INCINERATION AND INDUSTRIAL FLUE GAS TREATMENT

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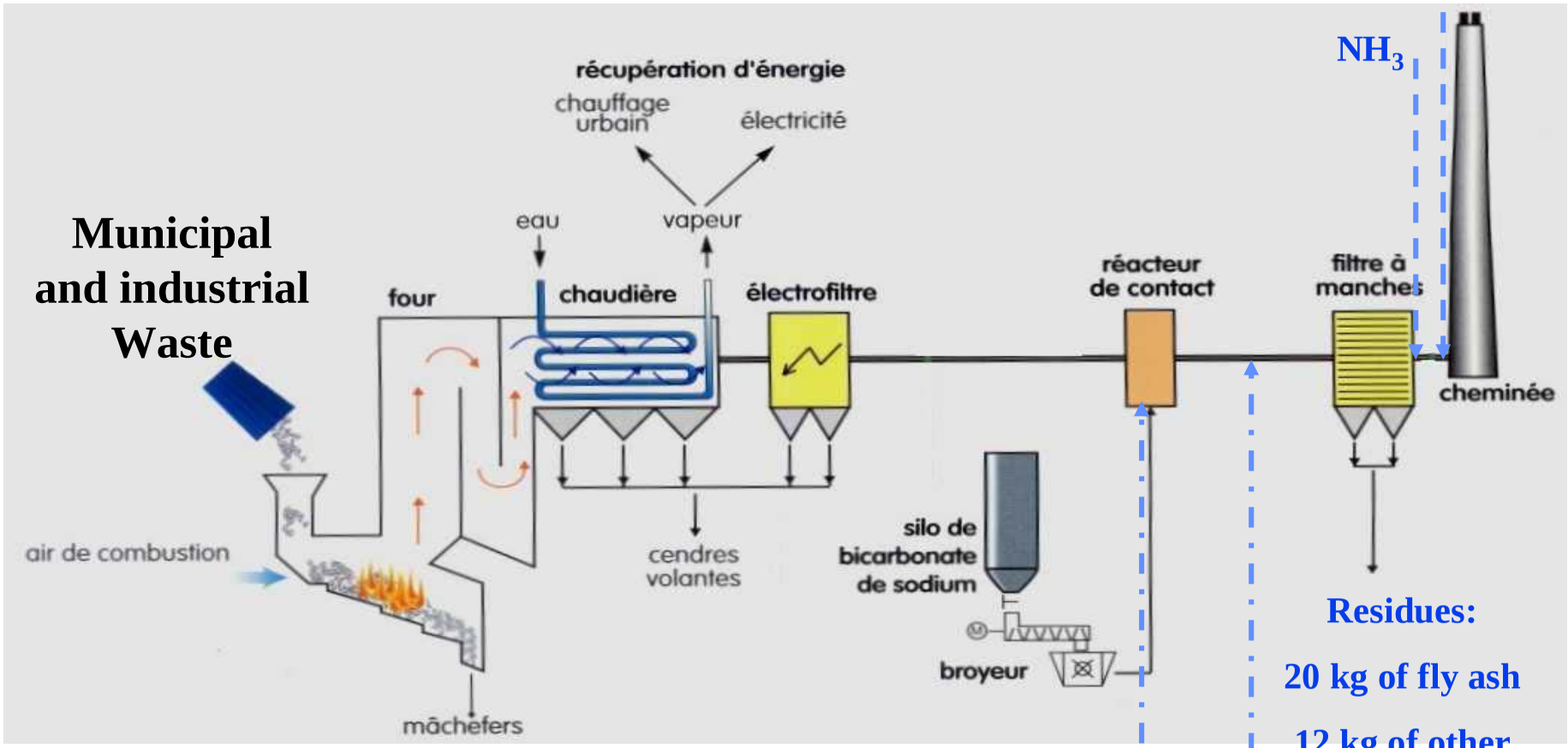
INCINERATION PROCESS



Behavior:

- **Stabilization with cement or concrete**
- **Landfill**

Pollutant treatment techniques

- **1 Neutralisation of HCl et SO2 from gas**
  - **Dry process** — low investments, excess of neutralization agent (na)
  - **Semi-wet process** — no wet emissions, moderate amount of na (additive)
  - **Wet process** — efficient, although wet emissions , heavy investment
  - **Process using sodium bicarbonate (Neutrec)** — recycling of salts
- **2 Scrubbing of NOx** — résidus solides minimum
  - **Catalytic process (SCR)** — delicate, expansive, heating of gas
- **3 Scrubbing of heavy metals and organics using actived charcoal**

  end of line treatment to match the emission standard
- **4 Dust removal** — efficient techniques available

1- Neutralization of SO_2 and HCl

- **Neutralization reactions**
  - **Semi-wet process:**

$CaO + H_2O \longrightarrow Ca(OH)_2$, less soluble: pS= 5,9 $(Ca^{++})(OH^-)^2 = 10^{-5,9}$

$SO_3 + Ca(OH)_2 \longrightarrow CaSO_4 + H_2O$ stoichiometry: 0,7 kg CaO / kg SO_3

less soluble: pS= 4,6: $(Ca^{++})(SO_4^{--}) = 10^{-4,6}$

$SO_2 + 1/2\ O_2 + Ca(OH)_2 \longrightarrow CaSO_4 + H_2O$ stoichiometry : 0,583 kg CaO / kg SO_2

less soluble

$2\ HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2\ H_2O$ stoichiometry : 0,767 kg CaO / kg HCl

soluble

$2\ HF + Ca(OH)_2 \longrightarrow CaF_2 + 2\ H_2O$ stoichiometry : 1,4 kg CaO / kg HF

  - **Wet process:**
    - **NaOH:**
    - **$CaCO_3$:** not soluble, (low base H_2CO_3 pK1= 6,4 pK2= 10,2)
  - **Dry process: CaO**
- **Processes**
  - **Dry:** dry reactants and dry products
  - **Semi-wet:** suspension (reactant) and dry products
  - **Wet:** suspension (reactant) and wet products

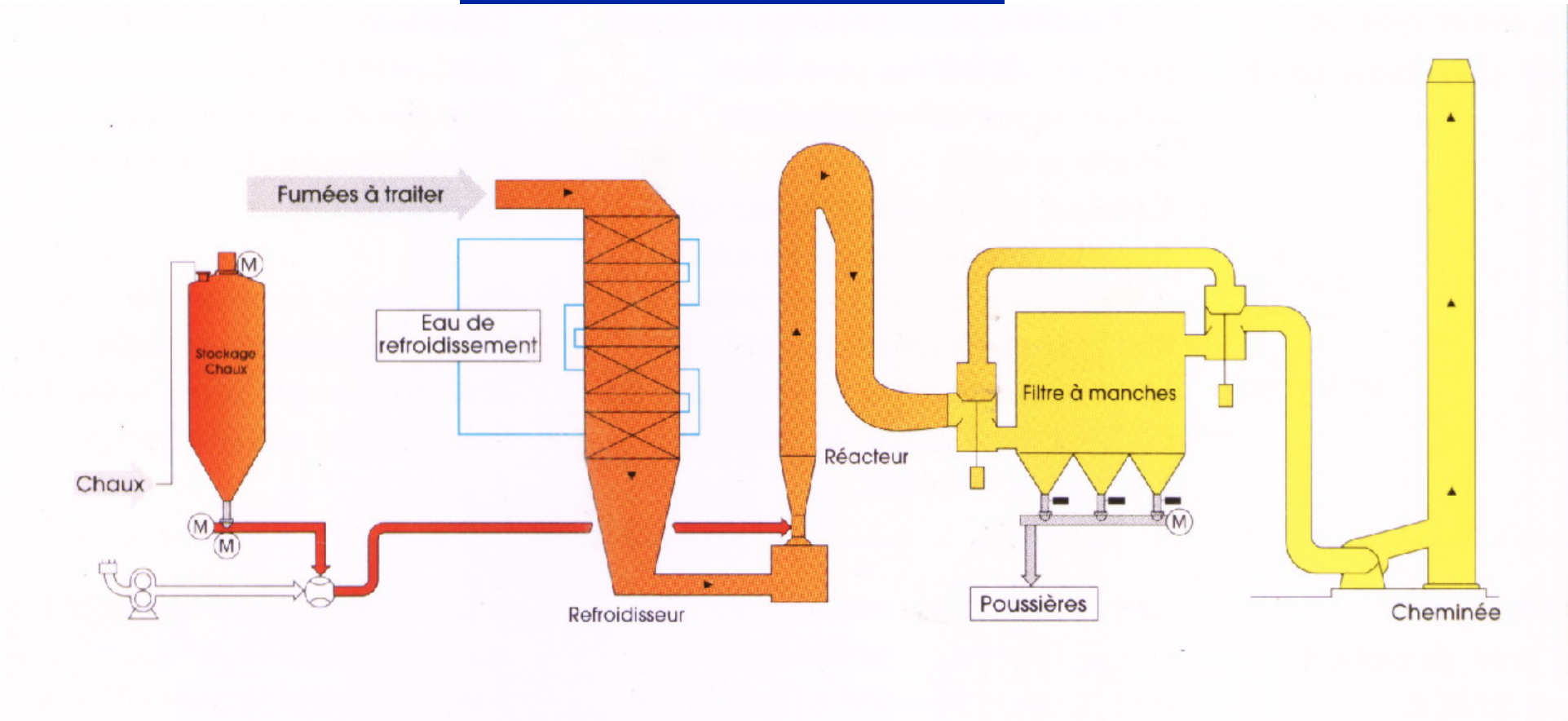
1.1 Dry process

- **Principles**
  - CaO sprayed into gas
  - Generation of contact between the gas and additive and filtration $CaO + 2HCl \rightarrow CaCl_2 + H_2O$

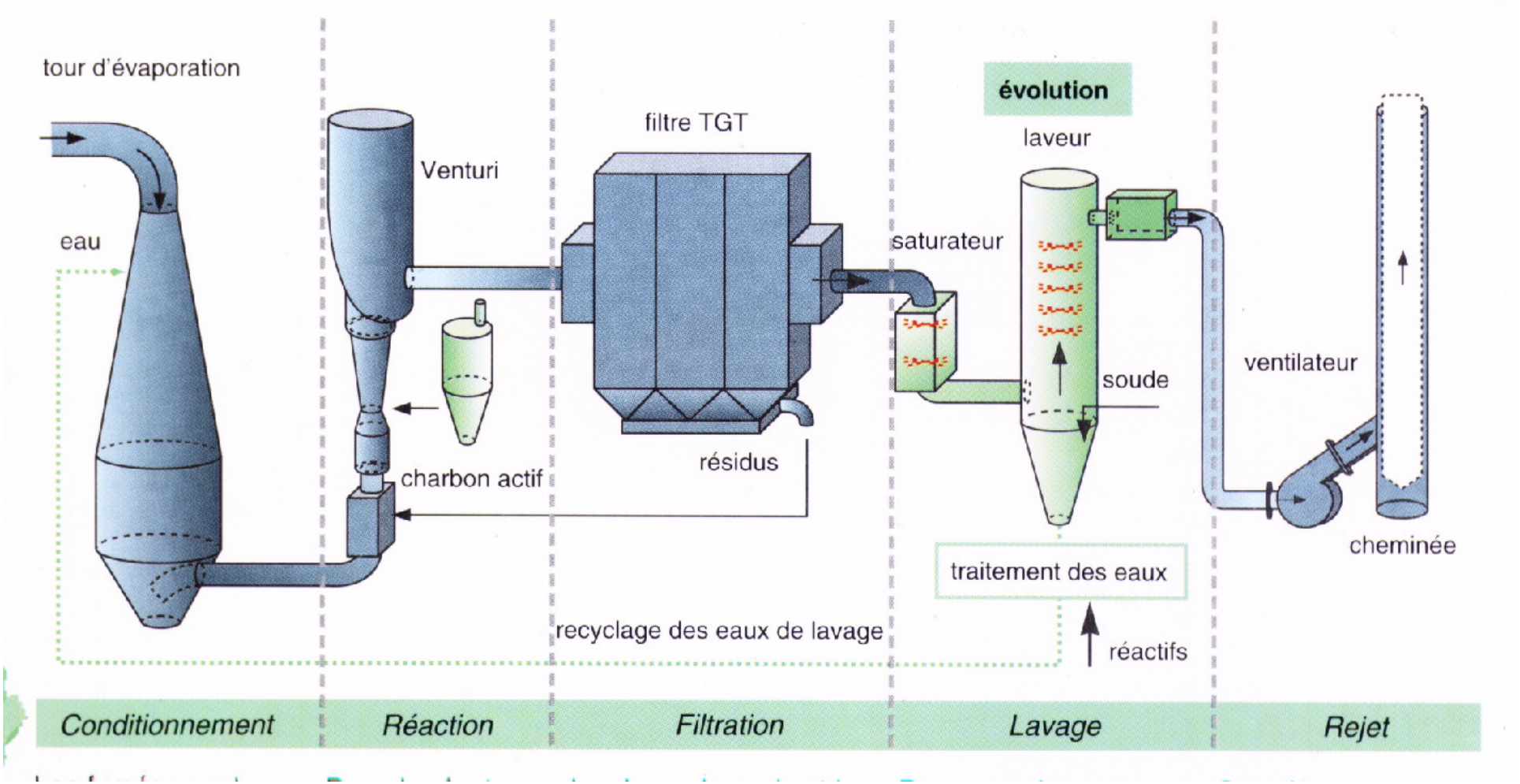
    $CaO + SO_2 + 1/2\ O_2 \rightarrow CaSO_4$
- **Key characteristics**
  - Lime sprayer for a good distribution of the gas
  - venture to generate the turbulence and needed contact between the gas and lime (6 to 8s)
  - Filter in which dust contributes to the neutralization (30s)
  - Cooling and humidification (140 to 150°C) to increase the reactivity of the lime
- **Performance**
  - Neutralization rate HCl: 90 / 95 %
    SO2: 50 / 70 %
    metals (particles) > 90%
  - Additive consumption: 20 kg/t : stoichio * 2,2
    electricity: 25 kWh/t
  - Residues: 50kg/t ash: 20 salts: 20 lime: 11

- **Advantages**
  - free of liquid emissions
  - simplistic
  - low investment cost
  - economically reliable if < 4t/h
- **Disadvantages**
  - excess of lime
  - significant amount of fly ash generated (ash, salt, lime)
- **Alternative**
  - provide a cleaner downstream
  - add a filter to lower the SO2 and HCl
  - addition of activated charcoal

Dry process


Fumées à traiter
Eau de refroidissement
Stockage Chaux
Chaux
Réacteur
Filtre à manches
Poussières
Refroidisseur
Cheminée

Dry process (alternative)



1.2 Semi-wet process

- **Principles**
  - Preparation of the suspension (lime)
  - Atomization in the gas
  - Reaction and filtration
- **Key characteristics**
  - Rotary atomizer for the pulverization
  - Absorption column/ reaction (15 / 20s)
    - Absorption of HCl in water
    - Neutralization of HCl and SO2
    - Drying of the residue and oxygenation S03
  - Filter to achieve the neutralization of S02
  - Control of the reactive flow rate /pH and water /T
- **Performances**
  - Neutralization rate HCl: 95 / 98%
    SO2: 75 / 85%
    metals (particles): > 90% (FAM)
  - Additive consumption : 15 kg/t (stoichio * 1,7)
    water: 300 kg/t
    electricity: 25kWh/t
  - Residues: 46kg/t: ash: 20 salt: 20 lime: 6

- **Advantages**

- moderate investment
- low operating cost
- no liquid effluent - good purification performance
- quench with water

- **Disadvantages**

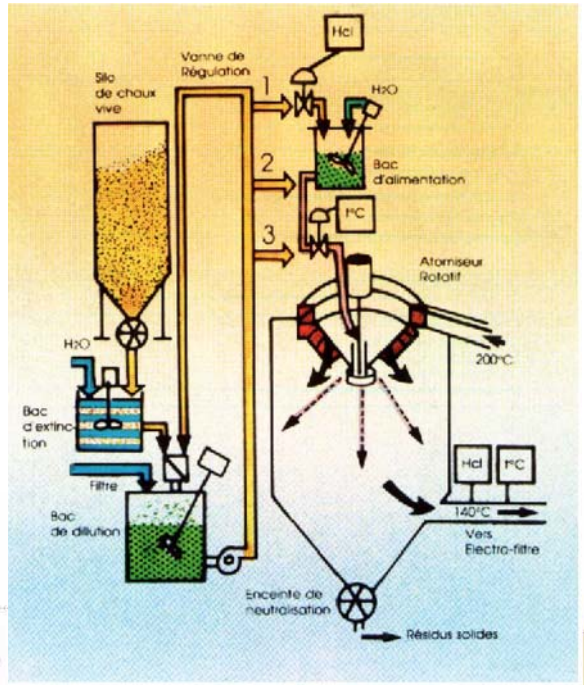
- mixed residues
- more complex:

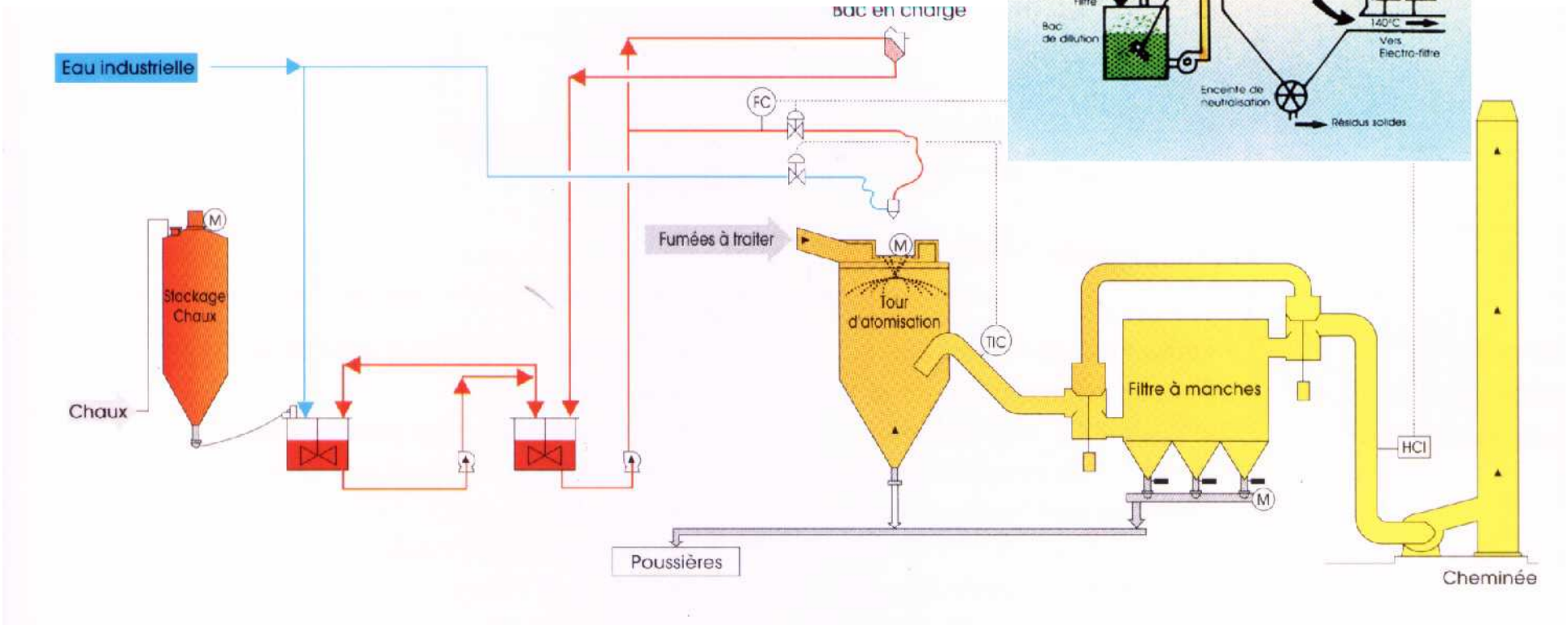
preparation of lime suspension, rotary atomizer

- **Alternatives**

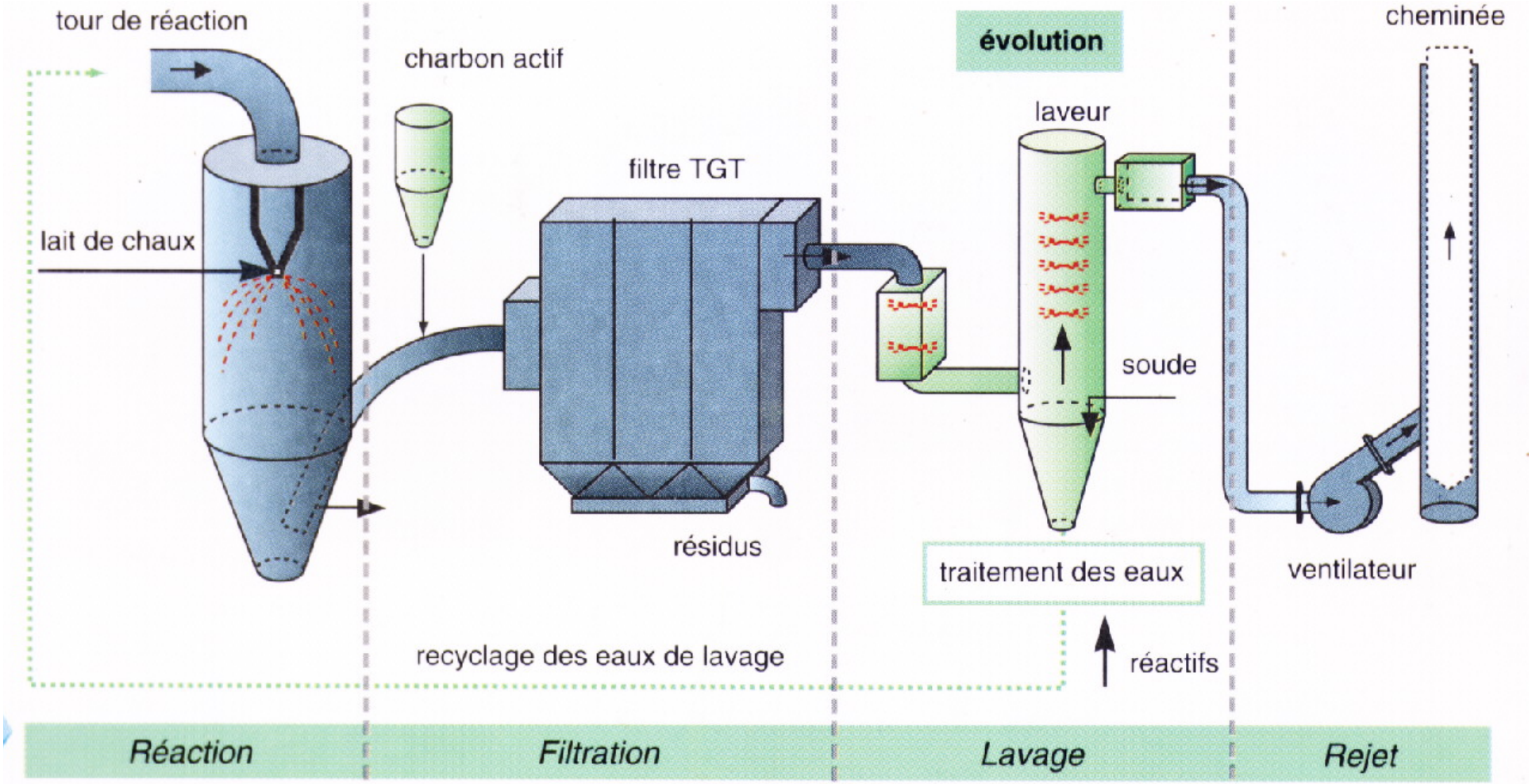
- vacuum-clean before-hand
- neutralization (to separate salts from ash)
- addition of a cleaner to improve the purification of SO2
- addition of activated charcoal

Semi-wet process





Semi-wet process (alternative)



1.3 Wet process

- **Principles**
  - Filtration with an electro filter
  - Quench at 65°C
  - Acid cleaning with water for HCl, HF, Hg
  - Basic cleaning with NaOH for SO2
  - Eventual reheating of gas
  - Liquid treatment:
    - neutralization with CaO,
    - decantation,
    - filtration
- **Key Points**
  - Washer against the current
    - pulverization by multiple jets or utilization of deflector plates creating bubbles
    - 2 separate recirculation steps
  - Regulation of pH level for neutralization of SO2: pH= 5,4
  - Choice of materials for acid-wash step

Ionic equilibrium of the solution:

$SO_2 + H_2O \leftrightarrow H_2SO_3$

SO2 low solubility

$H_2SO_3 + H_2O \leftrightarrow H_3O^+ + HSO_3^-$

pK1= 1,8 K1=(H30+)(HSO3-) / (H2SO3)

$HSO_3^- + H_2O \leftrightarrow H_3O^+ + SO_3^{--}$

pK2= 7,2 K2=(H30+)(SO3--) / (HSO3-)

$SO_3^{--} + 1/2\ O_2 \leftrightarrow SO_4^{---}$

$H_3O^+ + OH^- \leftrightarrow 2\ H_2O$ *2

With NaOH

$NaOH \rightarrow Na^+ + OH^-$ *2

Na2SO4 soluble

With CaCO3

$Ca^{++} + SO_4^{---} + 2H_2O \leftrightarrow CaSO_4, 2H_2O$

gypse, low solubility: pS=4,6

$Ca^{++} + SO_4^{---} + 1/2\ H_2O \leftrightarrow CaSO_3, 1/2H_2O$

sulfite, low solubility : pS=?

$CaCO_3 \leftrightarrow Ca^{++} + CO_3^{--}$ pS=?

$CO_3^{--} + H_3O^+ \leftrightarrow HCO_3^- + H_2O$

pK2= 10,2 K2=(H30+)(CO3--) / (HCO3-)

$HCO_3^- + H_3O^+ \leftrightarrow H_2CO_3 + H_2O$

pK1= 6,4 K1=(H30+)(HCO3-) / (H2CO3)

$H_2CO_3 \leftrightarrow CO_2 + H_2O$

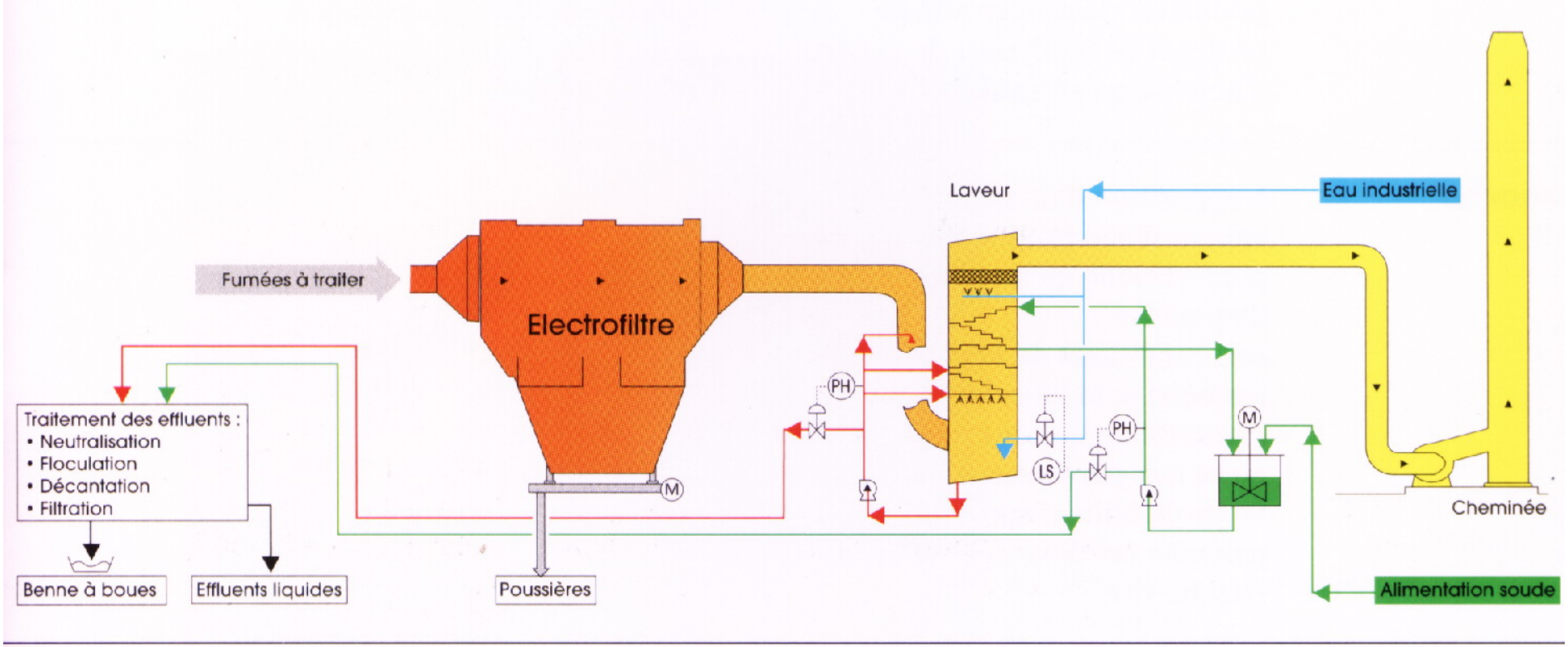
CO2, low solubility,

Wet process

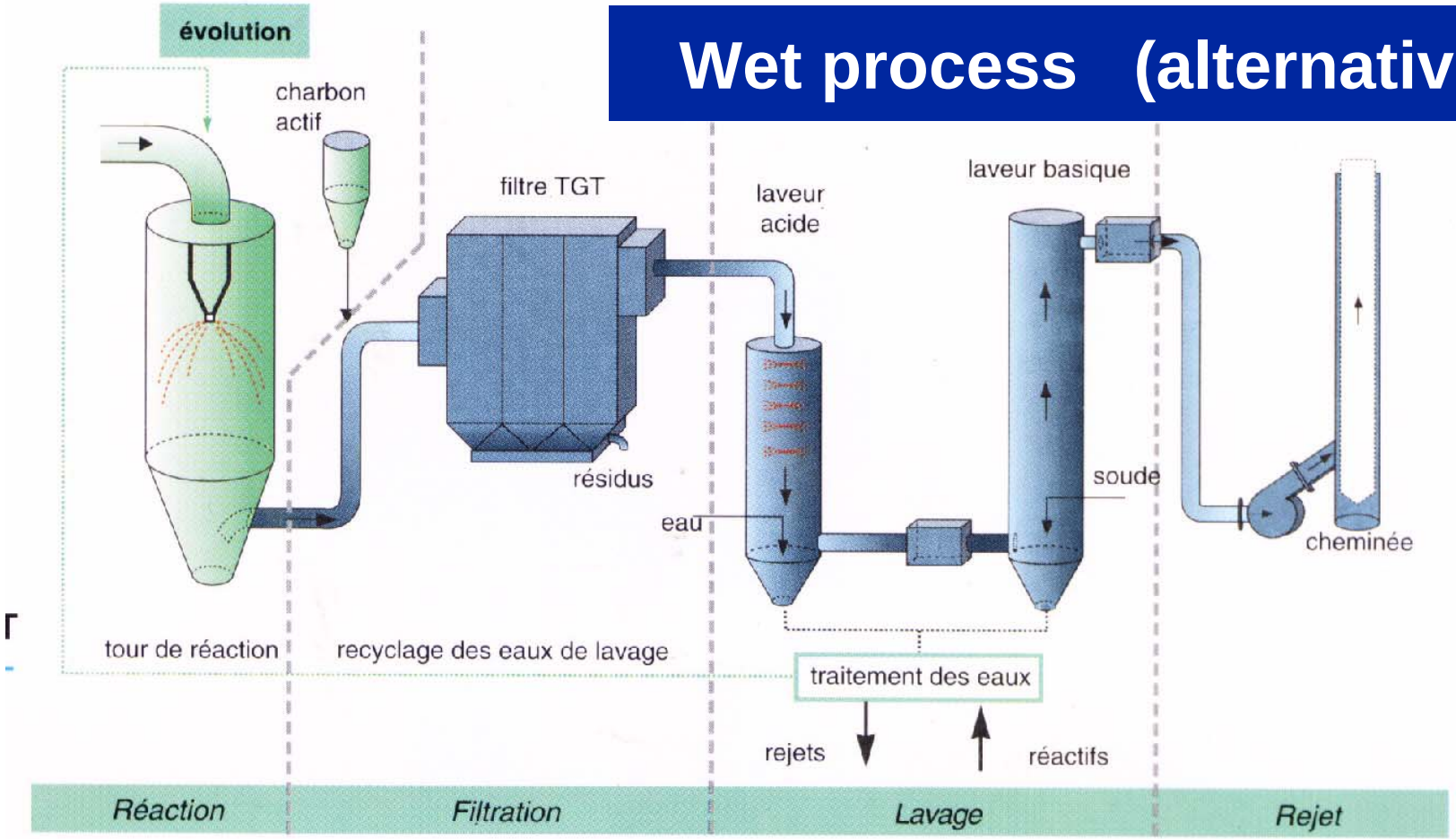
- **Performances**
  - Rate of purification: HCl: 99 / 99,98%
    SO2: 75 / 95%
    metals (particles): 50 / 90% (EF))
  - Consumption: reagent: 9 kg/t (stoichio * 1,05)
    water: 500 / 800 kg/tOM
    electricity: 30 / 40 kWh/tOM
  - Residue: filtration of impurities 4 to 10 kg/t ash EF: 20 kg/t
  - Outflow: 200 to 600l/tOM
- **Advantages**
  - Very good performance
  - Ash and neutralization products separated
  - Possibility to separate soluble salts and metals (hydroxides insoluble in an acid medium) through treatment of NaOH only
  - Possibility to valorize gypsum (CaSO4, 2H20) of the treatment of CaO , if metals are separated
- **Inconveniences**
  - Investment cost
  - Complexity of installation, regulation control
  - Panache of gas without reheating

- **Variants**
  - one-step wash with CaCO3 (instead of water, then NaOH) with oxidation SO3 en SO4 by injecting O2 into the bottom of the washer (ABB)
  - evaporation of waste liquids through upstream filtration by FAM (Procédair): more treatment of liquids, but ash and salt mixed together

Wet process


Laveur
Eau industrielle
Fumées à traiter
Electrofiltre
PH
PH
LS
M
M
Cheminée
Traitement des effluents :
• Neutralisation
• Floculation
• Décantation
• Filtration
Benne à boues
Effluents liquides
Poussières
Alimentation soude

Wet process (alternative)



Réaction	Filtration	Lavage	Rejet
Séchage : l'eau traitée provenant des laveurs est évaporée.	Les sels et les poussières sont récupérés dans le filtre TGT.	Un premier laveur acide capte le chlore, le fluor et le mercure. Le second laveur basique neutralise le soufre. L'eau recueillie est traitée pour être rejetée dans le milieu naturel ou recyclée dans le procédé.	Contrôles réglementaires et évacuation dans l'atmosphère.

Procédair

1.4 Sodium Bicarbonate process

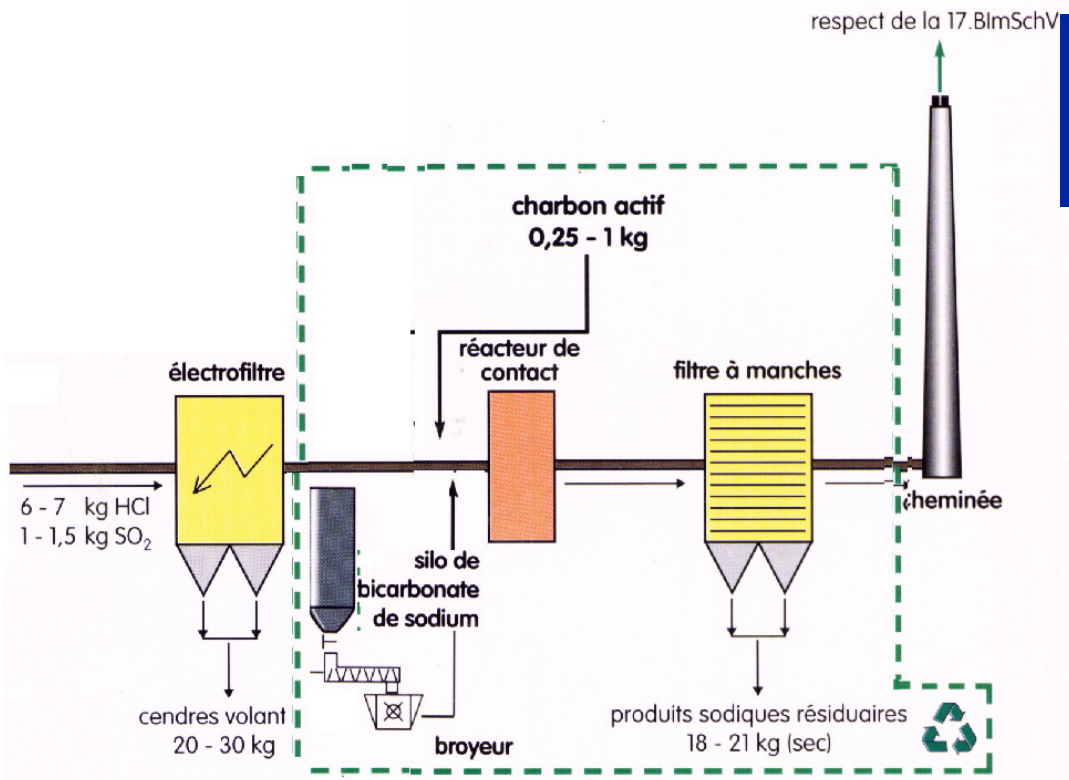
- **Basic Principles**
  - Spraying of sodium bicarbonate in gas
  - Creation of contact between the gas and reagents (2s, T > 140°C)

    $NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$
    $2NaHCO_3 + SO_2 \rightarrow Na_2SO_4 + 2CO_2 + H_2O$
    $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$
  - Filtration
  - Rinsing of products:
    - Precipitate the heavy metals
    - Dissolve residual products containing sodium
  - Purification of the products with sodium
    - Organic compounds (activated charcoal)
    - Metallic hydroxides (exchangeable resin of ions)
- **Key Points**
  - Probably identical to the dry procedure
  - Addition of phosphoric acid in order to improve the precipitation of heavy metals in the form of phosphates
- **Performance**
  - Purification rate: 99% HCl, 95% SO_2 at 1,5* stoichio
  - Residues: phosphate ash: 22 kg
  - Effluents: brine 65 kg at 250g/l of Na_2CO_3, Na_2SO_4, NaCl

- consumption: bicarbonate: 25kg/t
  phosphoric acid : 2 kg/t
  water: 60 kg/t
  electricity: ?

- **Advantages**
  - simplistic
  - investment cost
  - brine recyclable for production of sodium hydroxyde
  - phosphate ash unleachable, easy to neutralize: very little residue
- **Variants**
  - filtration before neutralization
  - addition of activated charcoal

Sodium Bicarbonate process

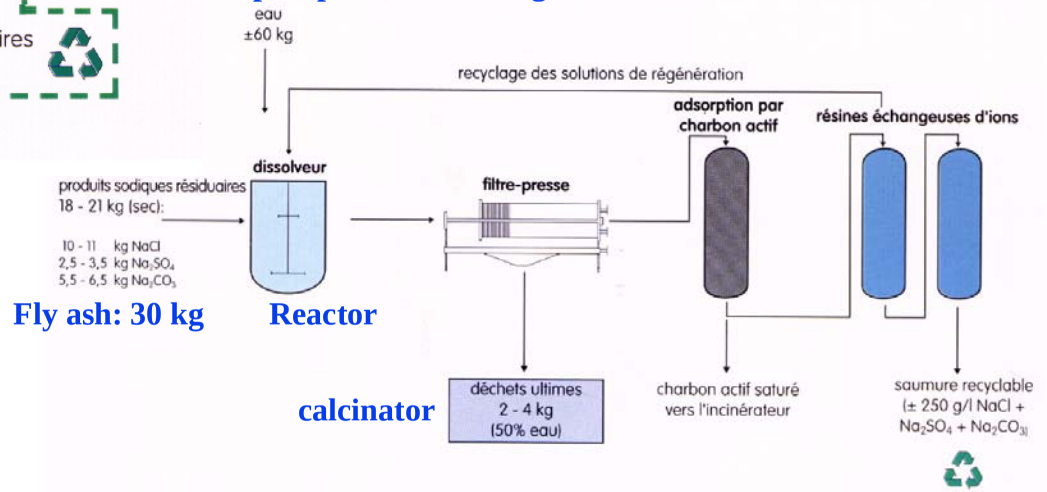


NEUTREC process

SOLATECH variant

cement: 10 kg

phosphoric acid: 2 kg



Fly ash: 30 kg

Reactor

calcinator

End of process waste (phosphatés): 30 kg