CO2 conversion factor decreases from 99% to 94% when the concentration increases from 0.7 to 2%. Since the O2/CHCl3 molar ratio is constant, increasing the CHCl3 concentration also increases the O2 concentration; the argon concentration therefore diminishes in the initial mixture. Argon is not only the plasma gas, but also the energy transfer vector. Consequently, as the argon concentration increases, the amount of excited argon Ar* increases in the plasma and the degree of conversion of the reactants also increases due to the greater frequency of collisions. In addition, when the CHCl3 concentration increases, the plasma energy density available for degradation diminishes. The lower available energy could account for the observed reduction in the conversion factor of CHCl3 molecules to CO2. Similarly, figure 8 shows that the overall molar conversion of initial Cl to HCl diminishes when the initial CHCl3 concentration increases. As the oxygen concentration also increases with the initial CHCl3 concentration, and the global Cl conversion to (HCl + Cl2) remain constant, the lower HCl conversion rate can be attributed to the Deacon reaction by which HCl is converted to Cl2 in the presence of oxygen according to the following overall equation:

\[
4\text{HCl}_\text{(g)} + \text{O}_2\text{(g)} = 2\text{Cl}_2\text{(g)} + 2\text{H}_2\text{O}_\text{(g)}
\]

4.4 Off-gas quality

Chloroform injected into the plasma is destroyed and converted mainly to CO2, HCl, Cl2, and H2O. However, it is very important to check the level of oxy-chlorinated byproducts from decomposition. We present on the table 4, the maximum quantities of phosgene obtained for the various CHCl3 injection rates are indicated.
Table 4. Maximum phosgene release per chloroform injected.

| Initial composition | COCl₂ conc. (ppm) | Mass of COCl₂ released (g·h⁻¹) |
|---------------------|-------------------|-------------------------------|
| CHCl₃ (g·h⁻¹) | O₂ (NL·min⁻¹) ||
| 100            | 7             | 11                   | 0.30           |
| 150            | 14            | 12.5                 | 0.37           |
| 200            | 20            | 30                   | 0.93           |
| 300            | 20            | 22.5                 | 0.70           |
| 400            | 20            | 28                   | 0.93           |

The maximum release rate was almost 1 g·h⁻¹ for waste injected at a CHCl₃ rate of 400 g·h⁻¹. Current French legislation requires that the phosgene gaseous effluents maximum permissible hourly flow rate is 10 g·h⁻¹, but if this value is exceeded, the release concentration limit is 1 ppm [15]. Table 4 clearly shows that the maximum phosgene formation rate from plasma reactor was well below the limit.

Concerning the overall off-gas quality (outlet the scrubber), Cl₂ and HCl formed by decomposition of CHCl₃ must not be released untreated into the atmosphere. One technique for their simultaneous trapping is their reactions in excess NaOH to form mineral salts.

At the outlet of the scrubber, the FTIR spectrum shown in figure 9 indicates that the final gas stream after destruction of CHCl₃ consists only of CO₂ and H₂O.

Figure 9. FTIR spectra of the final exhaust gas.

5. Conclusion

The effective destruction of chloroform - a model of liquid organochlorine - is proven using argon inductively plasma with oxygen as oxidant to obtain complete and safe destruction and minimize the energy losses observed in the original process when liquid water was used as the oxidant. Near-100% decomposition regardless of the test conditions with relatively high energy efficiency of 100 g.kWh⁻¹ and a satisfactory destruction rate (up to 400 g·h⁻¹) were achieved. CHCl₃ was converted to CO₂, Cl₂ and HCl and the production of toxic such as COCl₂ was limited (≤ 1 g·h⁻¹). These experimental results are very near the values predicted by thermodynamic simulations. The chlorinated acidic produced were suitably trapped in an aqueous soda scrubbing column before release of the final off-gas into the atmosphere with [Cl] < 1 ppm.

The system presented in this work can be considered as a clean technology for the destruction of liquid organohalogens with the advantage of direct liquid waste injection into the plasma without any prior evaporation or treatment. These results are of considerable importance for industrial applications. The final objective of this study is to use this reactor for small-scale treatment of radioactive chlorinated organic liquid waste. The waste is contaminated by ¹⁴C and ³H. The encouraging results and destruction efficiency observed on a pure compound containing 89 wt% Cl allowed us to validate this small-scale unit. The process can subsequently be installed in a radioactive zone to test the destruction of actual radioactive waste. The transfer operations are currently in progress.
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