Emission Control Strategy for Coal Fired Thermal Power Plants emphasizing the Roles of R&D: A Policy Analysis under Indian Regulatory framework

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Theme Lecture

Round Table- CCS in Power Sector, pros & cons and Issues in Environmental Norms

Workshop on Awareness and Capacity Building Carbon Capture and Utilization (ACBCCU) 2018

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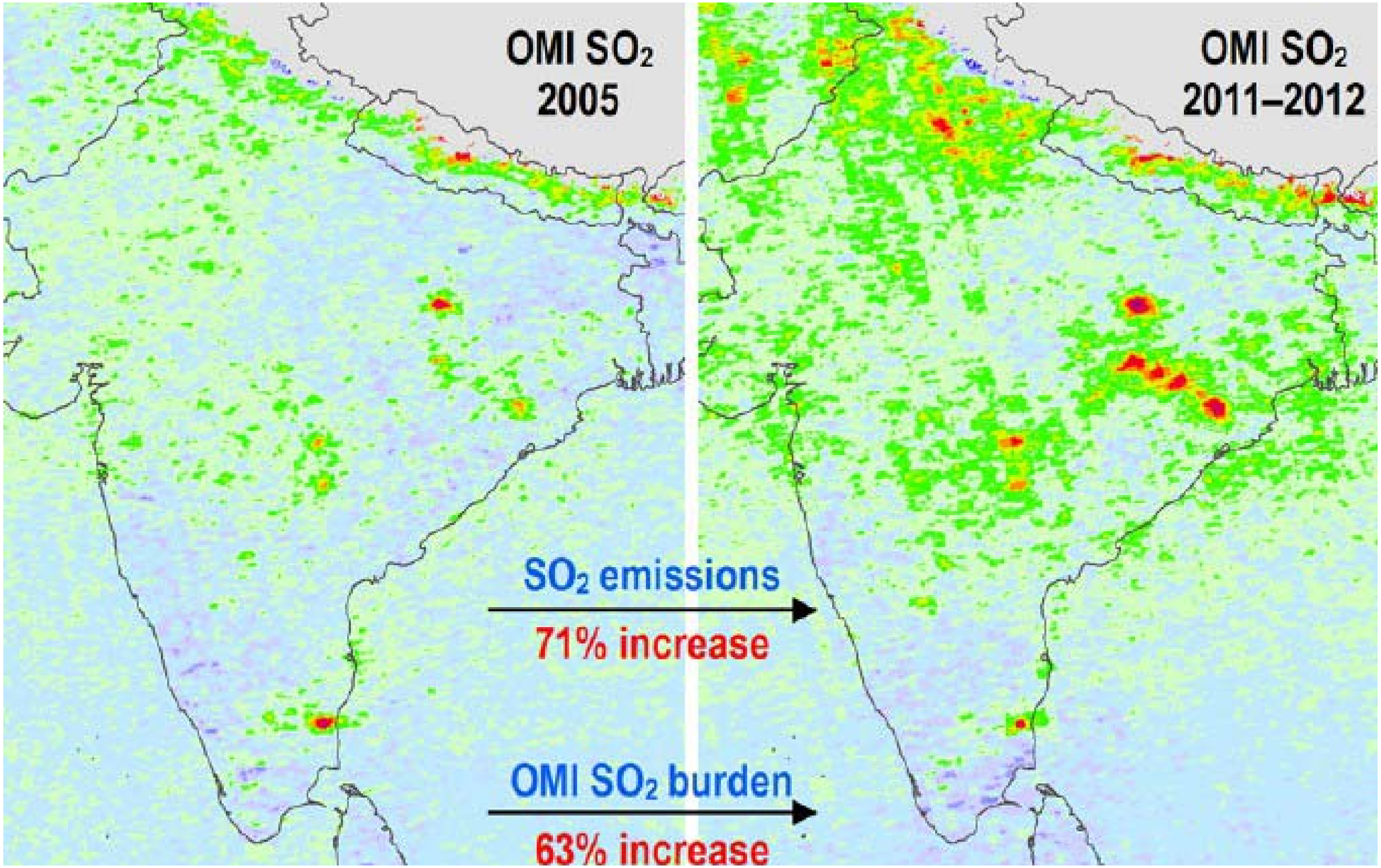
Outline

- # Why is SO_2 important for Indian TPPs?
- # Particulate laden gas cleaning status in Indian TPPs
- # Promulgation of new emission standards for Indian TPPs
- # Assessing FGD for TPPs under current Indian context
- # Multi-Pollutant Capture Technology (MPCT)
- # Assessing current emission control strategy for IndianTPPs
- # Status of current Research on CO_2 Capture in India
- # Policy recommendations for implementing emission standards for TPPs in India

TPP: Thermal Power Plant
FGD: Flue Gas Desulfurization

Why is SO_2 given importance?



Ref. Zifeng Lu, David G. Streets, Benjamin de Foy, Nickolay A. Krotkov. Ozone Monitoring Instrument Observations of Interannual Increases in SO_2 Emissions from Indian Coal-Fired Power Plants during 2005–2012. Environ. Sci. Technol. 2013, 47, 13993–14000

Current status on particulate-laden-gas cleaning to Indian TPPs

Particulate Matter (PM)	ESP with efficiency of 99.6% & Use of beneficiated coal
Sulfur Dioxide (SO_2)	Dispersion by Tall Stack
Oxide of Nitrogen (NO_x)	Low NO_x burners
Mercury (Hg)	No control
Only ESPs exist for fly ash (PM) removal No gas cleaning devices exist (except 6 TPPs having FGDs)	

Composition of Flue Gas in Indian coal fired TPPs

- Carbon Dioxide (CO_2) = 8 – 12 % [general range]
  From plant (10 to 15) monitored data (Paliwal, CPCB)
- Particulate Matter (PM) = 30 – 350 g/Nm^3 [with ESP]
- Sulfur Dioxide (SO_2) = 800 – 1200 mg/Nm^3
- Oxides of Nitrogen (NO_x) = 200 – 700 mg/Nm^3
- Mercury (Hg) = 0.005 – 0.0185 mg/Nm^3

Indian Coal fired Thermal Power Stations (as on 31.08.2016; CEA)	
State	64,210.5 MW
Private	70,992.4 MW
Central	51,390 MW
Total	1,86,593 MW

Ref.: S.K.Paliwal. Environmental Regulations for Coal based Thermal Power Plant. Central Pollution Control Board. Delhi , India. 17th WCAC & 9th BAQ Conference at Busan, South Korea Aug 29 – Sep 02, 2016
CEA, Govt of India. http://www.cea.nic.in/reports/monthly/installedcapacity/2016/installed_capacity-08.pdf

Promulgated Stack Emission Standards for TPPs Notified by MoEFCC, GoI on 07.12.2015

Parameters	All values are in mg/Nm^3		
	TPPs installed		TPPs to be installed
	Before 31.12.2003	01.01.2004 to 31.12.2016	After 01.01.2017
PM	100	50	30
SO_2	600 (< 500 MW) 200 (≥ 500 MW)	600 (< 500 MW) 200 (≥ 500 MW)	100
NO_x	600	300	100
Hg	0.03 (≥ 500 MW)	0.03	0.03
No. of Plants (MW)	302 (59,652 MW)	>279 (1,25,348 MW)	X

Ref.: **MoEFCC.** The New Emission Standards vide Notification No. S.O. 3305(E) dated 07.12.2015 in The Gazette of India: Extraordinary. Ministry of Environment, Forest and Climate Change. Government of India. New Delhi. 2015. http://www.moef.gov.in/sites/default/files/Thermal%20plant%20gazette%20 scan.pdf
S.K.Paliwal. Environmental Regulations for Coal based Thermal Power Plant. Central Pollution Control Board. Delhi , India. 17th WCAC & 9th BAQ Conference at Busan, South Korea Aug 29 – Sep 02, 2016

Challenges before the Power Industry

- CPCB & CEA have recommended wet limestone based FGD technology
- Non availability of space/land in the plants installed prior to 31.12.2003to retrofit:

  *FGD (to provide space for unit size ≥500 MW)

  *ESP (Possible to increase SCA/ conversion into hybrid ESP)
- 2 years' time for implementation of new norms
- Non availability of proven technology for control of NO_x
- Availability of Limestone and Disposal of Gypsum (???)
- Substantial increase in tariff due to implementation of Norms

Ref.: S.K.Paliwal. Environmental Regulations for Coal based Thermal Power Plant. Central Pollution Control Board. Delhi , India. 17th WCAC & 9th BAQ Conference at Busan, South Korea Aug 29 – Sep 02, 2016

Record notes of discussions of the meeting on 8th Dec 2017 at NRPC, Katwaria Sarai New Delhi held under Chairmanship of Member (Thermal), CEA, New Delhi on 'Adherence to Environmental Norms as per Environment (Protection) Amendment Rules 2015 for Thermal Power Stations' with IPPs-installations of FGD. 2017a. Available at http://www.cea.nic.in/reports/others/ thermal/umpp/mom_ environmentalnorms.pdf accessed on February 16, 2018.

REGION-WISE CAPACITY REQUIRING FGD INSTALLATION as per CEA

Region	Capacity (in MW)	No. of units
Northern	27,405	70
Southern	20,240	41
Western	16,670	39
Eastern	58,357	145
Total	**1,22,672**	**295**

Ref.: egion wise phasing plan for implementation of FGD; 2017b. Available at http://www.cea.nic.in/reports/others/thermal/tpece/fgd_installation/er.pdf for Eastern Region); http://www.cea.nic.in/reports/others/thermal/tpece/fgd_installation/nr.pdf (for Northern Region); http://www.cea.nic.in/reports/others/thermal/tpece/fgd_installation/wr.pdf (for Western Region) and http://www.cea.nic.in/reports/others/thermal/tpece/fgd_installation/sr.pdf (Southern Region) accessed on Sep 04, 2017

Assessing FGD for TPPs under current Indian context

Historic development of FGD

- **FGD studies began in 1850 (ca) in England**
- **1st Limestone based wet FGD commercialized in 1931 at Battersea Power Station under London Power Company**
- **Experiments on FGD in water commenced in 1960s**
- **Developed initially for catering Coal Fired TPPs**
- **Applied to TPPs using coal with S content ~ 3% (extended to low S coal also)**
- **Limestone based wet FGD reduces only SO_2 emission from the TPPs**

Ref.: A History of Flue Gas desulfurization Systems since 1850. JAPCA. 27, 10, 948–961, 1977
Kohl, A. & Nielsen, R. Gas Purification. Gulf Publishing. USA. 5th Ed. 1977

Assessing FGD for TPPs under current Indian context

Process	Alkaline Reagents	Inlet SO_2 (ppm_v)	By Products	Efficiency (%)
Lime Slurry	CaO	<100 - 6,500	Calcium based solids	90 - 95
Limestone Slurry	$CaCO_3$	1000 - 4,500		~95
Spray Drying – Lime	CaO, $Ca(OH)_2$	<100 - 3,000		90 - 95
Dual Alkali: Sodium + Lime stone or Lime	($NaOH/Na_2SO_3/Na_2CO_3$) & $CaCO_3$ or $Ca(OH)_2$	1,200 – 1,50,000		**99+**
Dual Alkali: Dowa	$CaCO_3$ & $Al_2(SO_4)_3$	1,000 - 25,000		85 - 98
Once Through Seawater	HCO_3^-	Up ~2,000		~98
Once Through Sodium	$NaOH$ or Na_2CO_3	<100 - 10,000	Na_2SO_3; Na_2SO_4	**99+**

Ref. A.Bandyopadhyay & M.N.Biswas. Modeling of SO2 scrubbing in spray towers. Science of the Total Environment. 383, 25–40, 2007.

Status of Six Indian FGDs

	Tata Trombay	Reliance Dahanu	Adani Mundra UMPP	JSW Ratnagiri	Udupi TPS	NTPC Vindhyachal stage V
Capacity, MW	750	500	1,980	1,200	1,200	500
Type of FGD	**Seawater wet FGD**				**Limestone-based FGD**	
Area of constrn., m^2/Acres	7,200	NA	1,500 (scrubber)	NA	10,000	10,000–20,000
Water consmpn., 10^{-5} m^3/year	147.73	876–1051	1.25 –1.40		3.06–3.50	6.13–8.76
Auxiliary power consumption, %	1–1.5	1.25	1.5	0.5–1.5	0.5	1.1
Reagent, kg/ hr	–	–	–	–	–	6,250

NA: Data Not Available

Ref.: Clearing the Air: Pollution-control technology for coal-based power plants. Research Directed by Priyavrat Bhati, Programme Director, Energy Group, Centre for Science & Environment (CSE), 2016.

Multi-Pollutant Control Technology (MPCT)

MPCTs developed for -

- Removing two or more pollutants in a single system
- To achieve new emissions standards
- Lower cost than series of single pollutant control systems

Assessing Four MPCTs for Indian case:

Sodium (NaOH or Na_2CO_3) based processes:

(i) Airborne™ Process

(ii) NeuStream® Technology

(iii) SkyMine®

Aq. NH_3 based:

ECO®-ECO_2® Technology

Ref.: A.M. Carpenter. Advances in multi-pollutant control. IEA Clean Coal Centre. 2013

MPCTs vs Limestone Wet FGD for India

Process, Reagents & Products	Pollutants removed	Status
Limestone wet scrubbers Limestone slurry as reagent. Gypsum is the by-product.	95–99% SO_2, <60% SO_3, >98% (HCl + HF), 75–99% oxidized Hg (>50% total Hg) ✗	Commercial. Costly & no total emission control
Airborne™ Process: Regenerable Na_2CO_3 injection with scrubbing & oxidant wash. Saleable fertilizers	99.9% (SO_2 + SO_3), 99% NOx, 99% Hg [C-neutral & CO_2 can be captured for use in the gas phase] √	Commercial
SkyMine®: NaOH is reagent. Saleable carbonates &/or bicarbonates, H_2 & Cl_2	>99% (SO_2 + NO_2), 90% Hg, 80–90% CO_2 √	Commercial demonstration (cement plant)
NeuStream®: O_3 injection for NO_x + dual-alkali scrubbing + CO_2 capture by Amines. Saleable by-products.	97% SO_2, >90% NOx, 98% HCl, >90% oxidized Hg, 70–90% CO_2 ✗ Amine emission problem	Commercial demonstration
ECO®-ECO₂®: Plasma Oxidation Reactor, NH_3 scrubber for SO_2, NO_2 & CO_2	> 98% SO_2, >90% NOx, 98% HCl, >85% oxidized Hg, & 90% CO_2 ✗ Ammonia leakage problem	Commercial demonstration not yet done

MCPTs shown here are relatively less costly than wet FGD + SCR

Ref.: A.M. Carpenter. Advances in multi-pollutant control. IEA Clean Coal Centre. 2013

Critical Appraisal of MPCTs

Airborne Process™ & SkyMine® produce saleable by-products
Lower Carbon & water foot prints than limestone based wet FGD

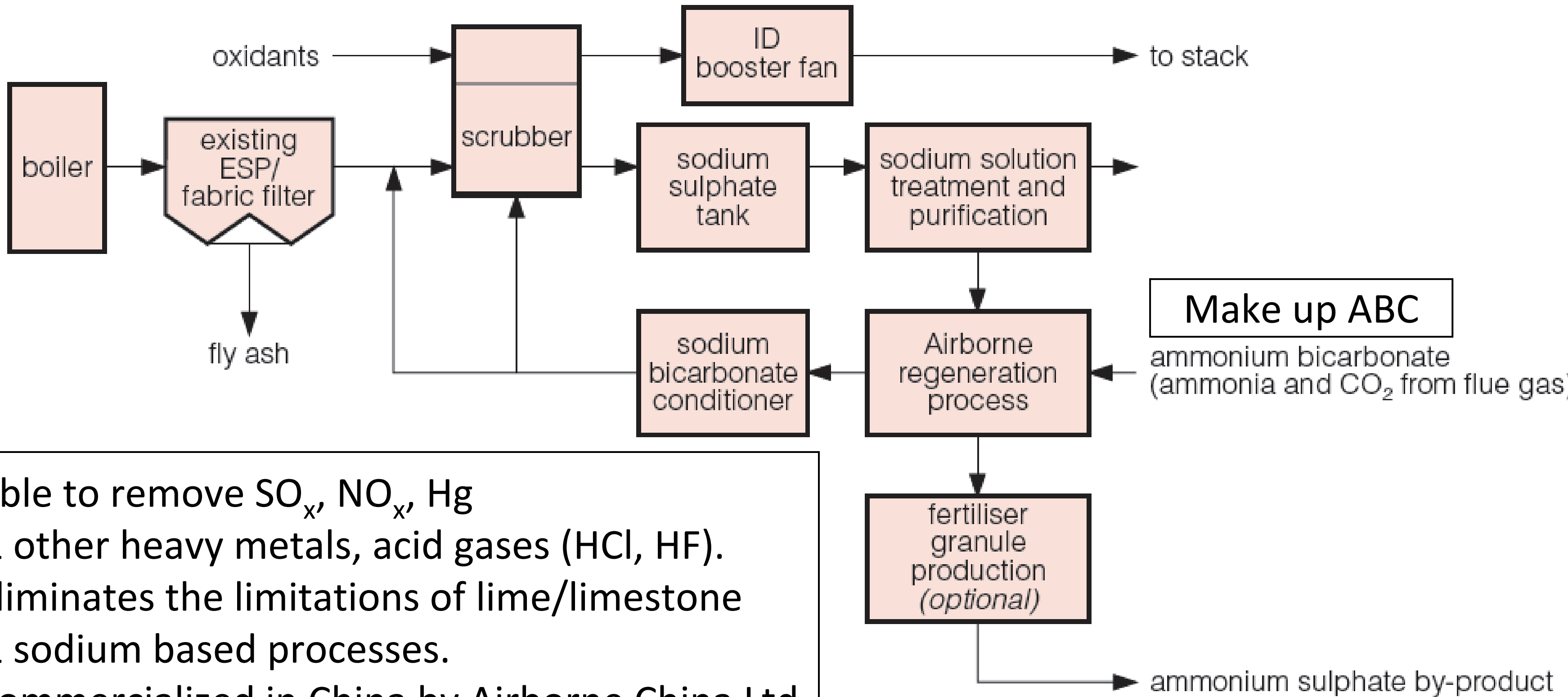
Indian advantage is reported by **Dr. L.L.Sloss (Nov 2015)** -

*"**Pollution control technologies are expensive and take time to install. It would therefore make sense for India to coordinate pollution control systems and to focus as much as possible on multi-pollutant control systems which will reduce emissions of several pollutants simultaneously**."*

Poullikkas (2015) reported that the emerging technologies for combined control of SO_2 & NO_x emissions have the potential to curb these emissions for less than the combined cost of conventional wet FGD for SO_2 & SCR for NO_x controls. Some of these technologies are commercially used on low to medium sulfur coal fired TPPs.

Ref.: A.M. Carpenter. Advances in multi-pollutant control. IEA Clean Coal Centre. 2013
L.L.Sloss. *Coal in the Indian Energy future – emissions and policy considerations.* IEA Clean Coal Centre, Nov 2015.
Poullikkas, A. Review of Design, Operating, and Financial Considerations in Flue Gas Desulfurization Systems. Energy Technology & Policy. 2:1, 92-103, 2015.

MPCT: Airborne™ Process



- Able to remove SO_x, NO_x, Hg & other heavy metals, acid gases (HCl, HF).
- Eliminates the limitations of lime/limestone & sodium based processes.
- Commercialized in China by Airborne China Ltd.

Saleable products: $(NH_4)_2SO_4$; NH_4NO_3; NH_4HCO_3 (with CO_2 capture)

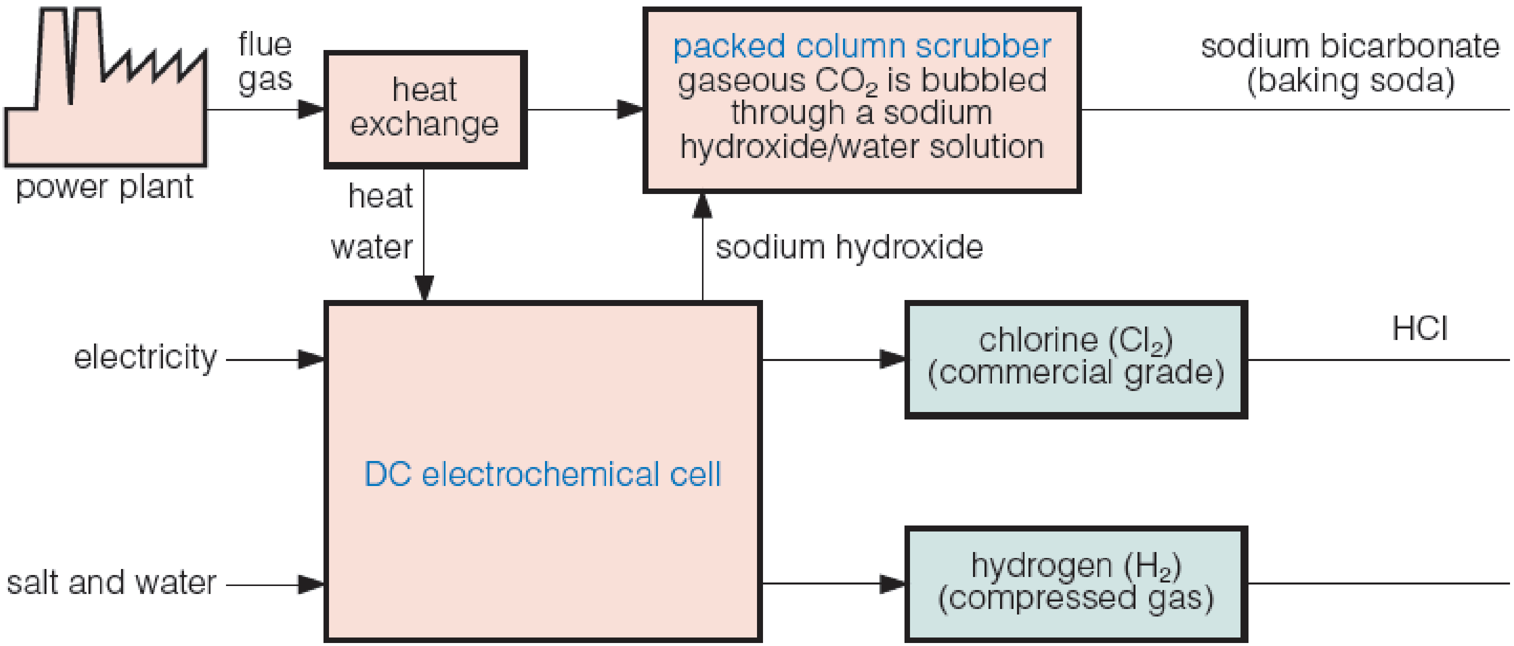
C-Neutral Approach: SO_x, NO_x & Hg stripped flue gas could be used as CO_2 source.

Removal: 99.9% (SO_2 + SO_3), 99% NO_x, 99% Hg.

Developer: Airborne Clean Energy Ltd, Calgary, Canada. www.airbornecleanenergy.com

Ref.: A.M.Carpenter. Advances in multi-pollutant control. IEA Clean Coal Centre. 2013

MPCT: SkyMine® Process



Reagent: NaOH from electrolysis of Brine. Saleable Products

SkyMine: Removes CO_2, SOx, NO_2, Hg & other heavy metals from flue gas

Cost: 600 billion USD for 1325 MW; 23 USD/t CO_2; Excluding revenue from products

Penalty: 20% as against 30 to 40% for CCS

Option (non-carbon mode) for removing SO_2, NO_2 & heavy metals (**SkyScrapper**)

Commercial Status: Commercial demonstration

Removal: >99% (SO_2 + NO_2), 90% Hg, 80–90% CO_2

Developer: Skyonic Corporation http://skyonic.com.

Ref.: A.M. Carpenter. Advances in multi-pollutant control. IEA Clean Coal Centre. 2013

Assessing the Current Emission Control Strategy

“Immediate Action Steps” proposed by CSE

Flown from the national workshop “*NEW ENVIRONMENTAL NORMS FOR THE POWER SECTOR*” held on September 07, 2016 organized by CSE

1. **MoEF should survey the implementation status of TPPs**
2. **CEA should act as the key technical advisor & prepare ‘Technology Guidelines’**
3. **CERC should prepare a simplified tariff application**
4. **CERC could consider uniform tariff increases based on minimum capital costs**
5. **CEA & CPCB should develop a monitoring mechanism**
6. **CEA & POSOCO need to prepare a scheduled shut-down plan**

CEA: Central Electricity Authority; CERC: Central Electricity Regulatory Commission
POSOCO: Power System Operation Corporation Limited

Recommendations of CSE

1. Government should divert a portion of National Clean Energy Fund (NCEF)—of around Rs 23,000 crore to support installation of pollution control equipment.

2. Government should work on an expedited plan to retire or replace old capacity.

3. For replacing the units no need for Environmental Clearances.

4. New investors can be encouraged.

3. Incentives for plants that meet norms by the deadline.

Ref.: NEW ENVIRONMENTAL NORMS FOR THE POWER SECTOR. Proceedings and Recommendations of the Stakeholder Workshop Organized by CSE. 7 September 2016

POLICY BRIEF: USING THE National Clean Energy Fund to Clean Coal Power Plants. CSE, New Delhi, 2017

Need for a sound Decision Support System

Reasons are as follows (Bandyopadhyay, March 2017) –

Use of a part of "NCEF" for erection of FGD technology needs review;

Newly promulgated Emission Standards for TPPs are concentration based & not technology/equipment based;

TPPs are free to choose any tech./equip. to meet emission standards as per Air (PCP) Act, 1981 & Environment (Protection) Act, 1986;

Techno-enviro-economic solution to achieve a holistic target is missing.

CEA has clarified (CEA, Dec 2017) *"that presently CEA has come up with standard technical specifications for wet FGD, however, this is only advisory in nature and power producers have liberty to choose any suitable technology for reducing SO_x."*

Thus there is a scope of consideration of FGD other than wet limestone based FGD under Indian context.

Ref.: A.Bandyopadhyay. Cleaning, but with a better strategy. Write Back in Financial Express. P 9. March 16, 2017.
CEA: Record notes of discussions of the meeting on 8th Dec 2017 at NRPC, Katwaria Sarai New Delhi held under Chairmanship of Member (Thermal), CEA, New Delhi on 'Adherence to Environmental Norms as per Environment (Protection) Amendment Rules 2015 for Thermal Power Stations' with TPPs-installations of FGD. 2017a. Available at http://www.cea.nic.in/reports/others/ thermal/umpp/mom_environmentalnorms.pdf accessed on February 16, 2018.

Status of Indian Current Research on CO_2 Capture

Legion of R&D projects are funded by various Govt. agencies in India for CO_2 capture from simulated streams by various methods.

These researches ignore the estimated CO_2 generation from the processes developed to capture the CO_2.

Number of seminars etc. are held in India for the past several years on CO_2 capture. In contrast, seminars or even funded R&D projects for SO_2 removal (or FGD) and MPCTs in India are few & far between.

The major research areas towards CO_2 capture/removal include –
(i) developing membranes (inorganic/organic) for CO_2 capture,
(ii) absorption of CO_2 in amine based blended solvents,
(iii) removal of CO_2 on synthesized nano-materials as adsorbents.
(iv) biological methods for CO_2 capture.

Status of Indian Current Research on CO_2 Capture

Main thrust on R&D: Material development for CO_2 capture

Demonstration project commissioned on a slip-stream from the flue gas of an Indian TPP has not yet been reported.

Presence of other gases & traces of PM has not yet been included in any of the Indian CO_2 capture projects.

These projects can not be directly put into practice in any Indian TPP without comprehensive studies taking into account of the plurality of pollutants present in the flue gas emitted from TPPs.

The life cycle analysis is left out in the current Indian CO_2 capture projects which essentially constitutes an integral approach under the present circumstances.

Policy Recommendations

1. **To constitute a Task Force at national level (under the aegis of CEA & MoEFCC/CPCB)**

***Proposed composition of the Task Force (as an example)**

i) Experts from TPPs like NTPC/DVC/SEBs/Pvt. Co.

ii) Experts from Inorganic Chemical & Fertilizer Industries

iii) Experts from MoP, MoC, MoEFCC, CPCB, CEA, CERA, POSOCO

iv) Technology Field Experts -

(a) Emission Control Technology [with knowledge of particulate &/or gas cleaning, gas-liquid mass transfer and TPPs]

(b) CO_2 Capture & Sequestration (Geologic & reuse of CO_2)

v) Policy Experts

Ref.: A.Bandyopadhyay. Assessing the Current Practice and Policy with Recommendations for Emission Control Strategy for Coal Fired Thermal Power Plants under Indian Regulatory Framework emphasizing the Roles of R&D. Environmental Quality Management for publication, 27, 49–55, 2017b"; https://doi.org/10.1002/tqem.21511

Policy Recommendations

2. Outline of *modus operandi* of the Task Force–

* To constitute 4 ***Regional Expert Committees*** (for 4 regions) and a ***Central Expert Committee*** under CEA & MoEFCC/CPCB to monitor the compliance status of the newly promulgated emission standards;

* **To explore MPCT for complying stack emission standards of Indian TPPs under "Swachh Bharat Mission"**

* **To avoid ignoring CO_2 capture in the MPCT, though it is not a listed parameter in the promulgated emission standards**

* **For CCS, to consider Zoning– typical examples are**
  # TPPs located at Durgapur, WB may have CCS for ECBMR
  # TPPs located elsewhere e.g. at Mejia, WB may have MCPT with saleable by products (avoiding CCS project here)

Ref.: A.Bandyopadhyay. Assessing the Current Practice and Policy with Recommendations for Emission Control Strategy for Coal Fired Thermal Power Plants under Indian Regulatory Framework emphasizing the Roles of R&D. Environmental Quality Management for publication, 27, 49–55, 2017b"; https://doi.org/10.1002/tqem.21511

Policy Recommendations

2. Outline of *modus operandi* of the Task Force–

* To consider utilization of captured CO_2 as
  (i) saleable products &
  (ii) sequestration as in CCS projects e.g. in ECBMR
* To consider market potential of the by-products of gas cleaning so that the same may not create disposal problems like gypsum
* To consider revamping ESP for controlling emission of fly ash
* To follow the principle of Charter on Corporate Responsibility of Environmental Protection (CREP) for coming up with "Technology Guidelines"
* To consider support for other logistics, if any
* The promulgated emission standards for the Indian TPPs may be reviewed under "Change in Law"

Ref.: A.Bandyopadhyay. Assessing the Current Practice and Policy with Recommendations for Emission Control Strategy for Coal Fired Thermal Power Plants under Indian Regulatory Framework emphasizing the Roles of R&D. Environmental Quality Management for publication, 27, 49–55, 2017b"; https://doi.org/10.1002/tqem.21511

Policy Recommendations

3. To propose for Capacity Building on Advanced Emission Control Technology to TPPs, SPCBs/ PCCs/ CPCB for framing post-implementation strategies.

4. To establish a National Emission Control Technology Research Centre (including CO_2 Capture Research) indicating the role of Indian R&D towards industrial gas cleaning (business to business or multi-sectoral approach) targeting lower water- & carbon- footprints. An interesting issue for the need for such R&D -

Pb as emission parameter in TPP in future?

Singrauli Madhya Pradesh – NGO activity
* 2000 MW NTPC + HINDALCO + others
* Initially fluoride emission from HINDALCO & later Lead (Pb) emission from TPP was reported to cause the health damage

Ref.: A.Bandyopadhyay. Assessing the Current Practice and Policy with Recommendations for Emission Control Strategy for Coal Fired Thermal Power Plants under Indian Regulatory Framework emphasizing the Roles of R&D. Environmental Quality Management for publication, 27, 49–55, 2017b"; https://doi.org/10.1002/tqem.21511

Policy Recommendations

6. **(*) Indian TPPs utilize electrical, mechanical, civil, instrumentation, electronics & computer science engineers.**

   (*) Chemists are utilized in the laboratories for chemical analyses.

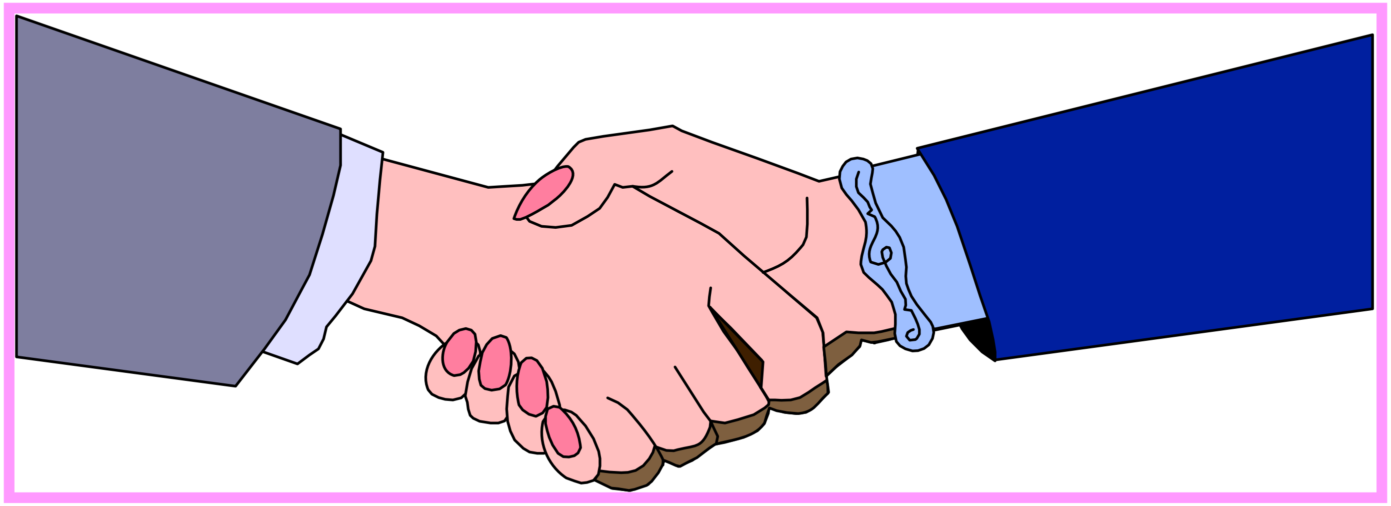
   (*) The gas cleaning plants require knowledge of thermodynamics, chemical kinetics & mass transfer. "*Chemical Engineers*" are appropriately equipped with this knowledge.

   (*) Indian TPPs will thus require "*Chemical Engineers*" for meeting the challenges of the new emission standards. Outsourcing "Chemical Engineers" may not be conducive.

   (*) "*Chemical Engineering*" curricula must be consolidated at the UG and PG levels to comply with the future demands of industries for improved gas cleaning operations in the country.

7. **Submission of recommendations by the *Central/Regional Expert Committees* to the Government of India for consideration.**

Ref.: A.Bandyopadhyay. Assessing the Current Practice and Policy with Recommendations for Emission Control Strategy for Coal Fired Thermal Power Plants under Indian Regulatory Framework emphasizing the Roles of R&D. Environmental Quality Management for publication, 27, 49–55, 2017b"; https://doi.org/10.1002/tqem.21511



Thank You