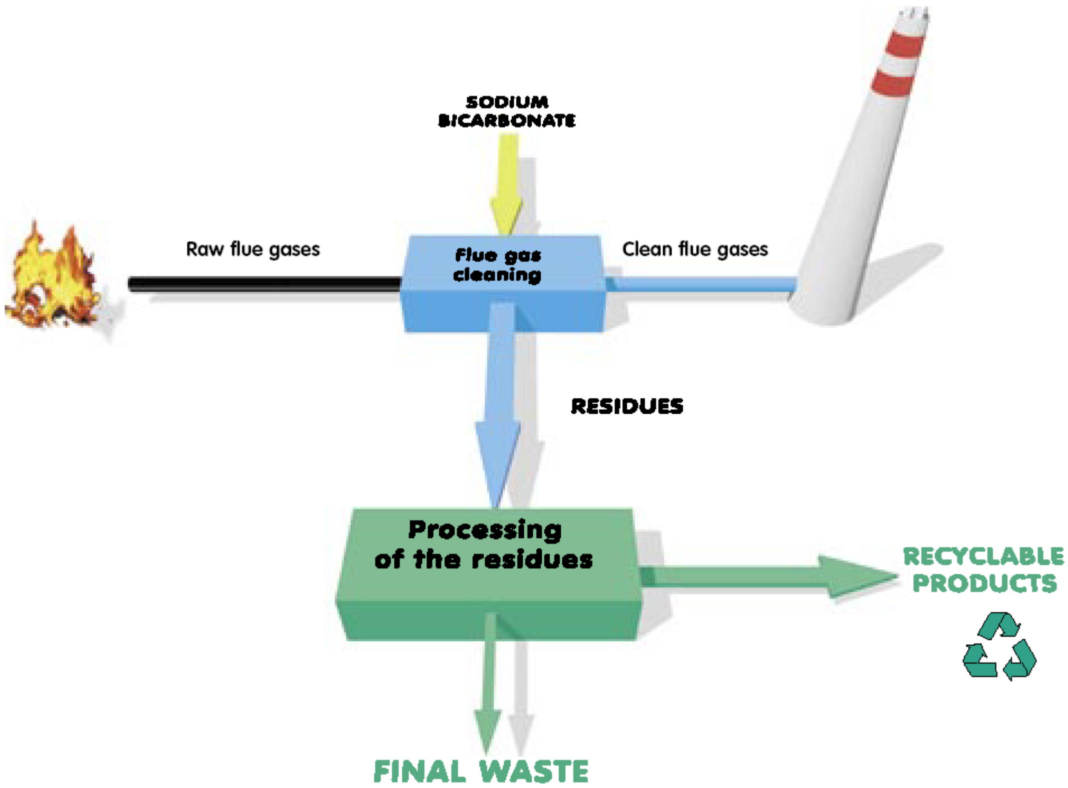
WASTE INCINERATION FLUE GAS CLEANING

DRY SCRUBBING SYSTEM WITH BAGS FILTER

Waste management is one of the biggest challenges facing our industrialized societies at the beginning of the 21st century.
Solutions must promote sustainable development by contributing without delay to the responsible management of nonrenewable natural resources.
Cleaning the flue gases produced by the industry and by the waste incineration processes makes it possible to preserve the quality of the air we breathe. But this is also an industrial process, which creates residues that must be managed with the same aim of preserving the environment as well as nonrenewable resources.
Da qui una soluzione globale attraverso due fasi: la neutralizzazione ed il recupero.
The proposed dry flue gas cleaning system, consists of two stages:

1. The dry flue gas cleaning;
2. The treatment and recovery of the Residual Sodium Chemicals (or **RSCs**) resulting from the filtration.



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DESCRIPTION OF THE PROCESS

The flue gas cleaning process is based on the injection of dry, finely ground Sodium bicarbonate into the gases to be purified.
The sodium bicarbonate neutralizes the acids (Hydrochloric acid, Sulphur dioxide, Hydrogen fluoride, etc.) with a very high degree of effectiveness. Heavy metals and Dioxins/Furans are removed by adding active Carbon or Lignite coke to the Sodium bicarbonate. This reagent combination meets the most stringent legal standards.
The by-products of the acid neutralization are Sodium salts (Sodium chloride, Sodium sulphate, Sodium fluoride, Sodium carbonate, etc.), known as Residual Sodium Chemicals (or **RSCs**). These are then filtered out of the flue gases.
As the process is totally dry, there are no effluents to be treated.
By mean of this innovative technology a complete solution is finally given to several incineration problems, like:

- **Air pollution;**
- **the mass of the final waste to be disposed of;**
- **consumption of nonrenewable natural resources.**

Below are described in more detail the stages of the process.

DRY FLUE GAS CLEANING PROCESS

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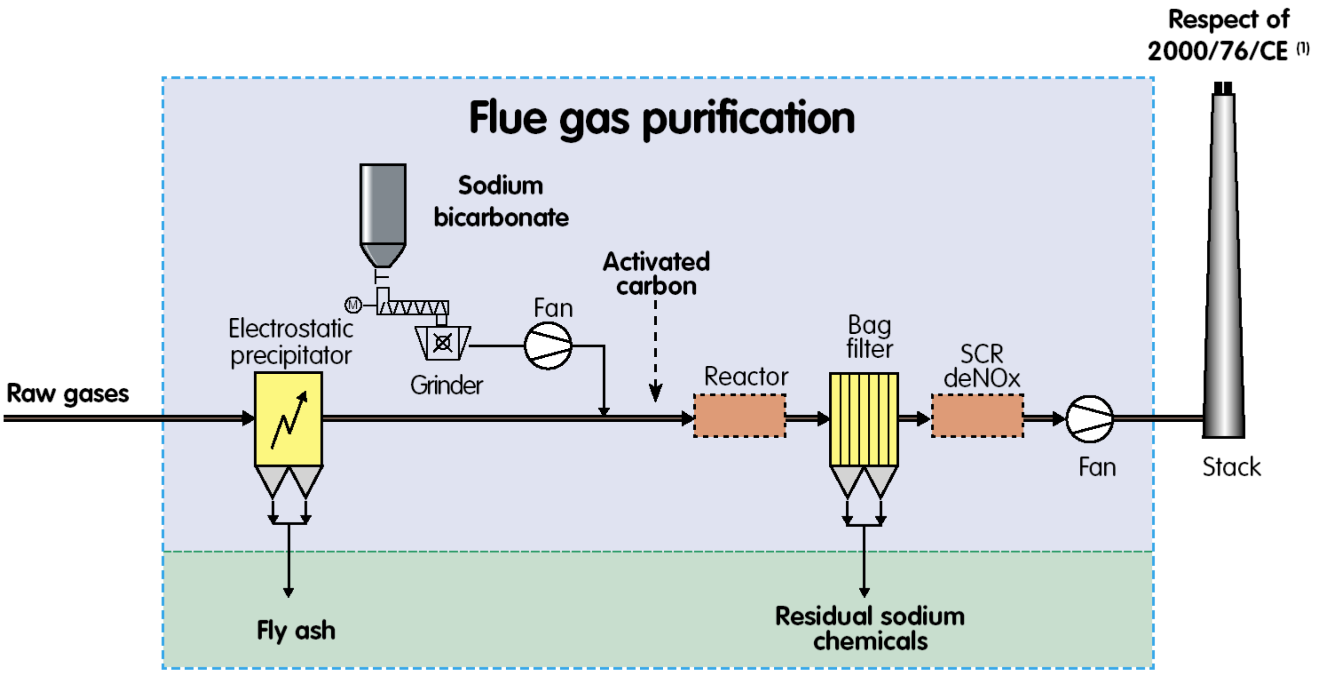


(1) European Parliament and Council Directive 2000/76/EC dd 4th December, 2000 concerning the waste incineration.

Whilst the nature of the raw flue gases depends largely on the combustion process producing them, generally they do contain:

- Dust (fly ash)
- Acid components: Hydrochloric acid (**HCl**), Sulphur dioxide (**SO_2**), Hydrogen fluoride (**HF**) and Nitrogen oxides (**NO** and **NO_2**), etc.
- Heavy metals (Lead, Mercury, Cadmium, etc.)
- Dioxins and Furans

The Sodium bicarbonate which is stored in a silo or in bulk-bags, depending on the application, is ground to an optimal grain size and immediately injected into the flue gas. A contact reactor is used where a residence time of one second cannot be reached in the flue gas.

The Sodium bicarbonate neutralizes the acids which are present in the flue gases (particularly Hydrochloric acid, Sulphur dioxide, Hydrogen fluoride) to form sodium salts (Sodium chloride, Sodium sulphate, Sodium fluoride, Sodium carbonate). These are the Residual Sodium Chemicals (or RSCs).

Sodium bicarbonate also has the property of adsorbing heavy metals, Dioxins and Furans. By adding moderate amounts of activated Carbon or Lignite coke, injected jointly with the Sodium bicarbonate, allows to meet the most stringent legal standards requirements.

The dry residues from flue gas cleaning (including any activated carbon or lignite coke and the fly ash in the absence of a first filtration) are captured by a bag filter, collected and placed in a silo. It should be noted that the acids in the flue gases are neutralized not only upstream the filter but in the layer of solids (filtration cake) which are deposited on the bags themselves, too.

Where appropriate, gases leaving the bag filter are cleaned of NOx in a catalytic system (SCR).

The process produces very favorable pre-conditions for the catalytic de-NOx process, as the operating temperatures are high (up to 200 °C, and even higher in certain cases) and SOx are substantially removed, avoiding the need to reheat the gases before entering the de-NOx SCR process.

Where a first filter is used for dedusting the flue gases before injecting the Sodium bicarbonate, we talk about a double filtration process. Differently we talk about a simple filtration process.

The clean gases are sucked into the stack by a fan. Their temperature is sufficient to avoid the presence of a smoke wreathe at the mouth of the stack, even without re-heating.

WHAT ARE THE CHEMICAL REACTIONS?

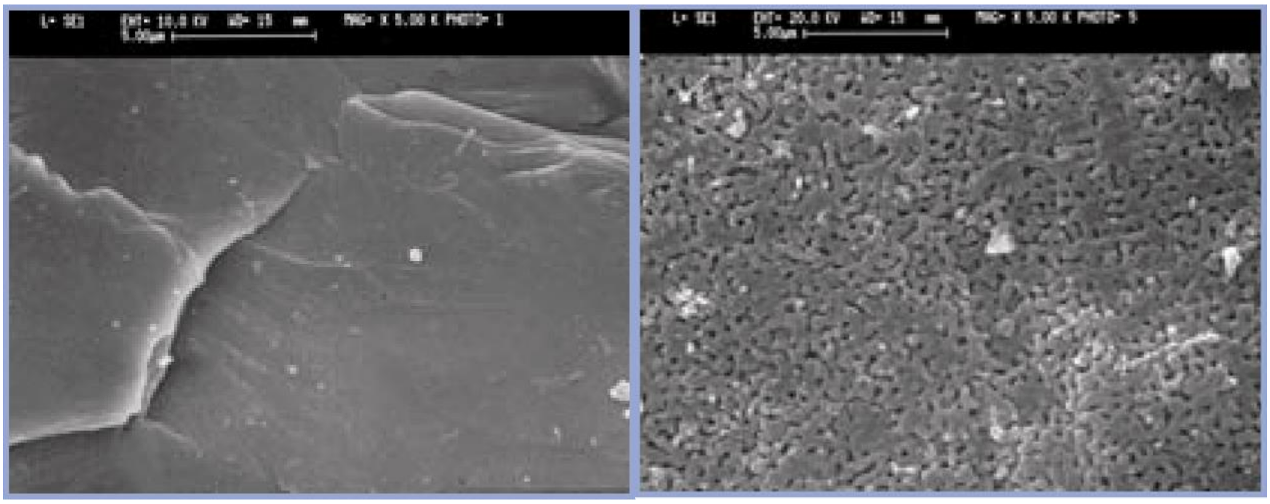
The overall chemical reactions of acid neutralization using sodium bicarbonate are presented below:

$$NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$
$$2\ NaHCO_3 + SO_2 + \tfrac{1}{2}\ O_2 \longrightarrow Na_2SO_4 + H_2O + 2\ CO_2$$
$$NaHCO_3 + HF \longrightarrow NaF + H_2O + CO_2$$

Why is Sodium Bicarbonate so effective?

Acid neutralization using Sodium bicarbonate involves a stage of thermal activation: brought into contact with the hot flue gases, the Sodium bicarbonate converts rapidly into sodium carbonate, with a high specific surface and porosity (see the electron microscope images below).

$$2\ NaHCO_3 \longrightarrow Na2CO_3 + CO_2 + H_2O$$



a) Sodium bicarbonate prior to thermal activation: very smooth grain surface.

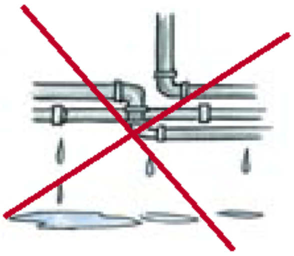
b) Sodium carbonate with a high specific surface after thermal activation of the sodium bicarbonate: highly porous grain surface.

The conversion of the Sodium bicarbonate into ‘activated carbonate’ makes the process an excellent way to neutralize acids (Hydrochloric acid, Sulphur dioxide, Hydrofluoric acid, etc.) and adsorb heavy metals, Dioxins and Furans.

At what temperature is Sodium bicarbonate effective?

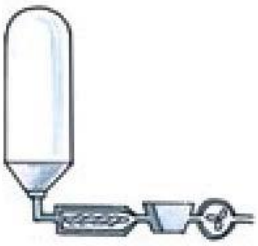
Thanks to the properties of Sodium bicarbonate, the dry scrubbing process remains effective across a wide range of flue gas temperatures, ranging from 140 °C to over 300 °C, and even beyond this range under certain conditions. Very high temperature applications (around 600 °C) also exist.

THE ADVANTAGE OF THE PROCESS: EASY AND FLEXIBLE APPLICATION



Dry Process

- Does not require any water (therefore, no effluents):
  - for the reagent preparation
  - as purifying agent



Very simple installation

- The needed equipment are very few and simple:
  - no reagent preparation tanks
  - no pulverization system
  - no washing tower
  - no specific Dioxins filters required

Easy to use reagent

- Sodium bicarbonate is a neutral, non-corrosive, non-irritant and non-toxic product, which is easy to handle and can be used in a wide range of operating conditions.

Easy Implementation

- The use and maintenance of this process are so simple and flexible that people used to other systems will be rather surprised: easy stop and start, no choking, no corrosion, easy-to-handle reagent, high productivity, etc.

Flexible operation

- The process stands effective over a wide range of flue gas temperatures, avoiding the need for precise temperature control. Furthermore, this process allows the use of additives for the caption of Dioxins and Furans in optimized conditions.

Prompt adjustment to the evolution of emission standards

• Whenever new and stringent emission limits shall come into force, only the modification of the operating parameters will be needed. No change of/to the equipment required.

EFFECTIVENESS

The flue gas cleaning process with Sodium bicarbonate allows to stay well below the most stringent standard emissions limits, while using very low quantities of reagents.

Compliance with the stringent European and Worldwide emissions limits standards

This process allows the full compliance with::

- European directive 2000/76/EC concerning the incineration and the co-incineration of industrial and municipal solid waste (NOx excluded);
- the most stringent legislation in other application areas.

Legislation		Directive 2000/76/EC replaces Directives 89/369/EEC, 89/429/EEC and 94/67EEC
Publication		4 December 2000
Type of waste		Industrial and municipal solid waste
Pollutant	Units	
Total dust	(mg/Nm³)	10
Total organic carbon	(mg/Nm³)	10
Hydrochloric acid (HCl)	(mg/Nm³)	10
Hydrogen . uoride (HF)	(mg/Nm³)	1
Sulphur dioxide (SO_2)	(mg/Nm³)	50
Nitrogen oxides (NOx)	(mg/Nm³)	200 (> 6 t/h) 400 (< 6 t/h)
Cadmium + Thallium (Cd + Tl)	(mg/Nm³)	0.05
Mercury (Hg)	(mg/Nm³)	0.05
Other heavy metals (total)	(mg/Nm³)	0.5
Dioxins / Furans (PCDD/F)	(ng TE/Nm³)	0.1

Reference conditions: dry gas temperature 273 K; pressure 101,3 kPa; Oxygen content 11% v/v

Low reagent consumption

- Where the installation is designed and managed according to the process guidelines, all the above quoted emission limits can be respected with low stoichiometric excesses, typically below 25%.

Performance guarantee

- Provided the installation is designed and managed according to the process guidelines, the emissions limits compliance can be guaranteed.

COST EFFECTIVENESS

Minimum equipments requirement

- The simple and reduced equipment requirements involve lower investments.
- The whole equipment takes up little space.
- In many cases the existing installation can be used or integrated.
- The removal of Dioxins and Furans does not require specific equipment other than the activated Carbon or Lignite coke injection system.

Reduced maintenance costs

- The simpleness of the equipment added with the lack of water use in the gas treatment process ensures very low maintenance costs (about 2% on the investment).
- The reduced maintenance requirement allows a higher work flow.

No effluents treatment plant

- As this is a dry process there are no needs for the treatment of effluents: thus no investment and no operating costs.

Little amount of final waste to be dumped

- The effectiveness of Sodium bicarbonate reduces the quantity of Residual Sodium Chemicals (or RSCs) produced.
- Recycling of the purified RSCs minimizes the quantity of final waste, thereby considerably reducing the cost of tipping.

RISPETTO DELL'AMBIENTE

No effluents or emissions of pollutants

- As the flue gas cleaning process is completely operated in dry conditions, it releases only solid residuals. Unlike in the wet processes, there are no effluents to be sent into sewage tanks.

Minimum final waste amount

Recycling and conservation of non-renewable resources

- The high degree of efficiency of both reagent and process minimizes the quantity of residual Sodium chemicals. Yet the Sodium nature of these products allows them to be recycled many a time (after purification), thereby decreasing substantially the consumption of non-renewable resources and at the same time the amount of final waste to be dumped on landfill sites.

No vapor wreath at the chimney-stack

- As the process is fully developed with dry filtration and does not require any substantial cooling of the flue gas, there is will be no water vapor wreathe at the stack mouth

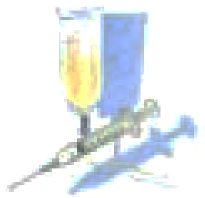
APPLICATION SECTORS

The main sectors of the waste-to-energy operations, are:

- **Municipal Solid Waste**

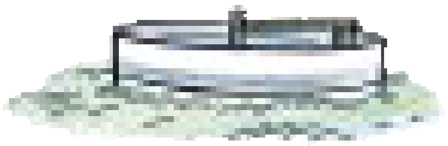
- **Industrial and Pharmaceutical Special Waste**

- **Hospital waste**



- **E.o.L Tyres**

- **sewage sludge**



CERTIFIED REMOVAL PERFORMANCES

ITALY - Incineration of municipal solid waste and hospital waste (*BETTER THAN REQUIRED BY EU NORM 2000/76*)

	Units	Characteristics of the flue gases before treatment	Limits to be respected (1)	Values obtained with S.R. ≈ 1.3 (2)
Temperature Dry gas flowrate ($11\%\ O_2$)	°C Nm^3/h	200 18,000		
HCl	mg/Nm^3	1,000 (average content)	30	5
SO2	mg/Nm^3	150 (average content)	200	2
HF + HBr	mg/Nm^3		1	
HEAVY METALS				
• Sb + Pb + Cr + Cu + Mn + Ni + As + Co + V + Sn	mg/Nm^3	± 10	0.5	< 0.05
• Cd + Tl	mg/Nm^3	± 0.5	0.05	< 0.05
• Hg	mg/Nm^3	± 0.5	0.05	< 0.05

(1) Legislation: decree n° 503 of the Department of the Environment related to municipal solid waste incineration, special non-dangerous waste and contagious hospital waste
(2) S.R. = Stoichiometric Ratio

FRANCE - Incineration of municipal solid waste (*BETTER THAN REQUIRED BY EU NORM 2000/76*)

	Units	Characteristics of the flue gases before treatment	Limits to be respected (1)	Values obtained with S.R. ≈ 1.3 (2)	Values obtained (1) with S.R. <1.15 (2)
Temperature Dry gas flowrate ($11\%\ O_2$)	°C Nm^3/h	180 - 200 25,00 - 28,000			
HCl	mg/Nm^3	500 - 800 - 2,000 (mini-average-maxi)	50	5	9
SO2	mg/Nm^3	20 - 100 - 500 (mini-average-maxi)	300	2	5
HF + HBr	mg/Nm^3	10	2		< 1
HEAVY METALS AT 7% CO_2					
• Cu + Pb + Zn + Ni + Cr + Sn + Ag + Co + Ba	mg/Nm^3	± 50			
• Cd + Hg	mg/Nm^3	± 1			
• As	mg/Nm^3	± 10			
Dioxins / Furans	ng TE/ Nm^3	13.4 25.7	0.1 0.1	0.02 (3)	0.02 (3)

(1) average daily values
(2) S.R. = Stoichiometric ratio

(3) with activated carbon at < 50 mg/m3 flue gases

FRANCE – Incineration of special industrial waste (*BETTER THAN REQUIRED BY EU NORM 2000/76*)

	Units	Characteristics of the flue gases before treatment	Limits to be respected (1)	Values obtained with S.R. < 1.2 (2)
Temperature Dry gas flowrate ($11\% O_2$)	°C Nm^3/h	240 60,000 - 80,000		
HCl	mg/Nm^3	3,600 Average (6.000) max.	10	6 to 8
SO_2	mg/Nm^3	100 Average (2.000) max.	50	13 to 18
HEAVY METALS • Hg	mg/Nm^3	0.5	0.2	0.03 (3)

(1) average daily values
(2) S.R. = Stoichiometric ratio
(3) with activated carbon at < 50 mg/m3 flue gases

AN EXAMPLE OF THE PROCESS FLEXIBILITY

The performance recorded on an industrial site equipped with the dry scrubbing system of the flue gas shows how the installation can be easily adjusted to the variation of the imposed emission limits.

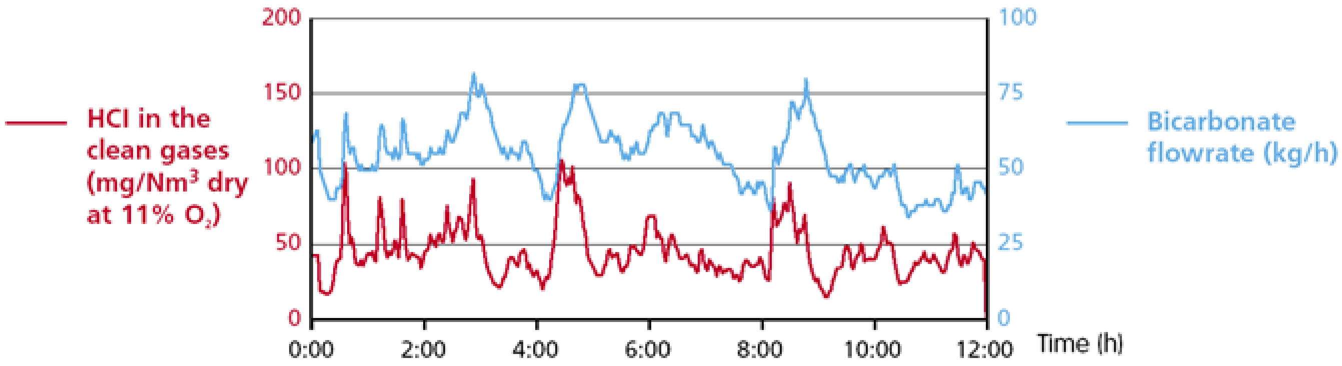
The records evidenced here below refer to a 12 hour operation period for both cases:

- **CASE #1**: meeting the required average HCl emission limit of 50 mg/Nm^3 dry at 11% O_2
- **CASE #2**: meeting the required average HCl emission limit of 10 mg/Nm^3 dry at 11% O_2

To switch from the first to the second case, all the operator had to do was adjust the control parameters of the Sodium bicarbonate flow. This was automatically adjusted and no further action was required.

	Unit	Case 1: "respect 50 mg"	Case 2: "respect 10 mg"
Average HCl content	mg/Nm^3 dry at 11% O_2	45	9
Average sodium bicarbonate flowrate	Kg/h	54	63
Average stoichiometric ratio		1.05	1.15

Case #1: Respect of an emission limit of 50 mg HCl/Nm³ dry at 11% O_2 (daily average)



Case #2 : Respect of an emission limit of 10 mg HCl/Nm³ dry at 11% O_2 (daily average)