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Characteristics of Fly Ashes and Processing Conditions Affecting Carbon-Ash Separation under Pneumatic Transport, Triboelectric Technology

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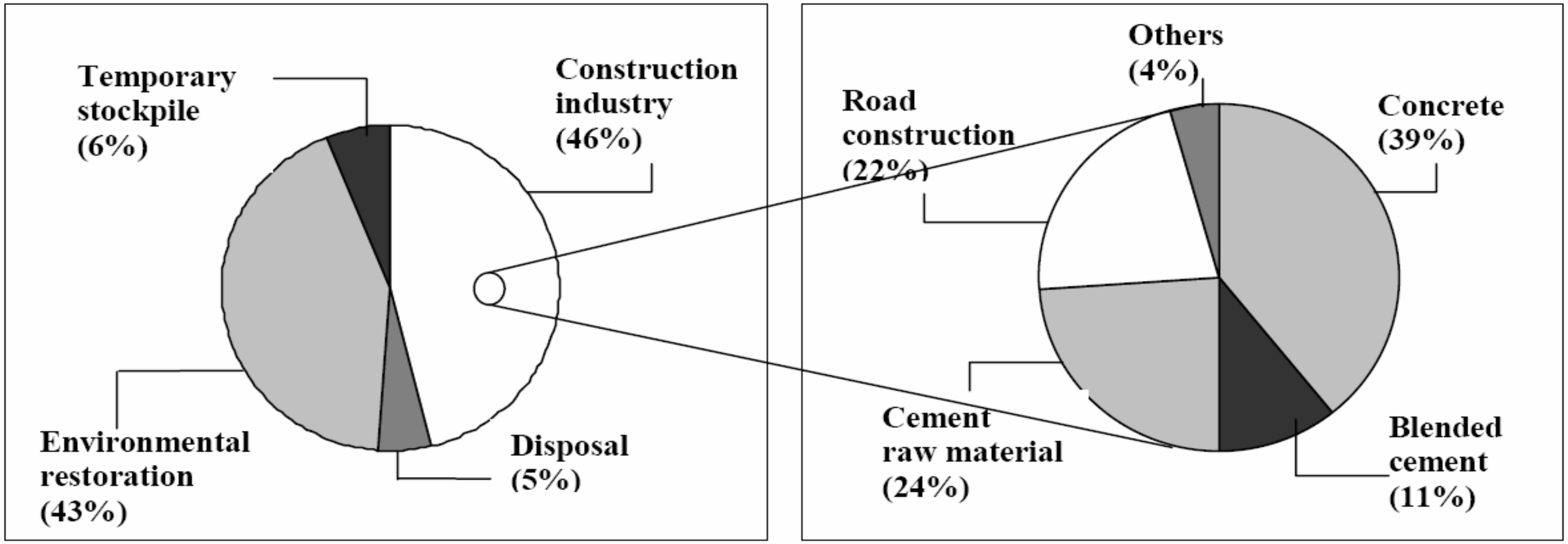
Fly ash utilization, Europe and Italy, in 2000*

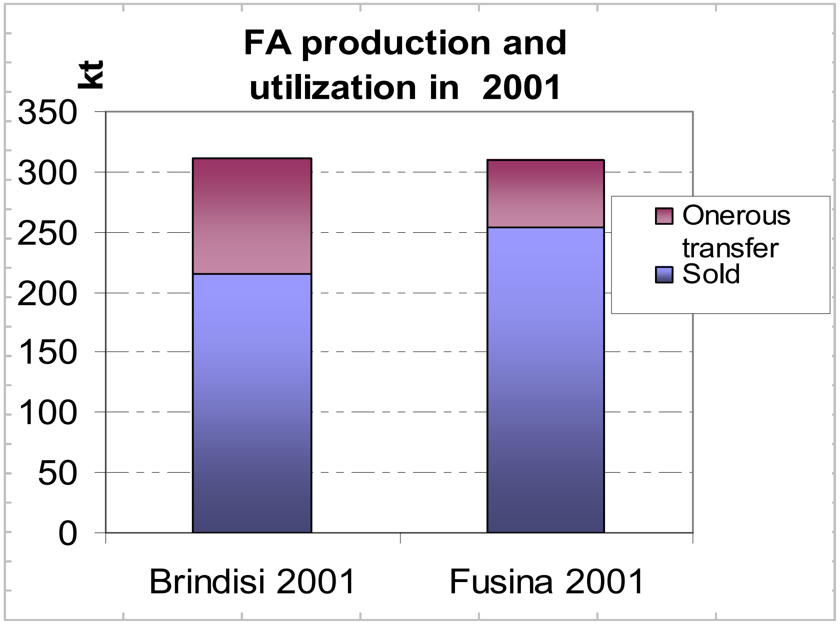


*ECOBA (European Coal Combustion Products Association)

- Unburned carbon in fly ash absorbs air entrainment agents that are used in cement.
- Large scale markets for fly ash as a mineral admixture in cement requires ***removal of carbon.***

UNI-EN 450 Conformity criterium on LOI:

$$LOI_c = LOI_c + K_A \sigma < 5\ \%$$



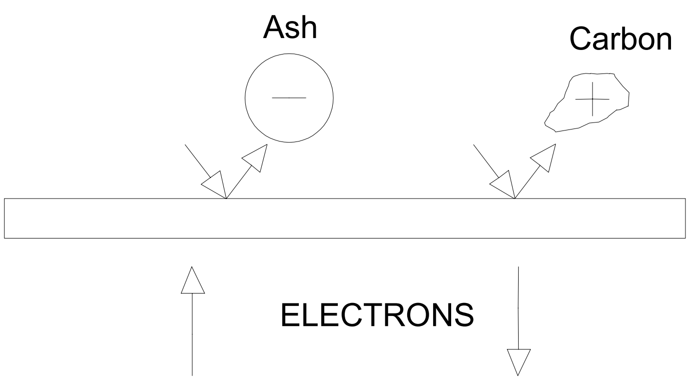
Triboelectric Separation Background

- Differences in the contact potential (or work function) between dissimilar surfaces cause electron transfer or **tribocharging**.

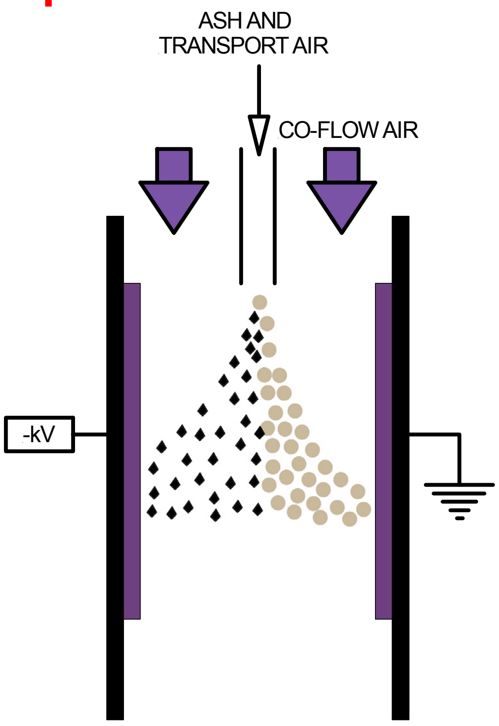
- A material with a lower work function donates electrons to a material with a higher work function.

- Tribocharging occurs between dissimilar particles or between particles and pipe wall during **pneumatic conveying**.

Differentially charged particles are separated in an electrostatic field



Tribocharging of ash and carbon particles in combustion fly ash



Schematic of charged fly ash particles being deflected to opposite electrodes of a separator

Pertinent questions arisen

Previous studies (Li et al., 1998; Baltrus et al., 2002) found that charge reversal occurred due to ion mobilization on the ash surface

Is it possible to take advantage of charge reversal during carbon-ash beneficiation?

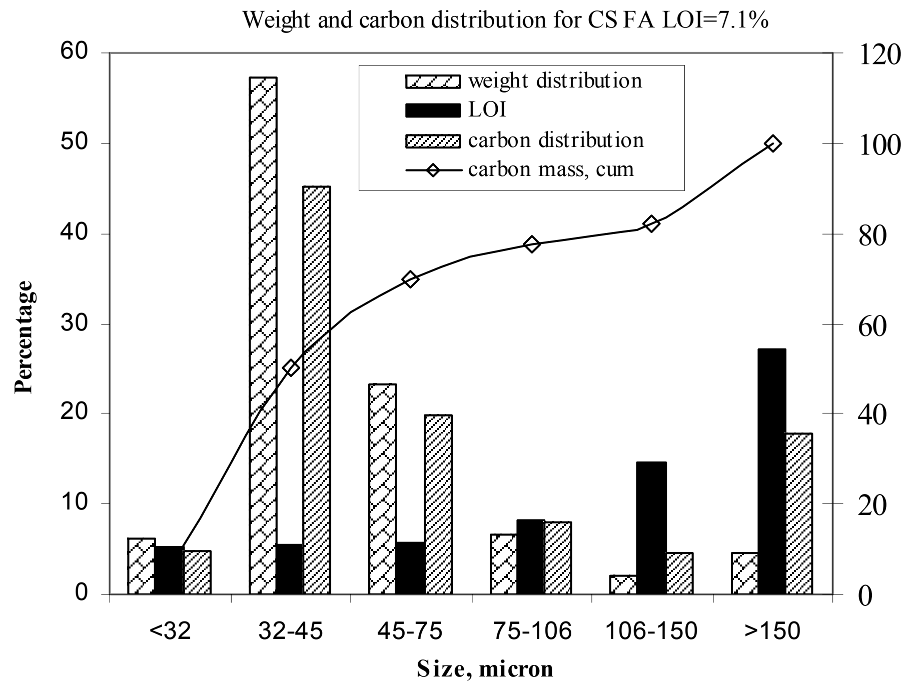
- Does surface conditioning play a dominant role during carbon-ash beneficiation?
- Are the effects of surface conditioning (by moisture) known and controllable?

Materials: Weight and carbon distribution/1

Fly ashes from two utilities, both fitted with low-NO_x burners

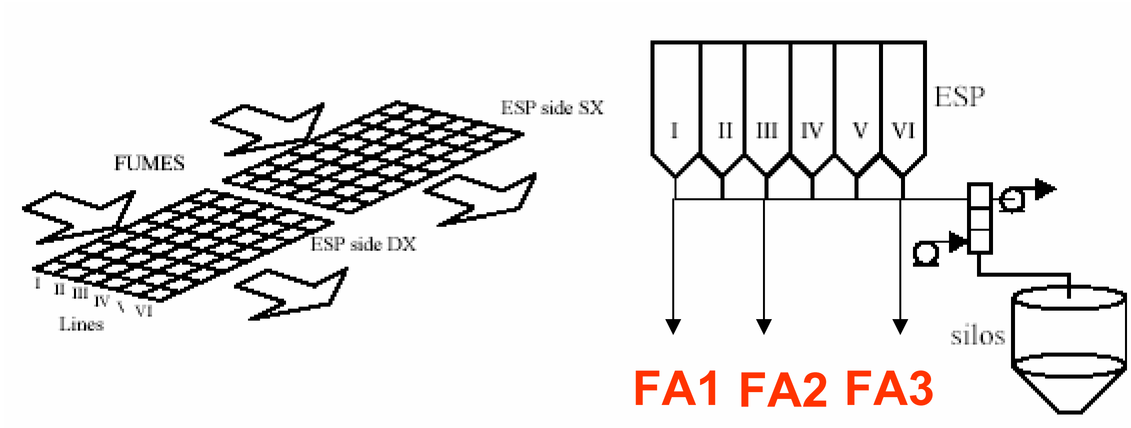
Fly ash CS:

American coal-fired utility

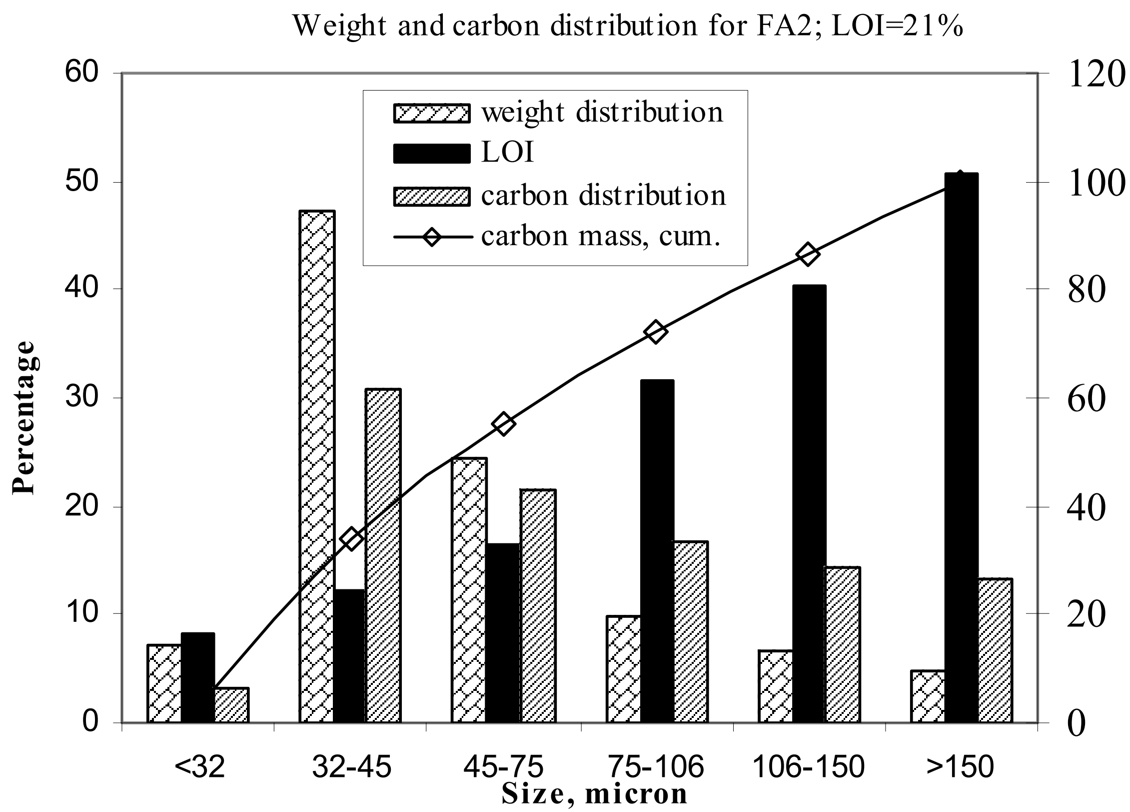


Italian Fly ashes:

From hoppers at different lines of ESP



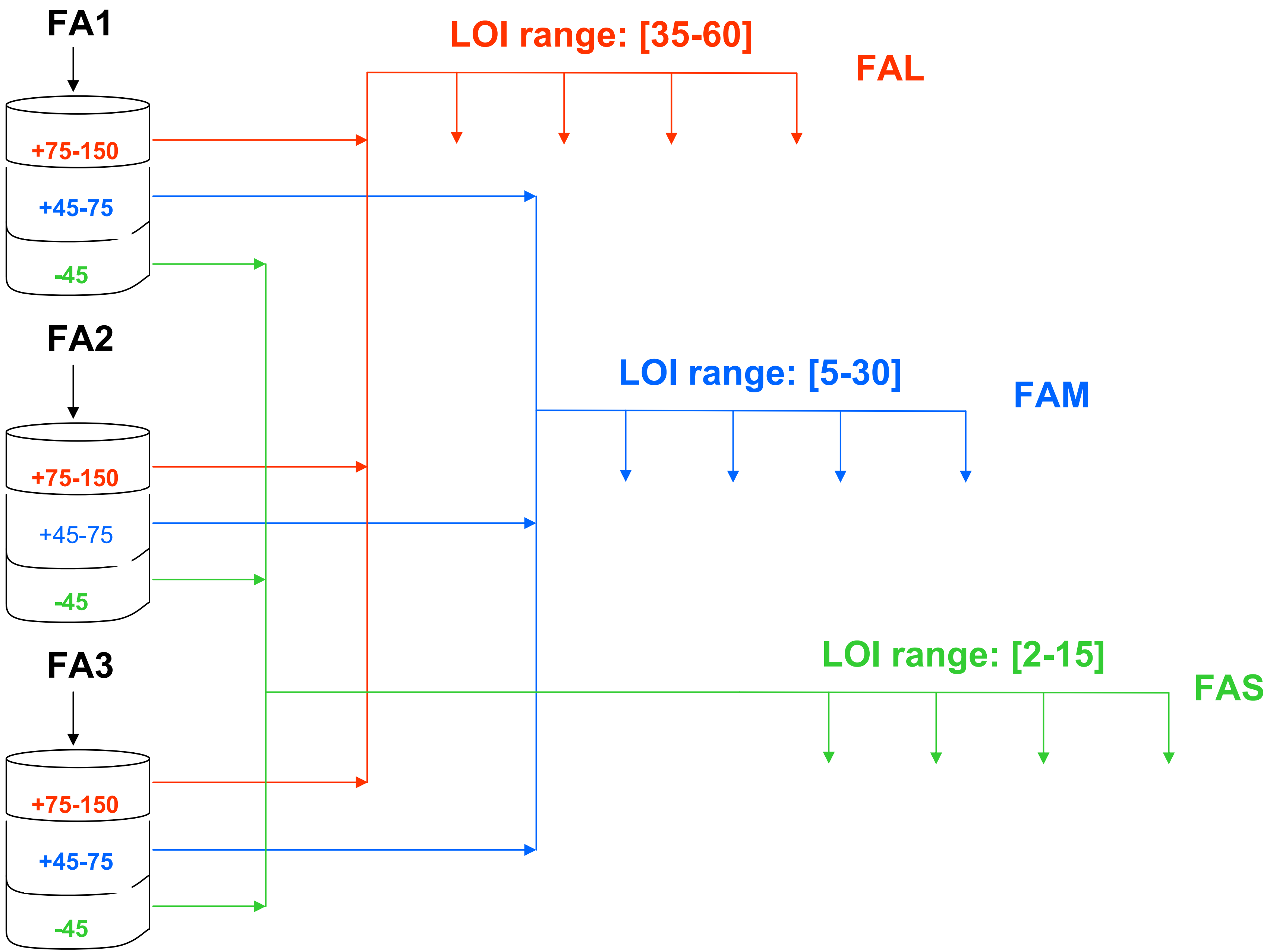
Materials: Weight and carbon distribution/2



In the first two-three ESP lines it is collected from 50 to 80% of the total ash production

LOI is sensibly lower and increases in the last lines

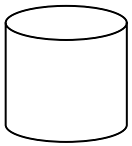
Materials: preparation of synthetic mixtures



Experimental procedures

Procedure TR1

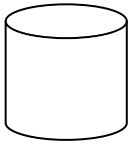
Glove box:



r.h: **100%;** T: **40°C**; E.t.: **12 hs**

→ Drying step: 90°C for 18 hr → SEPARATION

Procedure TR2

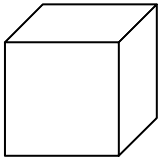


r.h: **45-to-85%;** T: **22°C**; E.t.: **1 hr**

→ Drying step: 90°C for 18 hr → SEPARATION

Procedure TR3

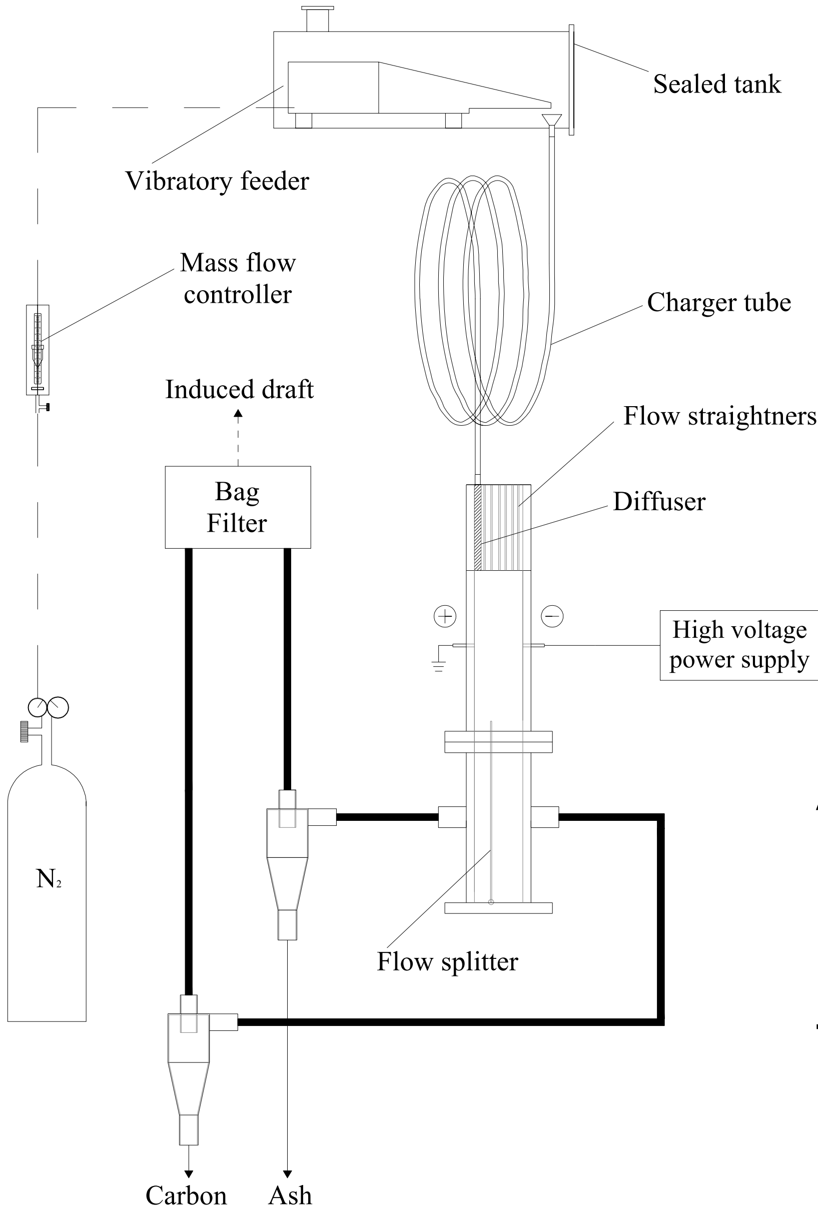
Oven



Dried over night

→ Samples exposed to ambient conditions (r.h.=55%, T=22°C) for different periods (up to 7 hr) → SEPARATION

Apparatus for carbon-ash separation



Separation facility

1)Laboratory-scale TEP™ system (feed rate up to 8 kg/h);

2)Feed rate: 6 kg /h

3)Electric field: from 1 to 5 kV/cm

Ash injected close to the positive plate to enhance carbon separation at high feed rates (*Cangialosi, 2005*)

Results obtained for the parent sample CS

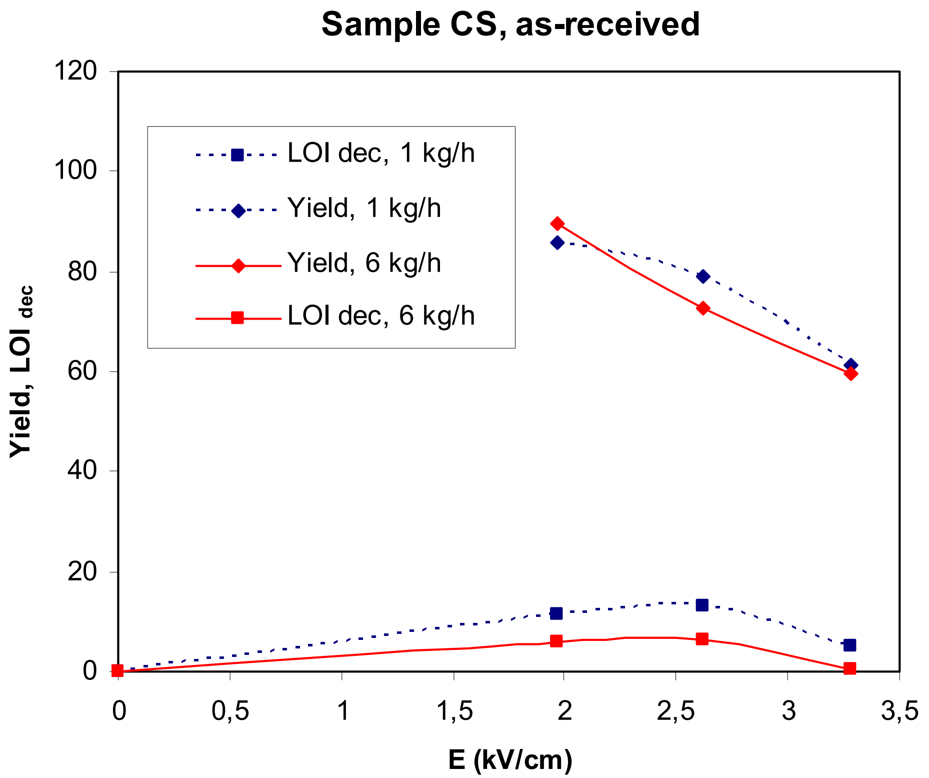
Selectivity of the process

Ash product yields: $$Y = \left(\frac{W_A}{W_F} \right)$$

Decrease in LOI $$LOI_{dec} = \left(1 - \frac{LOI_A}{LOI_F} \right)$$

where W_A , W_F and LOI_A ,LOI_F are the weight and the LOI contents of low LOI ash products and feed ash, respectively.

The parent sample exhibited very low carbon separation either at low (1 kg/h) or high (6 kg/h) feed rate.



Significance of charge reversal in carbon removal

Field: 2 kV/cm

Feed rate: 6kg/h

	CS As-received	CS-TR1	CS-TR1; **RP***
Ash Yield (%)	89.6	23.8	81.9
LOI parent (%)	6.4	7.4	7.1
LOI + (%)	6.1	8.4	5.9
LOI - (%)	9.7	4.3	12.3
LOI_{dec}	5.8	42.3	16.4

***: Reverse Polarity**

Charge reversal occurred (Li et al., 1999; Baltrus et al., 2002)

One-third of the carbon mass deflects toward the positive electrode:

More ash particles acquire positive charge than

carbon particles acquire negative charge.

Moisture sorption kinetics and ash beneficiation/1

How long/how much

moisture exposure is needed to observe charge reversal?

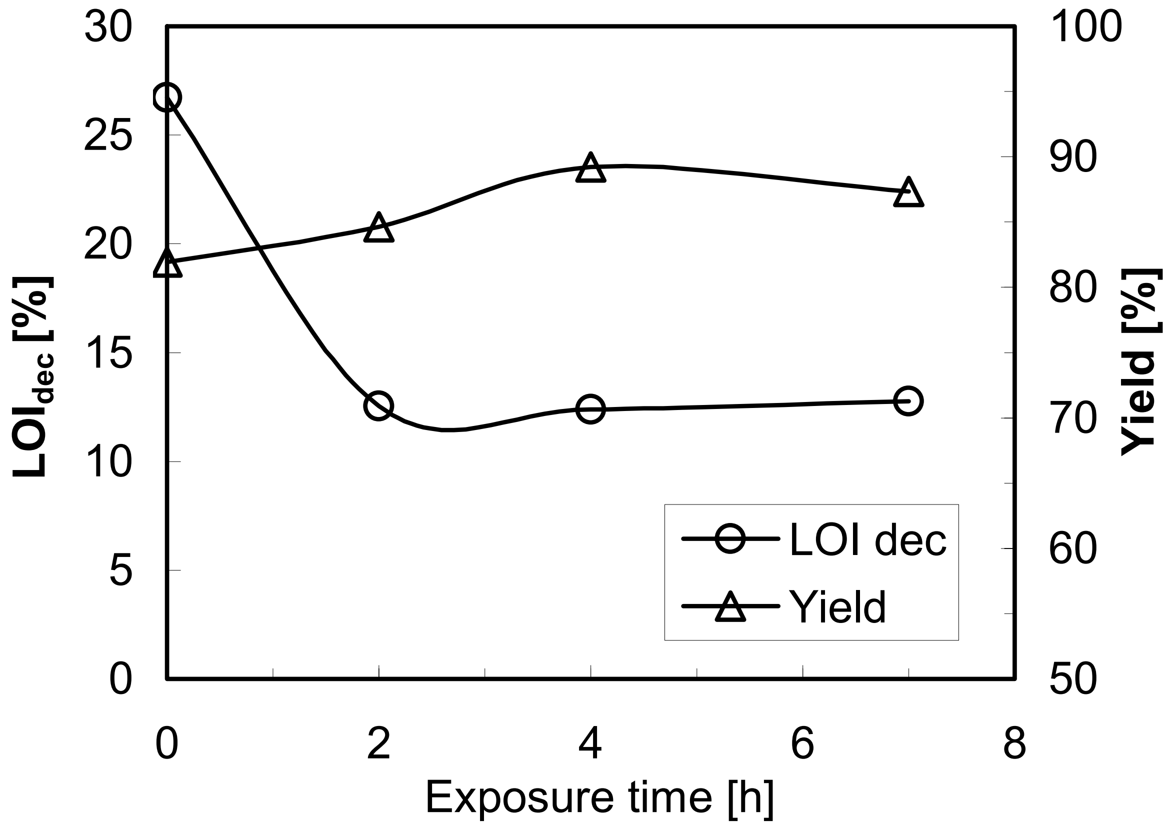
	CS As-received	CS-TR2
Ash Yield (%)	89.6	85
LOI parent (%)	6.4	6.5
LOI + (%)	6.1	6
LOI - (%)	9.7	10.1
LOI_{dec}	5.8	8.8

No significant change was observed, regardless the r.h. used during the tests:

Kinetics of ash-moisture interactions do not allow attainment of surface ion mobilization in 1 hr

Moisture sorption kinetics and ash beneficiation/2

Sample treatment protocol: TR3

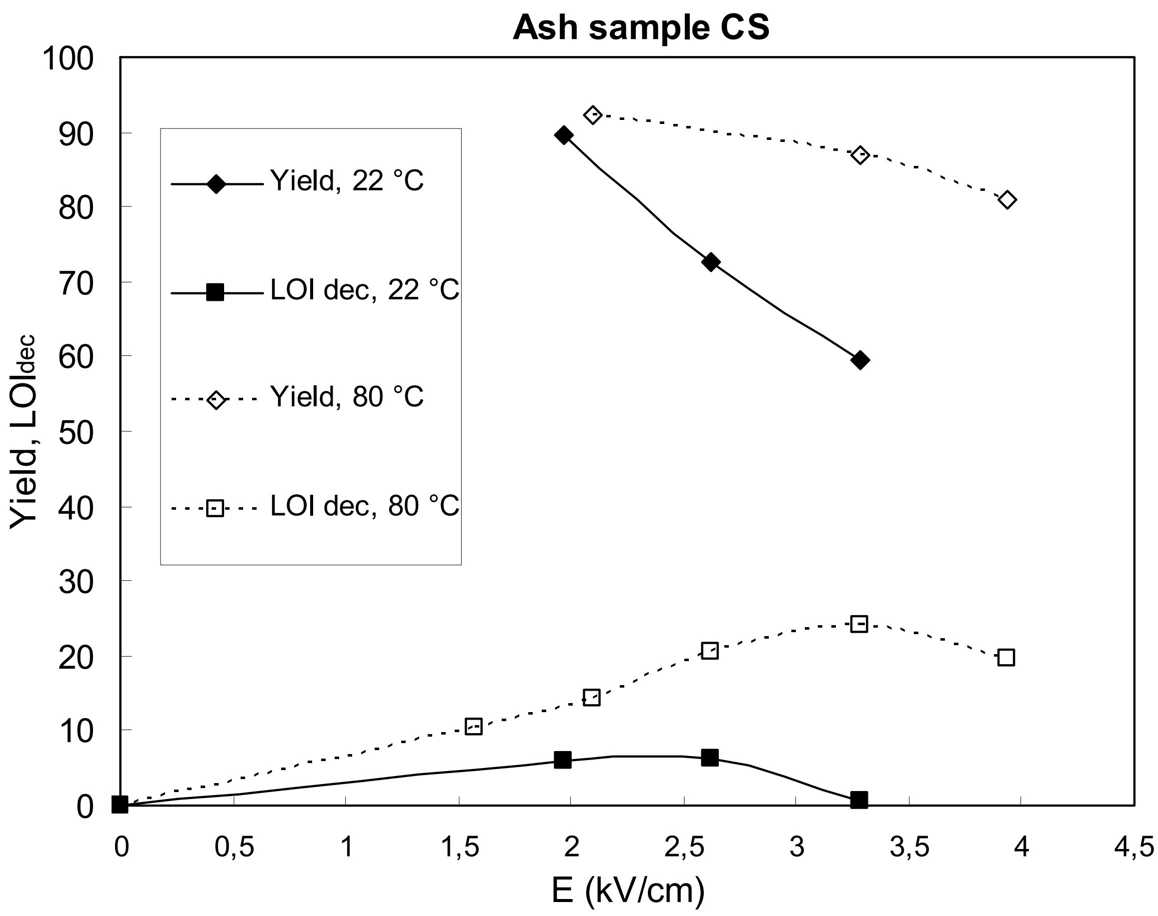


Three-fold decrease in carbon removal when ash exposed to ambient conditions

No charge reversal

Effects of in-line thermal treatments

In-line thermal treatments (Outlet Temperature 50-to-80 °C; residence time ≈1 s)



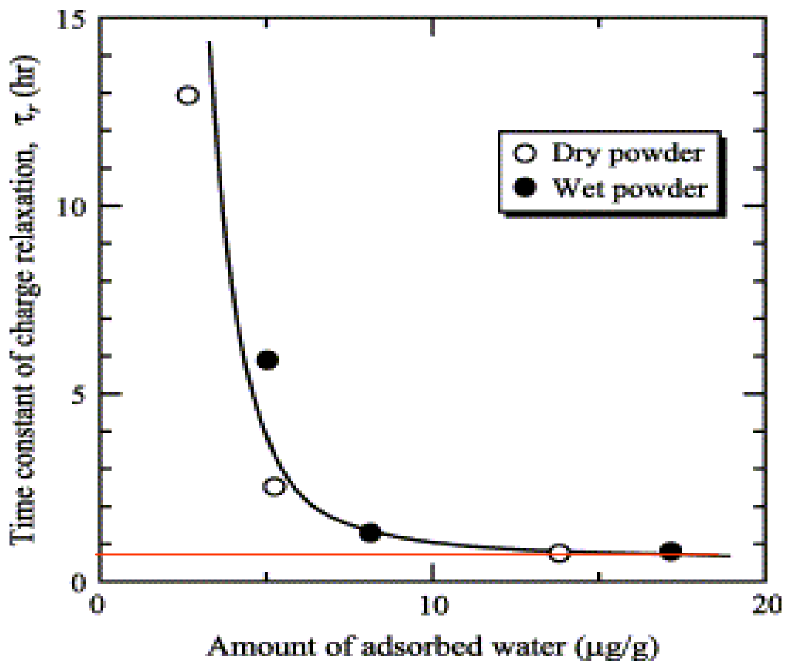
- Yield continues to improve as the temperature rises
- *Fast* and *slow* moisture desorption kinetics

Surface moisture removal and charging

Possible physical/chemical changes in charging step
(charging/ charge dissipation)

Particle charging → *Work function* and *time constant of charging* are not affacted by relative humidity (***Nomura et al., 2003***)

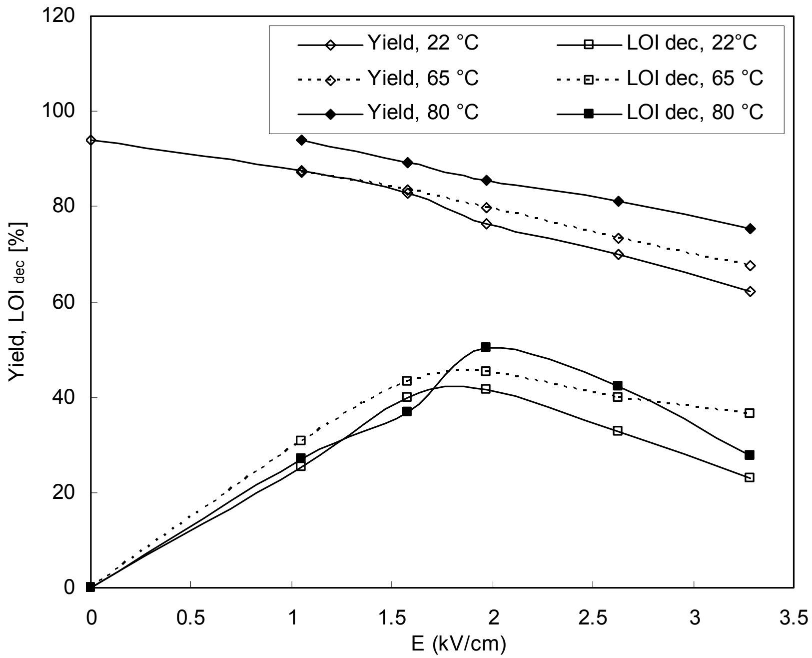
Charge relaxation →



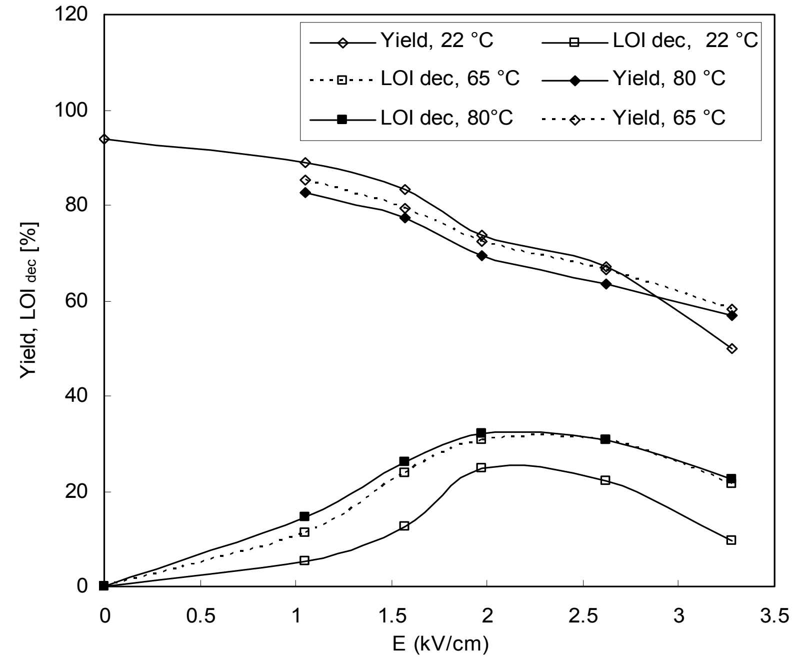
Particle charge does not dissipate in the characteristic timescales (≈1 s) of particle motion

Mechanisms of surface moisture removal

FA1: LOI_0=8.5%

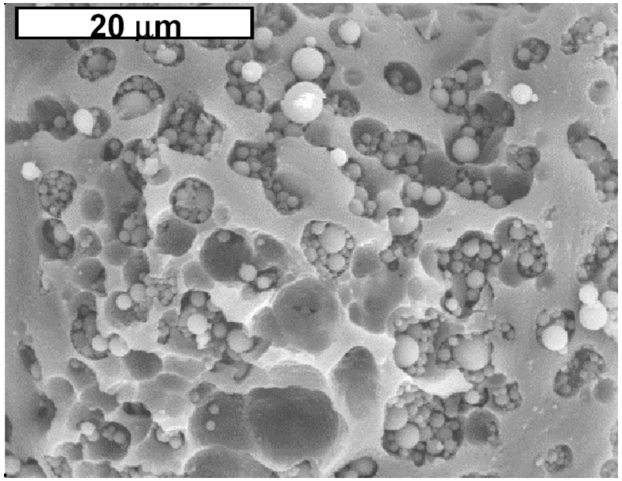


FA3: LOI_0=30.5%



- Remarkable increase in Yield
- "*Saturation effect*" for high-LOI fly ash

Adsorbed water affects the degree of *particle liberation*



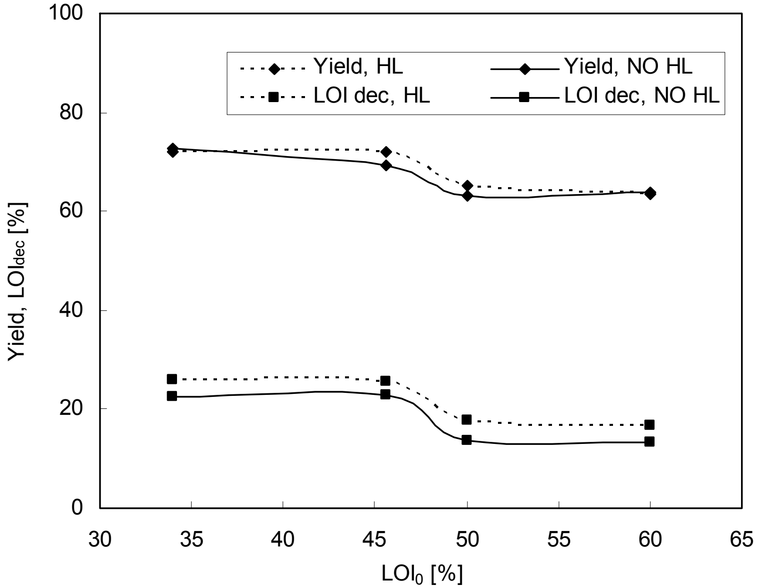
Ash/carbon clusters

Ash particles entrapped in big carbon particles

Effect of moisture on synthetic mixture/1

Would *thermal treatments* affect the LOI_{dec} when the ash and carbon particles were of the *same size*?

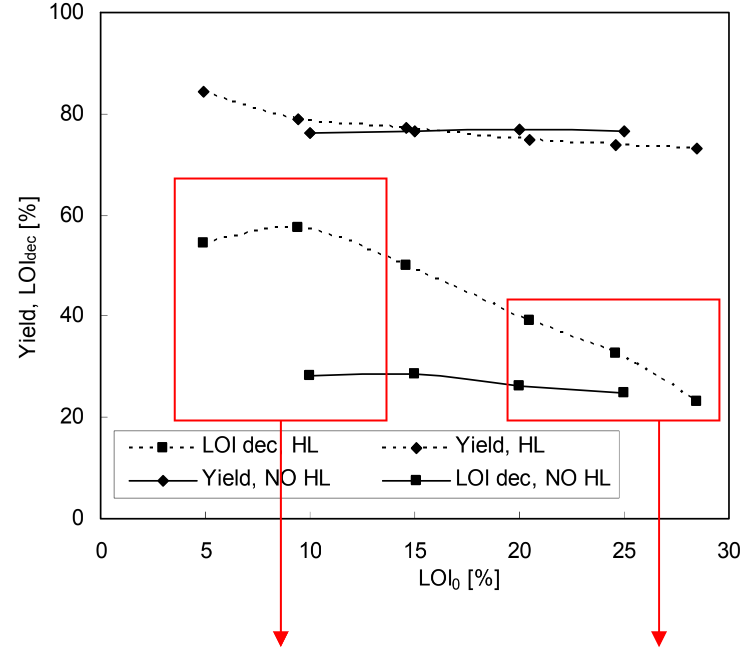
FAL (+75-150 µm) samples



No effect of Heating:

Small ash particles ***embedded*** in the char structure are not separated by dry sieving: moisture removal is not significant in liberating ash/carbon clusters

FAM (+45-75 µm) samples

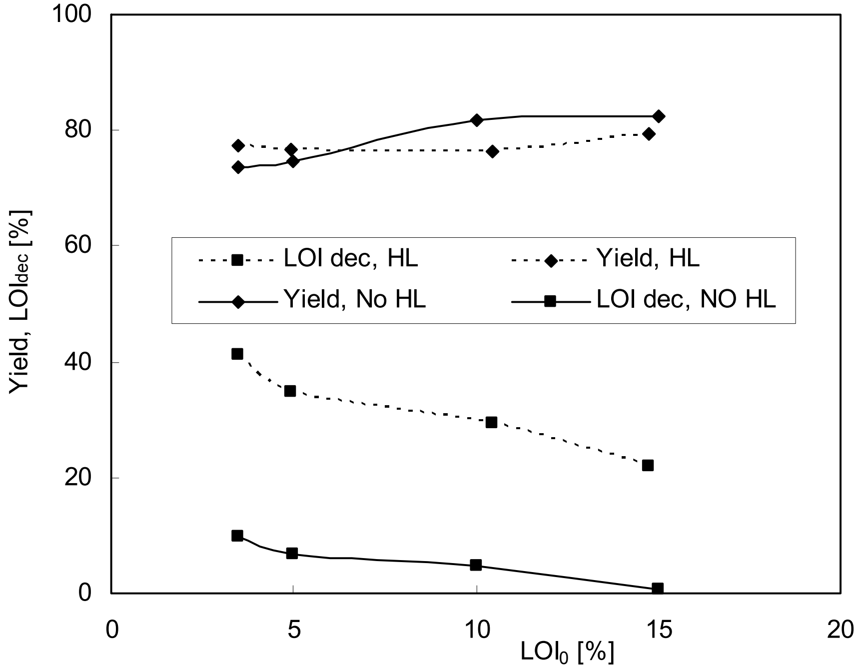


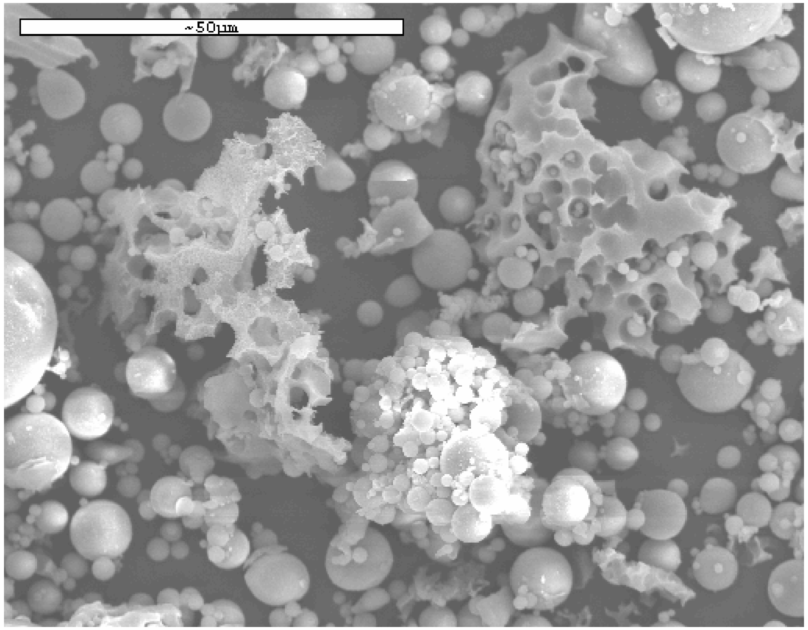
Ash/ash clusters breaking up

Ash/carbon clusters are not liberated

Effect of moisture on synthetic mixture/2

FAS (-45 µm) samples





Ash/ash clusters breaking up after moisture removal → Removal of *ash clusters* that surround char particles and may hinder their movement in the separation chamber

Conclusions

The effect of surface moisture on tribolectrostatic beneficiation of fly ash

- Complete humidification and long exposure times cause ash particles to acquire positive charge

- Moisture sorption is detrimental to carbon separation after two hours of exposure to ambient conditions for ashes studied

- *Fast* and *slow* moisture desorption kinetics may explain different behavior of off-line and in-line heat treatments

Conclusions

- Surface moisture affects the degree of particle liberation more than charging and/or charge dissipation kinetics

- Ash/ash clusters breaking up due to moisture removal provides better performance for low-LOI fly ashes

- Particles smaller than 45 micrometers experienced a four-fold change in separability upon reducing surface moisture

Acknowledgments

The financial support for the present study by MIUR under grant 12941/01 "*Sviluppo di un sistema innovativo per la produzione di ceneri di qualità - Ceneri DOC*" is gratefully acknowledged.

Thank You !