Hydrotalcites for pre-combustion high temperature CO_2 removal (IGCC conditions)

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CO_2 – Global warming

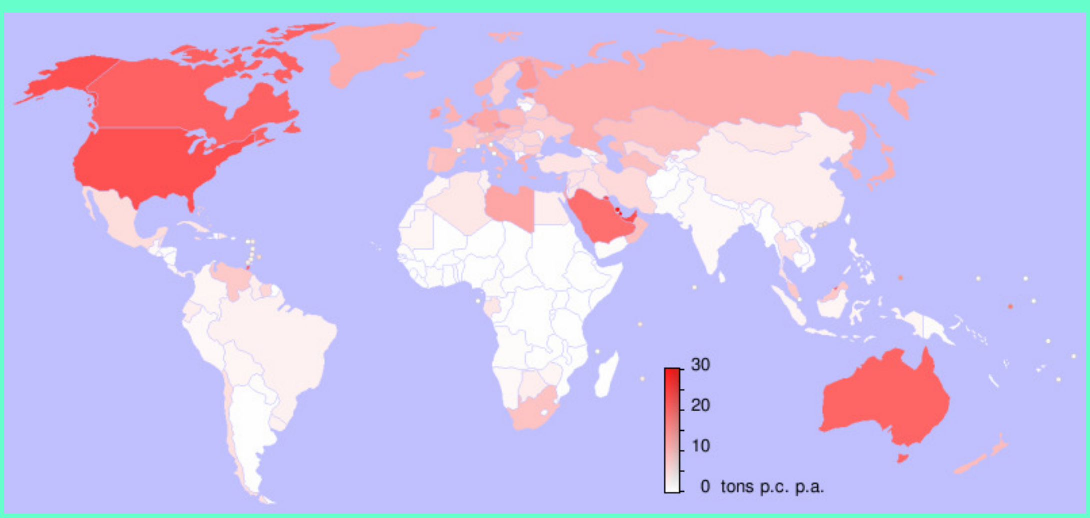
- Carbon dioxide (CO_2) is identified as the most important global warming gas.
- The uncontrolled emission of CO_2, if not addressed properly, causes irreversible and disastrous damage to the whole biosphere.
- Rising concentration of CO_2 in the atmosphere leads to change in energy balance and consequently the world's climate.
- CO_2 is the most abundant anthropogenic GHG responsible for the greenhouse effect.

Major CO_2 Emission Sources

S. No.	Stationary Source	Mobile source	Natural Source
1	Fossil fuel-based electric power plants	Cars, and sports utility vehicles	Humans
2	Independent power producers	Trucks and buses	Animals
3	Manufacturing plants in industry[a]	Aircrafts	Plants and animal decay
4	Commercial and residential buildings	Trains and ships	Land emission/leakage
5	Flares of gas at fields	Construction vehicles	Volcano
6	Military and government facilities	Military vehicles & devices	Earthquake

[a] Major concentrated CO_2 sources include chemical plants for manufacturing hydrogen, ammonia, cement, limestone, and soda ash as well as fermentation processes and chemical oxidation processes.

Country wise CO_2 per capita emissions

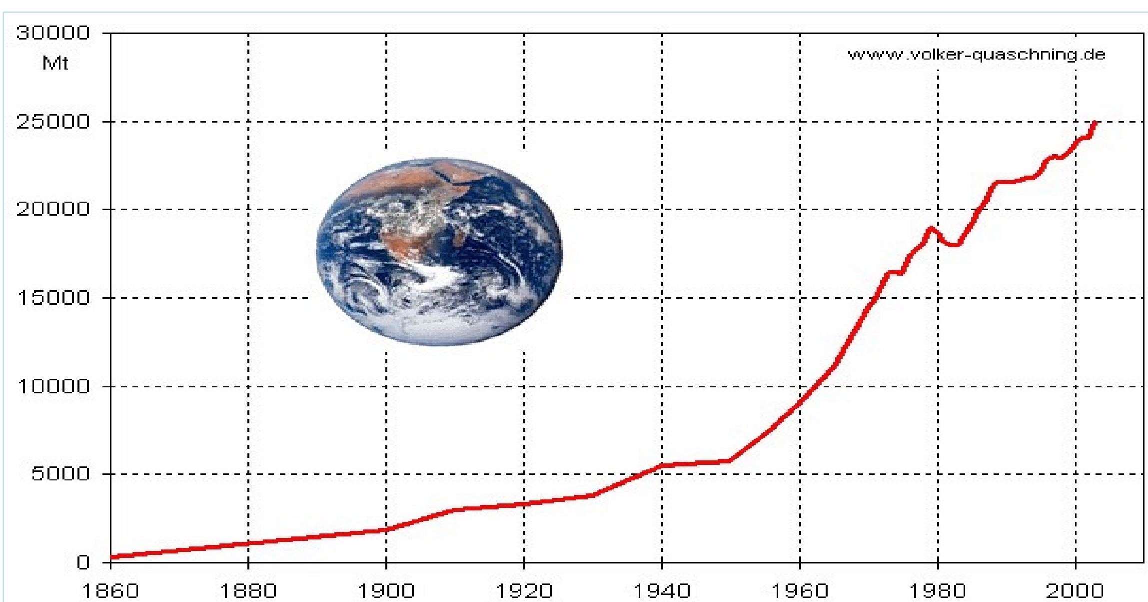


Countries with Higher CO_2 Emissions

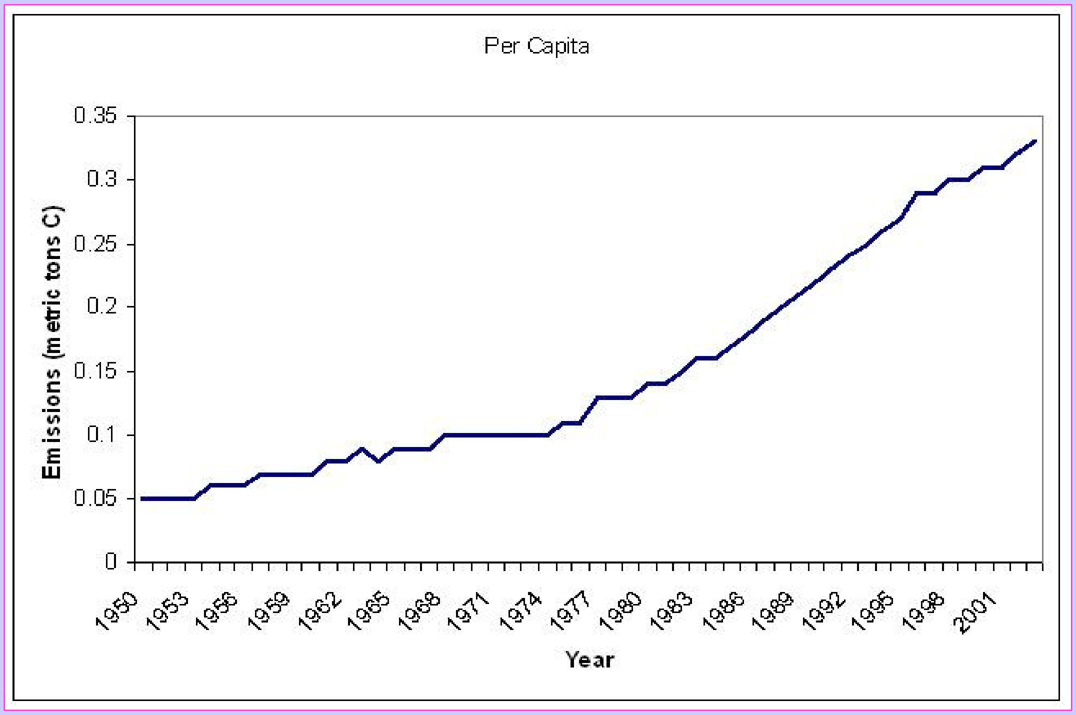
	Country	CO_2 emission from fuel combustion in Mt	Per capita CO_2 emissions in t
1	USA	5 729	19.68
2	China	3 719	2.89
3	Russia	1 527	10.64
4	Japan	1 201	9.41
5	India	1 050	0.99
6	Germany	854	10.35
7	Canada	553	17.49
8	UK	540	9.10
9	Italy	453	7.80
10	South Korea	448	9.36

Source: IEA, State: 2003

Global CO_2 Emissions from fuel combustion



Indian CO_2 per capita emissions (1950 – 2001)



Origin of the present investigations

Rise in atmospheric levels of CO_2 from pre-industrial levels of 280 parts per million (ppm) to present levels of 375 ppm.

Evidence for expanding use of fossil fuels for energy.

Methods of halting increase in carbon emissions:

Use energy more efficiently and reduce fossil fuel combustion.

Increase use of low-carbon and carbon-free fuels and technologies (nuclear power and renewable sources such as solar energy, wind power, and biomass fuels).

Capture CO_2 emissions and sequester them in carbon reservoirs such as deep aquifers, deep oceans, or minerals.

The first two options are practically difficult to be managed due to heavy energy demand.
It is imminent to look for option to capture carbon dioxide efficiently and sequester it.

The Various adsorbents used for CO_2 capture

Zeolites and Activated carbons

- Higher adsorption capacity at lower temperatures (e.g., RT)

  CO_2 adsorption capacity for zeolite 13X, 4A and activated carbon were about 82, 69 and 56 ml/g-adsorbent respectively at 25°C and 1 atm CO_2 partial pressure.

- The adsorption capacities rapidly decline with increasing temperature above 30 °C, and become negligible at temperature in excess of 200 °C.

  The CO_2 adsorption capacity for Nortit RBI activated carbon was 55 ml/g-adsorbent at 21.5 °C. With increasing temperature, the adsorption capacity decreased to 39 ml/g-adsorbent at 30 °C, 29 ml/g-adsorbent at 56 °C and 20 ml/g-adsorbent at 75 °C respectively

- Low selectivity to CO_2 in the presence of other gases (N_2, etc.).

  Physical adsorption of the gas occurs in these carbon and zeolite adsorbents.

  Chemical adsorption is necessary to reach high capacity and separation selectivity.

Materials for CO_2 Chemisorption

- MgO shows an adsorption capacity of 8.8 mg/g-adsorbent at 400°C.
- Both types of adsorbents need high temperature operation and have a low adsorption capacity, thus they are not suitable for practical use for CO_2 separation.

Demands for Practical application

- The material should be able to operate at elevated temperature, e.g., higher than room temperature and up to 150-200 °C and 500 to 650 °C for the flue gas of power plants.

Solution:

- Hydrotalcite are advantageous

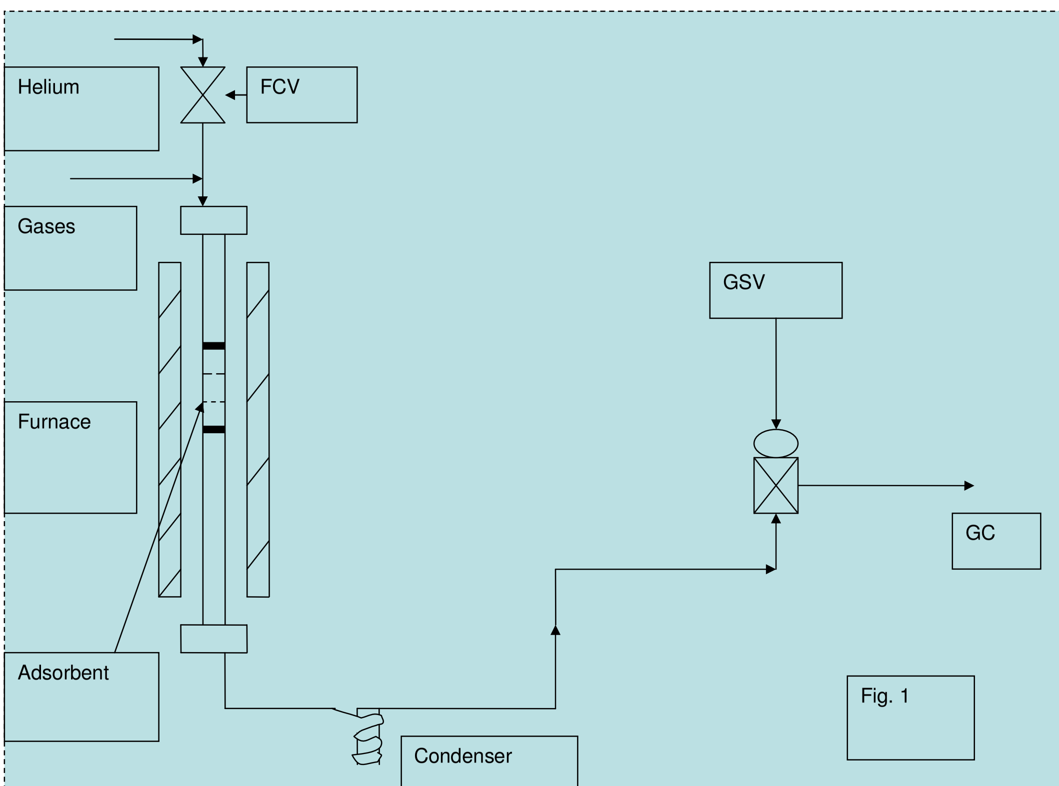
Flue Gases

- CO_2 =10-14 %
- N_2 = 78 to 80 %
- O_2 =2 to 6%
- CO = 70 -160 ppm
- NO_x = 50 -110 ppm
- SO_2 = 180-250 ppm
- Hydrocarbons = < 60 ppm

$$2H_2 + O_2 \rightarrow 2H_2O(g) + heat$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
$$CH_2S + 6F_2 \rightarrow CF_4 + 2HF + SF_6$$

$$CH_4 + 2O_2 + 7.52N_2 \rightarrow CO_2 + 2H_2O + 7.52N_2 + heat$$



Ca/Al and Mg/Al hydrotalcites

The reactions

$CO + CO_2 = CaCO_3$ (1000 °C)

$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$

$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$

$CaCO_3$ = Melting point 825 °C (Decomposition)

$Ca(HCO_3)_2$ = solubility16.6 g in 100 ml of water at 20 °C

$MgCO_3$ = Melting point 350 °C (Decomposition)

The reactive separation of CO_2 from CH_4, N_2, H_2,

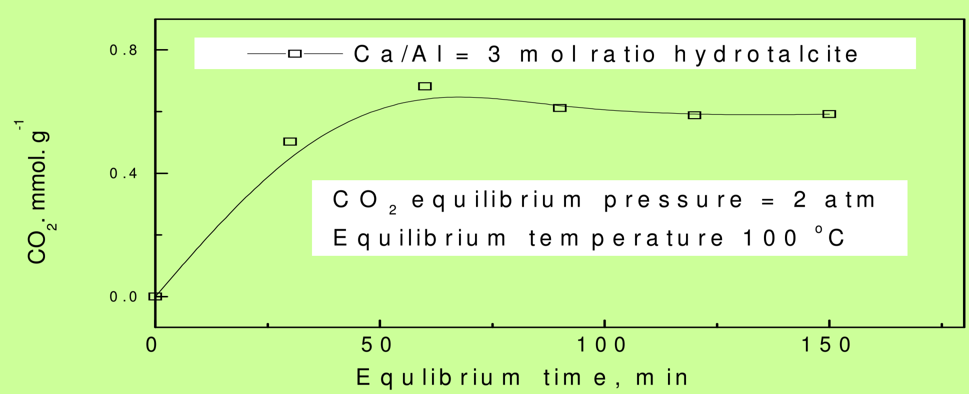
The interferences = SO_2 and NO_x

The operating temperatures = 500 to 700 °C

The Ca and Al are in the abundance

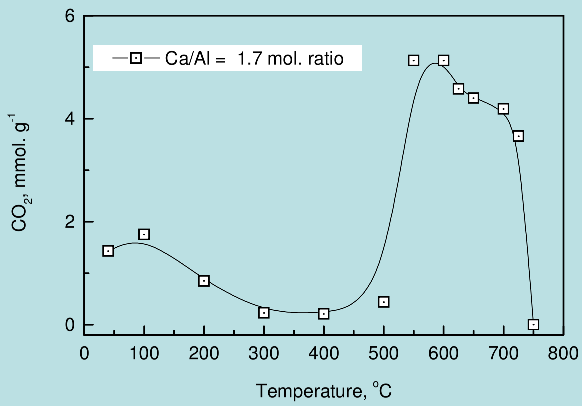
Ca/Al hydrotalcite = The precipitation method of preparation is simple and easy

Carbon dioxide adsorption over Ca/Al hydrotalcite at different time



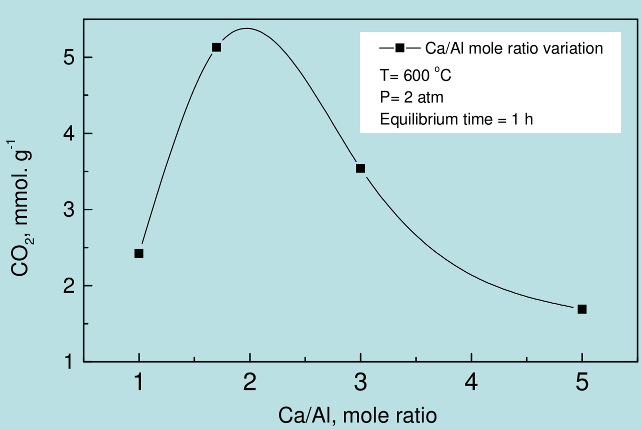
Carbon dioxide adsorption over Ca/Al hydrotalcite at different time

Adsorption of carbon dioxide over Ca/Al hydrotalcite



The CO_2 adsorption with respect to the temperature at the Ca/Al mole ratio 1,7

Adsorption of carbon dioxide over Ca/Al hydrotalcite at different mole ratios



The effect of the mole ratio of the Ca/Al variation over the CO_2 adsorbtion over the Ca-Al hydrotalcite

Carbon dioxide adsorption over Mg/Al hydrotalcite at different temperatures