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# Carbon Sequestration Technology using for Removal of Carbon Dioxide via Fly Ash

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***Abstract – The use of fly ash in the concrete industry continues to grow. Over 15 million metric tons of fly ash was added to Portland cement concrete. Its use is beneficial for a number of reasons. Since it is a byproduct material, using it as a concrete ingredient provides economic advantages and frees up landfill space. In addition, fly ash promotes concrete workability, especially useful for pumped concrete mixtures. Fly ash reduces concretes permeability and increases its resistance to sulfate attack and alkali-silica reaction. Various $CO_2$ scrubbing process removes $CO_2$ from the air. As carbon sequestration describes long term storage of $CO_2$ in the form of either mitigate or defer global warming. $CO_2$ is naturally captured from the atmosphere through biological, chemical or physical processes while some use entirely artificial process. This research paper mainly focus on traditional cement manufacture releases large amount of $CO_2$ a technique in which fly ash generated by sugar factory could be used as sorbents for $CO_2$ mineral sequestration. The amount of $CO_2$captures average 60-65% of the carbonaceous $CO_2$ & 10-11% of the total $CO_2$ emission which is removal from using chemical scrubber.***

***Keyword: Carbon Sequestration, $CO_2$ Absorption, Fly Ash.***

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## 1. INTRODUCTION

Carbon sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir. When carried out deliberately, this may also be referred to as carbon dioxide removal, which is a form of Geoengineering. The term carbon sequestration may also be used to refer to the process of carbon capture and storage, where $CO_2$ is removed from flue gases, such as on power stations, before being stored in underground reservoirs. The term may also refer to natural biogeochemical cycling of carbon between the atmosphere and reservoirs, such as by chemical weathering of rocks. Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes. Some anthropogenic sequestration techniques exploit these natural processes, while some use entirely artificial processes.$CO_2$ may be captured as a pure by-product in processes related to petroleum refining or from flue gases from power generation. $CO_2$ sequestration includes the storage part of carbon capture and storage, which refers to large-scale, permanent artificial capture and sequestration of industrially produced $CO_2$ using subsurface saline aquifers, reservoirs, ocean water, aging oil fields, or other carbon sinks.

**Fly ash** is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. Fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled (Wong et. al., 2004). often used to supplement Portland cement in concrete production. Some have expressed health concerns about this. In some cases, such as the burning of solid waste to create electricity, the fly ash may contain higher levels of contaminants than the bottom ash and mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as nonhazardous waste in a given state, whereas, unmixed, the fly ash would be within the range to qualify as hazardous waste.

## 2. MATERIALS AND METHODS

### 2.1 Fly ash as sorbents

Fly ash is fine powdery residue obtained by separating the solids from the flue gases during the combustion of coal. The fly ash studied in this paper obtained from Bhima Sugar Factory in Solapur district of Maharashtra state, India. The pH of the sample was measured after 3 g of fly ash was mixed with 10 ml of distilled water and shaken at $35^0$c for 24 hr and then the slurry was filtered and the pH was measured by pH meter as 11.0 the physic-chemical properties of the adsorbent was determined using standard procedure.

**Fig. 1 Raw fly ash**

### 2.2 Characterization Studies

A similar morphology to those of other standard activated carbon as reported in literature. The investigation reveals that most of the particles present in the fly ash are spherical in shape with smooth shape. Fig. 2 shows spherical particles nature

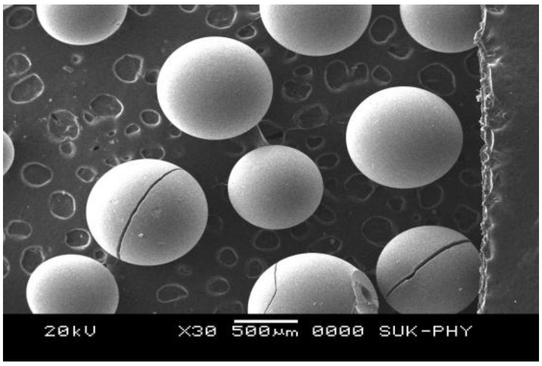

**Fig. 2 SEM Micrograph**

### 2.3 Quantitative Elemental Analysis

The result of the X-Ray fluorescence quantitative analysis of the elements in the fly ash is shown in table 1. The result shows that fly ash is a class F fly ash which can be used as to capture $CO_2$ as per literature survey.

**Table1.** Composition of Fly Ash

| Element as oxide | Weight% |
|---|---|
| $SiO_2$ | 54.1 |
| $Al_2O_3$ | 33.2 |
| $Fe_2O_3$ | 3.3 |
| CaO | 2.4 |
| MgO | 1.94 |
| $TiO_2$ | 1.99 |
| $K_{2}0$ | 0.65 |
| $P_2O_5$ | 0.54 |
| $Na_{2}0$ | 0.40 |
| S | 0.304 |
| Ba | 0.113 |
| Sr | 0.071 |
| Loss on ignition | 1.35 |

## 3. DISCUSSION

### 3.1 Possible Process Routes for carbon sequestration

### 3.1.1 Chemical Scrubbing Technique

Chemical Scrubbing Technique is the process of removing or reducing the $CO_2$ content of streams normally released to the atmosphere, and transporting the captured $CO_2$ to a location for permanent storage. $CO_2$ can be captured from a wide range of large sources, such as process streams, heater and boiler exhausts, and vents from a range of industries, such as power generation, cement production, refining, chemicals, steel and natural gas treating. There are three main groups of Carbon Capture Technologies employed shown in fig. 3 – their applicability varies according to the $CO_2$ source:

- **Pre-combustion capture**
- **Post-combustion capture**
- **Oxyfuel combustion capture**

Once captured, the $CO_2$ is compressed, dried and transported to a suitable storage location such as saline aquifers, depleted oil fields (where enhanced oil recovery could be employed) and depleted gas fields.

- **Pre-Combustion Capture**

A solid or gaseous hydrocarbon feedstock is fed to an oxygen or air-blown gasifier or reformer where it is converted to syngas. The syngas is then passed through a shift reactor which increases the hydrogen and $CO_2$ content of the syngas. The high temperature syngas is then cooled, before being washed with a solvent to absorb the $CO_2$, leaving a hydrogen-rich stream and a $CO_2$ rich solvent stream. The solvent regeneration process then releases a $CO_2$ stream which can be dried and compressed for export. This process offers significant integration potential as it can be configured to generate a high-purity hydrogen stream and the syngas cooling train can be used to raise a significant quantity of HP, MP and LP steam.

Compared with post-combustion technology, the fuel conversion steps required for this process are more complex, making it more challenging to apply to retrofits. But on the plus side, this process offers the potential of multi-product facilities, combining both power generation with hydrogen and/or syngas production for adjacent chemical and refinery use.

- **Post-Combustion Capture**

Post-combustion processes separate $CO_2$ from the exhaust gases produced by the combustion of fuel, such as coal, natural gas, oil and biomass, in air. The concentration of $CO_2$ in the exhaust gas is low, typically 3-15% by volume, and the pressure is typically close to ambient. The exhaust gas is typically cooled by direct water contact before entering a blower designed to overcome the absorption system pressure drop. The exhaust gas enters an absorption column in which it is washed with a liquid solvent, such as an aqueous amine solution. The $CO_2$ rich solvent is then heated against lean solvent and regenerated in a stripping column. The solvent then returns to the absorption column while the released $CO_2$ is dried and compressed for export. This is ideally suited for new installations as well as retrofits. To date, it has only been used on a relatively small scale.

The next steps are to improve its energy efficiency and to deploy the technology on a much larger scale.

- **Oxyfuel Combustion Capture**

The feedstock is combusted with oxygen from an air separation unit. The temperature in the boiler is moderated by recycling a portion of the flue gas back to the combustion chamber. The flue gas passes through particle removal by electrostatic precipitator, sulfur removal by limestone scrubbing and water removal by cooling and condensation. The $CO_2$ can then be separated from the remaining flue gas, dried and compressed for export. Steam from the boiler is used to generate power via a steam turbine. This process is applicable to both new build and retrofit scenarios for steam and/or power generation. Existing boilers can be converted to Oxyfuel operation with the addition of an air separation unit, suitable boiler modifications and the addition of relatively small flue gas clean-up equipment (compared with pre- and post-combustion).

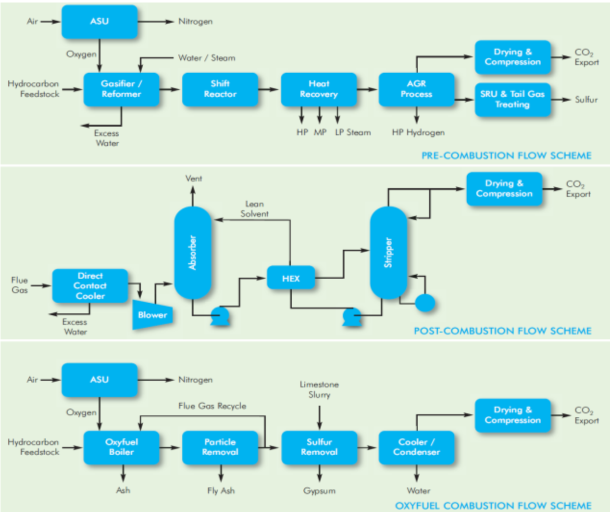

**Fig. 3 Chemical Scrubbing Technique**

### 3.1.2 Sorbent Energy Transfer System (SETS)

SETS transfer the energy of the fuel to the air without bringing the carbon along. The SETS works by using the fossil fuel (gasified coal, petroleum fuels or natural gas) in a pressurized fluidized bed to reduce a metal oxide, thereby producing a metal (or lower valence metal oxide), $CO_2$ and water. The water is condensed and its energy used to raise steam leaving a stream of pure $CO_2$ at 3-6 atmospheres that can be sequestered. The metal oxide is burned or re-oxidized in air to produce heat and the metal oxide required for the reduction step.

SETS utilize the full chemical potential of combustion of the fuel, even though the net reaction is carried out in two steps. However, as a result of the two-step process, no additional energy is needed to separate $CO_2$ from the combustion products, and the concentrated $CO_2$ steam produced can be further compressed for sequestration with very little additional energy. Both iron and nickel based oxygen sorbents have been tested. The lower cost iron based sorbents were strong, attrition resistance, and had enough oxygen capacity to fully oxidized fuel to $CO_2$ and stream. Measurements of the attrition rate showed that the iron-based sorbents would last for more than 1,000,000 cycles. However, testing also demonstrated that the iron-based sorbents could not be used for extended period at temperatures above $800^{o}C$ because the iron sinters into larger, less reactive crystallites. This temperature limitation would not allow the system to take advantage of modern, high efficiency gas turbines typically operating today. In this aspect, the Ni based sorbent fared better. It had excellent activity, strength, attrition resistance, and the ability to fully oxidize fuel ($CH_4$) to $CO_2$ and steam at 1,050°C without sintering.

Because the sorbents have very high surface areas and are small and porous to reduce mass transfer resistance, they can be fully oxidized in 3 seconds and reduced in less than 18 seconds. Thus, the SETS process can be carried out in small, high throughput (transport and fluidized bed) reactors. Because the reactors are small, internally insulated and do not require exotic materials the capital cost of the system is very low.

## 4. DISCUSSION

The last three novel concepts being developed which could be the breakthrough technologies of the future. $CO_2$ hydrate separation is currently aimed at synthesis gas separation. Its application to combustion flue gas has not been assessed. Electrical swing adsorption is a completely new technology of separation. Its potential is tremendous. The Sorbent Energy Transfer System opens a new way of burning fuels.

- Advanced Pre-Combustion Decarbonization

Assessment of a novel $CO_2$ capture technology applied within a petroleum coke-fed with carbon capture-to power flow scheme. The cost of capturing and storing $CO_2$ has a significant impact on the economics of electricity generation and therefore the aim was to achieve an overall reduction in the incremental capital and operating costs of carbon capture.

- Advanced Post-Combustion Decarbonization

Assessment of a novel post-combustion $CO_2$ capture technology. Study of the potential process performance and integration benefits and the scale-up of the process, compared with conventional amine-based post combustion $CO_2$ capture technology.

- Cost of $CO_2$ Capture

Study to develop a picture of the relative costs of $CO_2$ capture for a wide range of potential carbon capture projects on $CO_2$ captured basis. The aim was to identify those projects characterized by a high volume of $CO_2$ captured for relatively low cost, and included both retrofit cases and new-build power projects.

- Fly Ash

Fly ash in the absorption solvent may cause foaming in the absorber and stripper, equipment fouling, erosion, crevice corrosion, and increased solvent loss through chemical degradation and physical association with removed sludge. A coal-fired boiler flue gas has a typical loading of 2 grains of fly ash per dry standard cubic foot (gr/dscf), equating to ~2 tons of fly ash per 100 tons of $CO_2$. It is recommended that the loading be reduced to 0.0056 gr/dscf, requiring a removal efficiency of ~ 99.7%. Particulates should be removed upstream of the $SO_2$ scrubber.

## 5. CONCLUSION

The threat of global warming and climate change provides a new driving force for $CO_2$ separation technologies. The separated $CO_2$ can be used for enhanced oil and gas recovery and for geological storage, thus eliminating its release to the atmosphere. Capture and storage of $CO_2$ is the only option that allows the world's huge investment in the fossil fuel infrastructure to be used whilst at the same time bringing about a major reduction in $CO_2$ emissions.

Adsorption is considered to be one of the more promising technologies for capturing $CO_2$ from flue gases. For post-combustion capture, the success of such an approach is however dependent on the development of an adsorbent that can operate competitively at relatively high temperatures. In this work, low cost carbon materials such as fly ash are presented as effective $CO_2$ sorbents through impregnation these with organic bases.

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