Guidelines for Handling and Management of Flue Gas Desulphurization (FGD) Gypsum

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Central Pollution Control Board
(Ministry of Environment Forest and Climate Change)
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1. Introduction

The installed capacity of Coal Based Thermal Power Plants is more than half of the total capacity of power plants in the country. Apart from particulate matter and oxides of nitrogen, Sulphur Dioxide (SO_2) is one of the major pollutants of concern. In the process of combustion, upto 95 % of the Sulphur present in the coal gets converted and released as SO2 gas.

The generation of SO_2 is directly proportional to the Sulphur content in the coal and quantum of the coal used. As per data available on the National Power Portal, about 2747 thousand tons of Coal is daily required to operate the existing 448 power generation units. India being the developing country cannot do away with the Coal based thermal power plants which are crucial in order to meet its daily electricity demand.

Therefore, in order to reduce the impact of SO_2 generated by power plants, Ministry of Environment, Forest & Climate Change (MoEF&CC) notified new stringent emission norms for coal based Thermal Power Plants (TPP) for sulphur dioxide (SO2) and other pollutants vide S.O. 3305 (E) dated 07/12/2015. To meet such norms, all coal based thermal power plants have to install Flue Gas Desulfurization system to control SO_2 emissions as per timelines prescribed by MoEF&CC (i.e. December 2025) as given below;

For TPPs installed prior to 31st December 2016: 600mg/Nm^3 for < 500MW TPPs; 200mg/Nm^3 for TPPs having > 500MW capacity.

For all TPPs installed after 1st January 2017: 100mg/Nm^3

In order to achieve new emission norms, power plants are required to install scrubbers which are called Flue Gas Desulfurization (FGD) systems. SO2 emission from coal burning can be neutralized using sodium or calcium based alkaline reagents such as lime, limestone, Sodium Hydroxide, ammonia, sea water, Calcium Carbonate, Sodium Bicarbonate, etc. The same principle is used in Flue gas desulfurization (FGD) which is used for removal of Sulphur Dioxide from flue gas produced at coal-fired thermal power plants.

Taking a step towards promoting the Circular Economy on Mission Mode as announced by Hon'ble Prime Minister, NITI Aayog had constituted various Committees on various focus Areas. "FGD Gypsum" being one of them for which Department for Promotion of Industry and Internal Trade (DPIIT) has been appointed as Nodal Ministry. CPCB has been assigned the task of developing guidelines for handling and management of Gypsum.

These guidelines are based on international practices and studies carried out in three operational plants in the country. It is expected that new FGD plants will come up gradually and FGD gypsum management practices are expected to evolve, in line with implementation timelines for SO2 emission standards, with effect from 2024. Therefore, a revision of these guidelines may be made subsequently, if required.

2. Flue Gas Desulfurization (FGD) Process:

There are various types of Flue Gas Desulphurization systems, predominantly the following 03 types of FGD system are adopted worldwide:

1. Dry Sorbent Injection
2. Wet Limestone Based
3. Sea Water Based

The dry sorbent scrubbing systems is also known as dry injection or spray drying systems, where SO2 reacts with limestone in flue gas prior to dust control systems. Wet desulfurization scrubber systems are the most commonly used technology, suitable for large-scale flue gas treatment, and uses a low cost alkaline scrubbing reagent (limestone) to produce stable gypsum and high SO_2 removal efficiency. Sea water based process can achieve 70-95% reduction in SO2 with alkaline sea water, and can be adopted when SO2 emission norms are relaxed. The initial cost of seawater based process is lower than the wet limestone-gypsum FGD process due to the simple equipment configuration.

Types of wet scrubbers used in FGD: Wet scrubber designs such as spray towers, venturis, plate towers, and packed beds can be used. Considering operational issues such as scale buildup, plugging, etc., industry adopt simple scrubbers such as spray towers. However, these spray towers however, require a higher liquid-to-gas ratio requirement for equivalent SO2 removal than other absorber designs.

Scrubbing reagents: Limestone and sodium hydroxide can be used as alkaline scrubbing reagents. Limestone slurry is typically used in scrubbers of large coal / oil fired boilers in power plants, as it is very much less expensive than caustic soda.

In case of caustic soda, the spent sodium sulfite/bisulfite solution needs disposal, especially where there is no downstream utilization in industry such as pulp and paper mill.

Other techniques of lesser use are scrubbing with sodium sulfite solution and gas-phase oxidation followed by reaction with ammonia.

Due to abundant presence, limestone is used in FGDs in the country for reduction of SO_2 which in turn produce calcium sulphate di-hydrate [$CaSO_4.2H_2O$] also known as Gypsum. This guideline document therefore, mainly focuses on wet lime based Flue Gas Desulphurization systems.

Wet Limestone based Flue Gas Desulphurization systems

Wet limestone based flue gas desulfurization (FGD) plant can be installed for removal of sulfur dioxides (SO2) from flue gas produced by boilers, furnaces, and other processes using combustion fuels like coal or fuel oils. This processes can treat a large range of SO2 concentrations with removal efficiencies up to 99%. Apart from So2 gases, this system also helps in substantial reduction of particulate matter, thus helps in improving efficiency of dust reduction from power plants.

The Wet limestone based FGD system generates large quantity of synthetic gypsum while removing SO2 from flue gases. The same could be a cause of concern for power plant operators and regulatory agencies due to its high volume and handling aspect.

In wet scrubbing system the flue gas containing SO_2 reacts with slurry of limestone (Ca Co_3)to produce calcium sulfite (CaSO3) and CO_2 in 1st stage. Thereafter, calcium sulfite can be oxidized to produce by-product gypsum ($CaSO_4 \cdot 2H_2O$) in 2nd stage reaction, which is marketable for use in industry. A flow diagram depicting the manufacturing process of FGD Gypsum is given in ***Figure 1*** and the chemical reactions that take place in FGD process are given below sequentially, however, they may occur simultaneously:

SO_2 Absorption:

SO_2 is absorbed when the flue gas is intercepted by tiny droplets of slurry in the absorber. Water in the slurry captures the SO_2, changes it into a liquid sulfur-based acid.

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$H_2SO_3 \rightarrow H^+ + HSO_3^-$$

Limestone Dissolution:

$$CaCO_3 + H_2O \rightarrow Ca^{2+} + HCO_3^- + OH^-$$

Oxidation:

Through the process of oxidation, sulfite (SO_3) is converted to sulfate (SO_4). The sulfate byproduct, when combined with the calcium, forms calcium sulfate.

$$HSO_3 + O_2 \rightarrow H^+ + SO_4^{2-}$$

Precipitation:

Precipitation is the process by which a substance separates from a solution due to a chemical change in the solution. The absorbed SO_2 reacts with the dissolved limestone to form new products i.e. calcium sulfate ($CaSO_4$), or gypsum

$$Ca^{2+} + SO_4^{2-} + 2H_2O \rightarrow \underbrace{CaSO_4 * 2H_2O}_{\text{Gypsum}}$$

The said process gives an efficiency of 90% -99% towards neutralization of SO_2. Parameters such as boiler load, limestone fineness, Chloride control (Lesser is better), reagent ratio (Ca/S ion), pH & density of absorber tank, etc. affect the performance of FGD process.

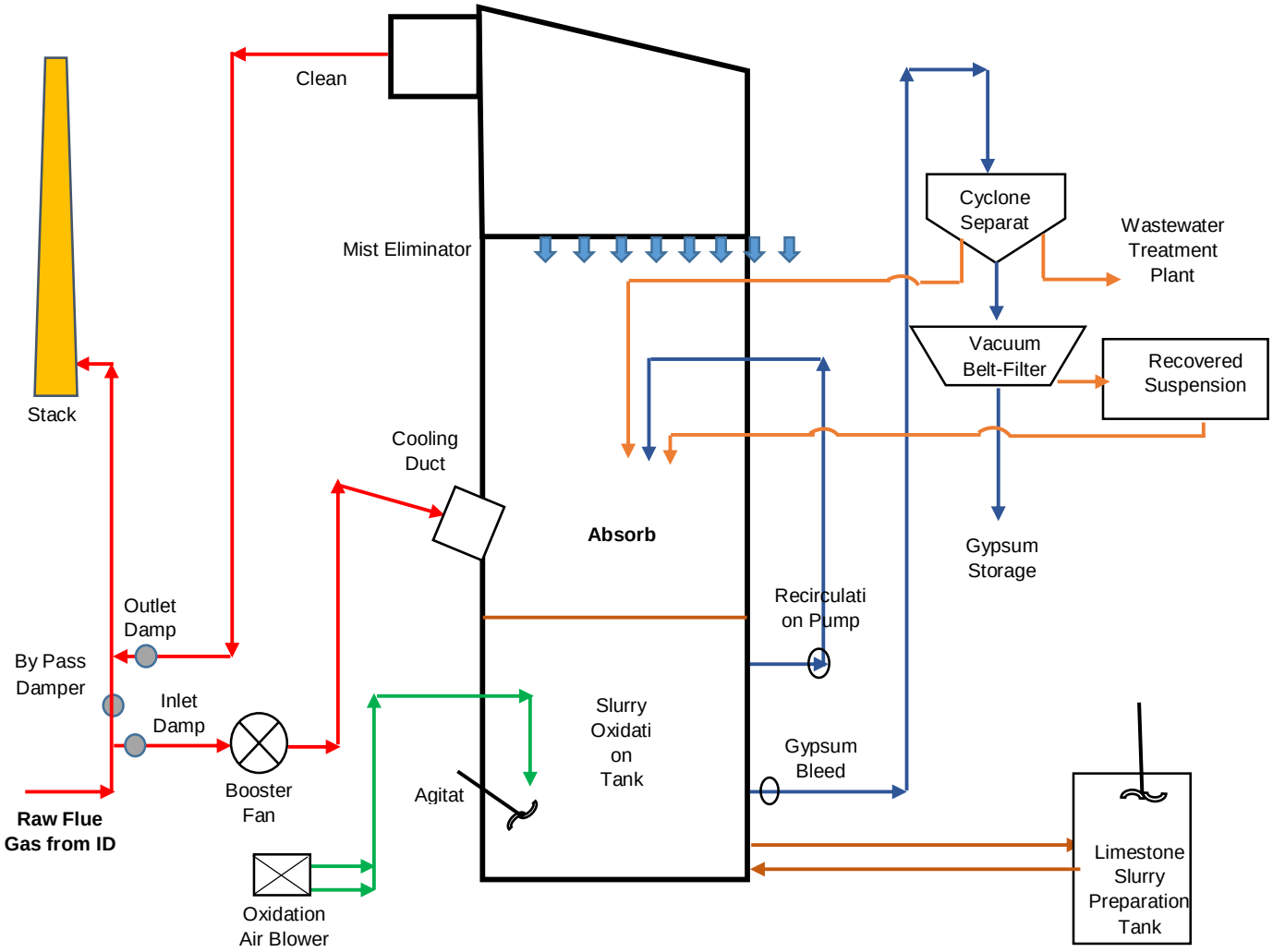

FIGURE 1: FLOW DIAGRAM OF FLUE GAS DE-SULFURIZATION

3. FGD Gypsum generation scenario in India

The production of gypsum (CaSO4.2H2O) based on SO2 removal can be estimated from the above chemical equation considering their molecular weights, 1 mole of SO2 produces 1 mole of gypsum. The SO2 emissions in the flue gas depends on the sulphur content of the coal burned. Considering the sulphur content of Indian coal to be around 0.35% and considering variation in specific coal consumptions of various unit sizes, Central electricity Authority (CEA) has estimated the FGD gypsum generation in tonnes per annum (tpa) per MW considering plant utilization or plant load factor (PLF) of 80% and 55% which is tabulated below:

Unit Capacity (MW)	**Specific Coal Consumption (kg/kWh)**	**FGD gypsum generation**	
		TPA/MW @80% PLF	**TPA/MW @55% PLF**
Upto 250	0.764	100.7	69.25
250-500	0.684	90.18	62
500-600	0.584	76.99	52.93
Abobe 600	0.524	69.08	47.49

Source: Central Electricity Authority

Till December 2022, only the following 03 Coal Fired thermal power plants have installed Flue gas desulfurization (FGD) system:

1. Mahatma Gandhi Thermal Power Project, Haryana
2. The Vindhyachal Thermal Power Station, Madhya Pradesh
3. Udupi Power Plant, Karnataka

As previously mentioned, FGD operation and production of FGD gypsum directly depends upon the coal consumption, Sulphur content in coal, quality of limestone etc. Therefore, the efficiency of FGD process may differ from unit to unit. The FGD operational parameters at different thermal power plants is as below:

S.No.	**Parameters**	**Mahatma Gandhi TPP, Haryana**	**The Vindhyachal Thermal Power Station, M.P.**	**Udupi Power Plant, Karnataka**
1.	Sulphur in coal	0.35 %	0.49 %	0.53 %
2.	Absorber Inlet SO_2	1094 mg/Nm^3	1852 mg/Nm^3	2007.17 mg/Nm3
3.	FGD Outlet SO_2	108 mg/Nm^3	178 mg/Nm3	984.96 mg/Nm3
4.	Desulfurization Efficiency	90.1%	90.4 %	85%
5.	Flue gas Inlet Temperature	125°C	145°C	140 ºC

6.	Operating Condition	BMCR	BMCR	Wet condition (25% of the total flue gas)

BMCR: Boiler maximum continuous rating
Source: Information provided by respective TPPs

The quantity of coal and limestone used by a unit and the simultaneous electricity and FDG gypsum generation are given below:

S.No.	Component	2018-19	2019-20	2020-21	2021- 2022
Mahatma Gandhi TPP, Haryana					
1.	Quantity of Coal Used (MT)	4130802	3634817	2863123	4488479
2.	Quantity of Lime Used (MT)	32986	49913	38448	68703
3.	Power Generation (MWh)	6898352	5888946	4873031	7357037
4.	FGD Gypsum Generation (MT)	44044	91190	63130	94849
The Vindhyachal Thermal Power Station, Madhya Pradesh#					
1.	Quantity of Coal Used (MT)	2513537	2816645	2651328	2472501
2.	Quantity of Lime Used (MT)	7276.4	8942	16784	8282
3.	Power Generation (Mu)	3875	4085	3984	3664
4.	FGD Gypsum Generation (MT)	10915	13413	25176	12423
Udupi Power Plant, Karnataka*					
5.	Quantity of Coal Used (MT)	2219731	1402515	988114	556333
6.	Quantity of Lime Used (MT)	1030	1433	611	521
7.	Power Generation (MWh)	595	373	268	162
8.	FGD Gypsum Generation (MT)	575	1678	1042	112

 # Installed for 500 MW
**Installed FGD capacity is only about 25% of the Flue gas.*
Source: Information provided by respective TPPs

CEA has estimated that when FGD system will be installed by all 448 TPPs, about 9.94 Million MTA of FGD gypsum @ 55% PLF and 14.46 Million MTA @ 80% PLF. However, the FGD gypsum generation is estimated to be around 9.94 Million MT due various challenges like financial, logistics and manpower constraints, faced in implementation of FGD systems at TPPs. The year wise expected FGD generation is shown below:

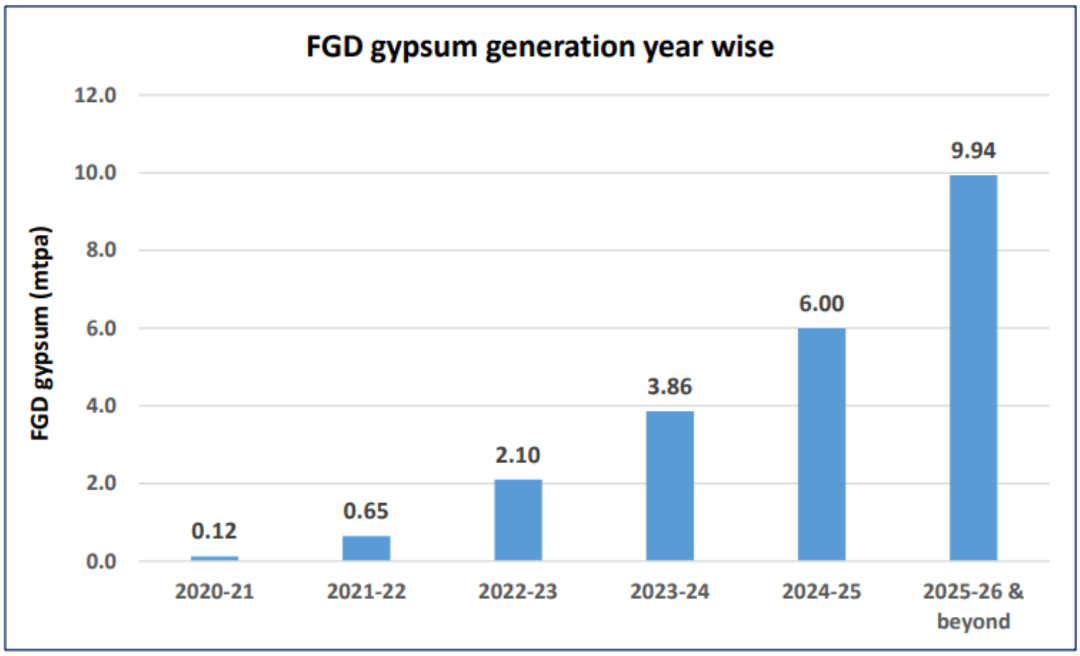

Figure: Year wise estimated FGD gypsum generation (Million TPA)

Source: Department for Promotion of Industry and Internal Trade report on Achieving Circular Economy in Gypsum

4. Characteristics of Flue Gas Desulfurization (FGD) Gypsum

FGD Gypsum is a gray colored, fine grained powder having moisture content ranging 10-15%. The FGD gypsum contains 80-90% Calcium Sulphate Di-hydrate ($CaSO_4.2H_2O$) by mass and around 3% silica (as SiO_2). The range of oxides in FGD Gypsum depends highly on the quality of limestone used in the process. The characteristics of limestone and the FGD Gypsum generated from different thermal power plants is given below:

Limestone Characteristics

S.No.	Components	Mahatma Gandhi TPP, Haryana	Udupi Power Plant, Karnataka
1.	Size	10-80mm (>90%); Below 10mm (<10%)	50-60 mm
2.	$CaCO_3$	> 90 %	80-98
3.	CaO	> 50.5 %	-
4.	$MgCO_3$	< 2.5 %	1.0-8.0
5.	MgO	< 1.35 %	-
6.	Silica	< 2.5 %	1.0-8.0
7.	Fe_2O_3	< 2 %	1.0-4.0
8.	Al_2O_3	< 2 %	-

Source: Information provided by respective TPPs

FGD Gypsum Characteristics:

(i) Chemical

S.No.	Components	Mahatma Gandhi TPP, Haryana	The Vindhyachal Thermal Power Station, M.P.	Udupi Power Plant, Karnataka
1.	pH	8.20	7.61	8.1
2.	Moisture (%)	22.5%	23.5	12.1
3.	Conductivity (µmho/cm)	3250	2687.5	6410
4.	Exchangeable Na (mg/100g)	19.06	13.69	-
5.	Exchangeable K (mg/100g)	4.69	3.57	-
6.	Exchangeable Ca (mg/100g)	4027.5	4270	-
7.	Exchangeable Mg (mg/100g)	712.5	462.5	-
8.	ESP (%)	0.11	0.23	-
9.	$CaSO_4.2H_2O$	90%	95.1 %	-
10.	$CaCO_3$	2.5%	0.7 &	-
11.	CaO	35%	-	-
12.	$MgCO_3$	-	-	-
13.	MgO	0.5%	-	-
14.	Silica	2.5%	-	-
15.	Fe_2O_3	0.1%	2100 ppm	-
16.	Al_2O_3	0.1%	2600 ppm	-
17.	Chloride	250ppm	49 ppm	0.104%

Source: Information provided by respective TPPs & Analysis carried out by CPCB

(ii) Total Metal Concertation:

S.No.	Components	Mahatma Gandhi TPP, Haryana	The Vindhyachal Thermal Power Station, M.P.	Udupi Power Plant, Karnataka
1.	As (mg/Kg)	BDL	BDL	-
2.	Cd (mg/Kg)	BDL	BDL	-
3.	Cr (mg/Kg)	23.96	10.17	-
4.	Cu (mg/Kg)	1.68	1.56	-
5.	Fe (mg/Kg)	589.92	2188.89	-
6.	Mn (mg/Kg)	91.4	12.44	-
7.	Ni (mg/Kg)	1.34	1.405	-
8.	Pb (mg/Kg)	6.95	1.835	-
9.	Sb (mg/Kg)	BDL	BDL	-

S.No.	Components	Mahatma Gandhi TPP, Haryana	The Vindhyachal Thermal Power Station, M.P.	Udupi Power Plant, Karnataka
10.	Se (mg/Kg)	3.81	1.725	-
11.	V (mg/Kg)	12.26	2.83	-
12.	Zn (mg/Kg)	BDL	BDL	-

Source: Analysis carried out by CPCB

(iii) TCLP

S.No.	Components	Mahatma Gandhi TPP, Haryana	The Vindhyachal Thermal Power Station, M.P.	Udupi Power Plant, Karnataka
1.	As (mg/Kg)	BDL	BDL	BDL
2.	Cd (mg/Kg)	BDL	BDL	BDL
3.	Cr (mg/Kg)	BDL	BDL	BDL
4.	Fe (mg/Kg)	0.4	0.80	-
5.	Mn (mg/Kg)	1.31	0.73	0.78
6.	Pb (mg/Kg)	BDL	BDL	BDL
7.	Sb (mg/Kg)	BDL	BDL	-
8.	Se (mg/Kg)	0.02	0.01	BDL
9.	V (mg/Kg)	BDL	BDL	-

Source: Analysis carried out by CPCB

FGD gypsum due to its low effect, shall be treated as non-hazardous waste owing to the characteristics and as per the recommendations in 74th meeting of Technical Review Committee (TRC) of the Ministry of Environment Forest and Climate Change.

5. FGD Gypsum Management Practices:

5.1 Global Practices:

FGD system for removal of Sulphur from flue gas of Coal Fired Thermal Power Plant has been adopted globally decades ago. Thus, the FGD gypsum is being managed Globally through various methodologies. Globally, the following practices have been majorly adopted for utilization of FGD gypsum:

1. Production of Gypsum Board
2. Cement Manufacturing
3. Composite Binder
4. Soil Amendment
5. Mine Backfilling

Status of utilization of FGD gypsum in various countries is summarized below:

1. Germany: Thermal Power Plants in Germany have adopted FGD system earliest in the world due to large-scale combustion equipment regulations which came into effect in 1983. About 80% of power plants generate FGD gypsum which has created a option for utilization of FGD gypsum that resulted in evolution of

quality standards of FGD Gypsum for use in the Gypsum industry. 75% of the FGD gypsum generated is being utilized predominantly in the areas of Plaster, Cement and Floor Screeds.

2. Japan: Utilization rate of FGD gypsum is over 90%, of which cement industry accounts for about 30-40% and other main areas of utilization is Gypsum Board. Japan has enacted legislation to control exploitation of natural gypsum which has also helped encouraging the comprehensive utilization of FGD gypsum.
3. Denmark: Nearly all the FGD gypsum produced are being utilized in the building material, gypsum boards or use in cement production
4. United States of America: Majority of the FGD gypsum is utilized as resource for Gypsum board manufacturing sector, followed by cement industry and other areas such as s structural filling, agriculture, and mine reclamation
5. China: China is the lead generator of the FGD gypsum in the world, major quantity of the FGD gypsum is utilized in Cement Manufacturing, Gypsum Board manufacturing and utilization of Gypsum as retarder, Gypsum block, mortar, wall insulation materials, building plaster, wall plaster, etc. Further, in case of disposal, guidance for site selection, dust prevention measures and leakage monitoring have been provided for disposal site.

Studies have been carried out to verify the feasibility of directly reusing the flue gas desulphurization (FGD) gypsum generated from coal-fired power plants to adsorptive removal of Pb(II) and Cd(II) from wastewater.

5.2 National Practices

The current practices for management of FGD Gypsum being followed by aforesaid units in India are given below:

a. M/s Jhajjar Power Limited, Haryana

M/s Jhajjar Power Limited (JPL) Haryana, is 1320 MW (2*660) capacity coal based TPP has installed FGD system. Unit is transporting the FGD gypsum for utilization in (i) Cement Manufacturing and (ii) Gypsum Board Manufacturing. The quantity of FGD gypsum utilized by M/s JPL is given below:

S.No.	Component	2018-19	2019-20	2020-21	2020-21
1.	Cement Manufacturing (MT)	35,874.6	90,556.6	62,249.9	98,309.9
2.	Gypsum Board Manufacturing (MT)	-	98.5	-	2,703.7

Source: Information provided by TPP

M/s JPL utilizing the benefit of availability of Cement plants within its vicinity is sending most of the quantity to Cement Manufacturing in comparison to Gypsum manufacturing. Further, the requirement of high quality gypsum by the Board Manufacturers also plays a critical role of sending the FGD gypsum to cement plants. However, in order to ensure the consistent Gypsum offtake, M/s JPL has tied up with

cement units and gypsum board manufacturing units available in the vicinity of the plant.

FGD gypsum generated in the unit is directly send to the utilizers from the collection chambers below vacuum filters. Unit has day storage capacity of 800 MT and storage shed of 2200 MT has been provide.

Gypsum is loaded to the trailers of procurer with the help of loader/JCB and same is covered to avoid any fugitive dust emission during transportation.

FIGURE 2: ABSORBER TANK

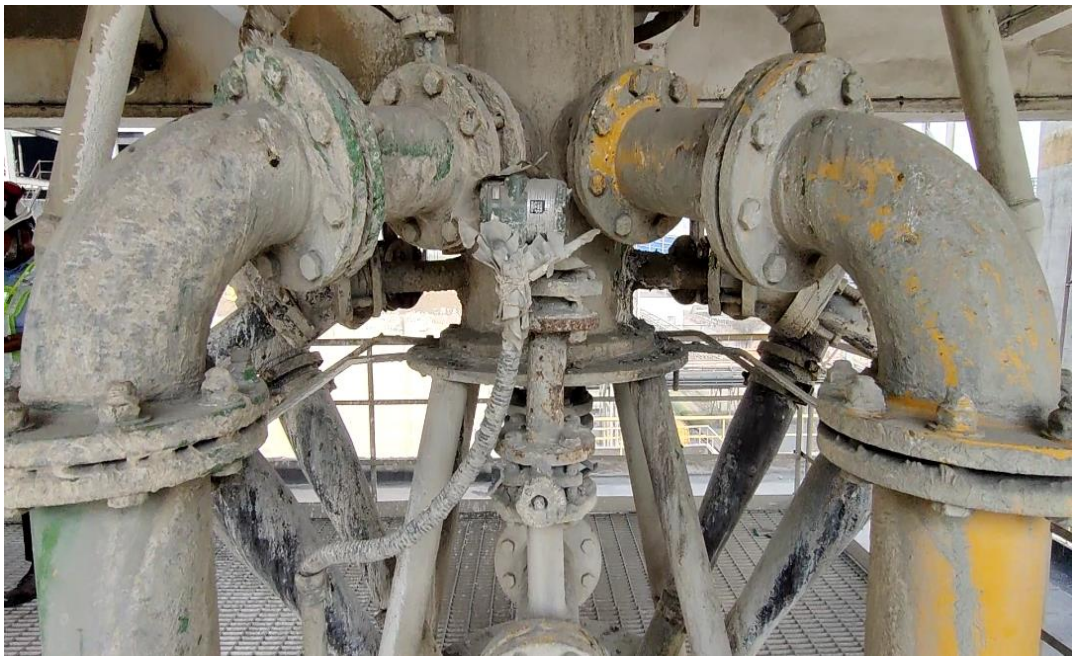

FIGURE 3: CYCLONE SEPARATOR

FIGURE 4: VACUUM FILTER BED

FIGURE 5: FGD GYPSUM

b. M/s Vindhyachal Super Thermal Power Station, Madhya Pradesh

The FGD system is currently installed only for 500 MW capacity boiler. The Gypsum Handling System uses PLC based Control System to operate FGD, including convey of gypsum from the Vacuum Belt Filter to the gypsum storage area.

The unit has sold nearly all the FGD gypsum produced to the various cement plants, details of which is as following:

S. No.	Calendar Year	Quantity Sold to Cement plants (MT)
1.	2018	20,680.4
2.	2019	3,977.3
3.	2020	24,338.0
4.	2021	16,613.9

Source: Information provided by TPP

Unit is storing the gypsum in the dedicated storage yard having capacity of about 1500 MT which is having hard paved surface. Gypsum from this area is loaded in trucks with the help of JCB. After completion of loading, trucks are covered and dispatched after weighing.

FIGURE 6: ABSORBER AND RECIRCULATION PUMPS

FIGURE 7: CURTAINS ON FGD STORAGE YARD

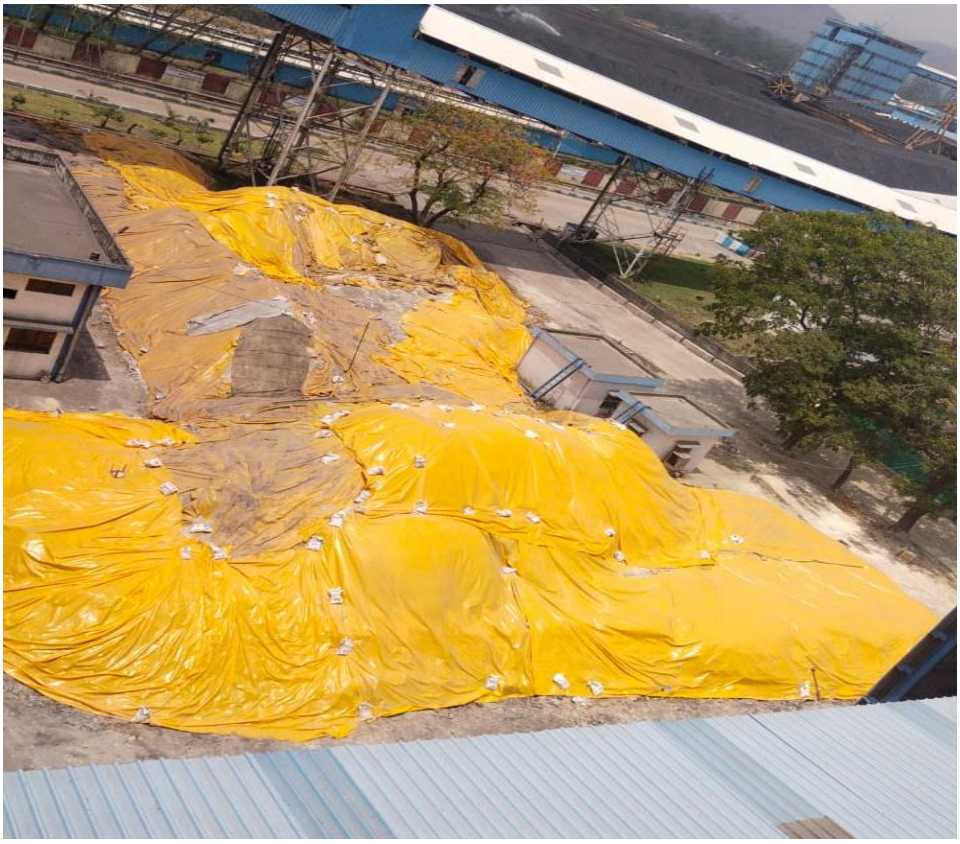

FIGURE 8& 9: FGD GYPSUM STORED OUTSIDE SHED, COVERED WITH IMPERVIOUS SHEETS

c. Udupi Power Corporation Limited, Karnataka

M/s UPCL has utilized 100% FGD Gypsum through nearby Fertilizer and Cement Industries and the quantity utilized application wise is as below:

S.No.	Component	2018-19	2019-20	2020-21	2020-21
1.	Cement Industry (MT)	500	1143	1175	244
2.	Fertilizer Industry (MT)	74	391	70	-

Source: Information provided by TPP

UPCL has established FGD Gypsum shed with a storage capacity of 400 ton. The gypsum coming out is collected directly in Tipper and is transported to gypsum shed, from where it is transported out by various vendors in Trucks.

6. Applicability of these Guidelines

These guidelines are applicable for:

1. All the existing coal based thermal power plants which are utilizing FGD process and generating FGD gypsum using limestone.
2. Upcoming coal based TPPs who will be operating FGD using limestone. Utilizers of FGD Gypsum, whether as FGD Gypsum or treated to produce some other product.
3. Storage and Transportation of FGD gypsum.
4. Importers/Exporters and traders of FGD gypsum.

7. General guidelines regarding approvals required:

TPPs which have not yet installed FGD systems shall submit the following details for complying with new emission standards for SO_2 to the concerned SPCB/PCC:

1) Schedule for installation and commissioning of FGDs with timelines;
2) Details of the proposed handling including facilities for storage and area allocated for onsite storage of FGD Gypsum;
3) Proposed utilization plan;
4) Details of transportation (within the unit and outside the plant to end user of FGD Gypsum);
5) Operational, maintenance and monitoring protocols;
6) Remedial plans including disaster management plan; and
7) Any other relevant information.

SPCB/PCC shall make periodic visits to ensure that the construction, operation, maintenance of the FGD unit is as per the approved designs.

8. Management and handling of FGD Gypsum

FGD handling systems set-up by Thermal Power Plants shall have adequate infrastructure to handle total quantity of FGD gypsum expected to generate at full capacity operation. The infrastructure provided shall envisage collection, treatment, storage and transfer of FGD gypsum for complete utilization. There shall be adequate storage facilities to hold the FGD gypsum stock in case the options for utilization are yet to be finalized.

a) Storage Area:

i. Primary Storage area for a capacity of 07 days of generation shall be provided beneath the floors of the filters for further transportation to utilizers. If the same is not feasible, gypsum shall be transported on conveyor belts to a separate storage building in the plant for further transportation to utilizers.

ii. A dedicated secondary storage area shall also be provided for FGD gypsum.

iii. There shall be dedicated storage sheds of adequate capacity based on daily generation, FGD gypsum transfer schedule and contingencies in case of non-lifting of gypsum by utilizers. However, temporary storage in lined pits with daily covers may be used till the time such dedicated storage sheds are constructed.

iv. Steps shall be taken to ensure no fugitive emissions occurs from the storage area.

v. Storage area shall be covered with adequate openings for movement of trucks and loaders.

vi. Storage area should be designed to withstand the load of material stocked and any damage from the material spillage.

vii. Storage areas should be provided with RCC/impervious base. (as per CEA Standard Technical Specification for Retrofit of Wet Limestone Based Flue Gas Desulphurisation (FGD) System in a Typical 2x500 MW Thermal Power Plant)

viii. The storage area should be provided with impervious base and the floor must be structurally sound and chemically compatible with wastes.

ix. Measures should be taken to prevent entry of runoff into the storage area. The Storage area shall be designed in such a way that the floor level is at least 150 mm above the maximum flood level.

x. Storage area should be provided with proper slopes, peripheral drainage system connected with the sump so as to collect any accidental spills in roads or within the storage area as well as accidental flow due to fire fighting.

xi. Records pertaining to generation of FGD gypsum, quantity stored, daily lifting of FGD gypsum, Movement of vehicles etc. shall be maintained.

xii. Floor wash water, wastewater generated from vehicle washing bay and run-off contaminated with FGD gypsum shall be collected properly and routed to Effluent Treatment Plant (ETP) so as to comply with the effluent discharge norms stipulated under the Environment (Protection) Act, 1986.

b) Transportation:

i. Adequate precaution shall be taken to ensure no spillage and leakage.

ii. Provisions should be made to ensure immediate cleaning up in case of any spillage/leakage and such incidents should be recorded and details submitted to the SPCB/PCC concerned.

iii. Transportation shall be carried out in trucks/dumpers covered with trampoline.

iv. The trucks/dumpers used for FGD Gypsum transportation shall specifically be designed, operated and maintained to prevent spillages/leakages.

v. The dumpers and loading equipment used for FGD Gypsum loading and transportation shall be regularly cleaned to ensure clean bodies and no dispersal of FGD Gypsum sticking to the bodies.

vi. Carrying of passengers is strictly prohibited and only haulers shall be permitted in the cabin.

vii. No other material shall be transported or mixed with FGD gypsum.

viii. Each truck shall carry first-aid kit, spill control equipment and fire extinguisher.

ix. Driver(s) shall be properly trained for handling emergency situations and safety aspects involved in the transportation of FGD Gypsum. They should be aware of procedures outlined in Emergency Response Plan and trained on emergency spill control procedures.

x. In case of accidental spillage, the FGD gypsum shall be collected and transported to the utilizer/generator on priority.

xi. No trans-shipment shall be permitted en-route.

xii. Provisions of Central Motor Vehicles Act 1989, as amended vide Central Motor Vehicles Amendment Act 2019 shall be complied by the vehicles and drivers for transport of FGD gypsum.

xiii. In case of transportation through railways, adequate arrangements shall be made to ensure no spillage and generation of fugitive emissions.

xiv. Intermediate storage area at the railway yard shall be provided with a security /restricted entry. Covered shed shall be preferred for handling, however, open storage can be permitted provided adequate arrangements are made for control of fugitive dust, minimization of run-off and its collection and treatment.

xv. Floor wash water, and run-off at Railway yard shall be collected and routed to effluent treatment plant (ETP) for treatment and to ensure compliance with the effluent discharge norms stipulated under the Environment (Protection) Act, 1986.

c) Record keeping:

The occupier and utilizer of FGD Gypsum are required to maintain date wise records with regard to the following and same shall be provided as and when required by the regulatory authorities:

(i) Quantity of FGD Gypsum generated/ Procured.
(ii) Quantity of FGD gypsum exported.
(iii) Quantity of FGD Gypsum stored in storage area.
(iv) Quantity sold or auctioned to the end users and their complete addresses
(v) Quantity of FGD gypsum utilized.

The above records can be maintained in the portal for national hazardous waste tracking system of CPCB, once it's made operational.

d) Export:

The Exporters and Traders shall ensure to obtain necessary permission for MoEF&CC for export of the FGD gypsum as per the provisions laid under HOWM Rules, 2016. Further, they shall also ensure to adhere to these guidelines and maintain records of waste exported alongwith name and address of agency from which the same has been procured.

Utilization of indigenously generated FGD gypsum shall be promoted by regulatory agencies and stakeholders which are involved in generation and utilization of FGD gypsum.

e) Disposal

Disposal of FGD gypsum by land filling in existing ash ponds or blending with fly-ash or in separate compartment in existing ash pond or in any other form without any potential utilization shall not be preferred.

f) Utilization:

A significant number of studies and research projects have been undertaken globally as well as in India to find out beneficial utilizations of FGD Gypsum. The utilization of the FGD gypsum is directly proportional to its quality. The major parameters which affects the utilization potential of the FGD gypsum are Moisture, Purity for which Central Electricity Authority (CEA) in its "Standard Technical Specification for Retrofit of Wet Limestone Based Flue Gas Desulphurisation (FGD) System in a Typical 2x500 MW Thermal Power Plant" has outlined that *"The system shall be capable of producing gypsum with residual moisture not more than 10 %, chloride content less than 100 ppm and purity not less than 90 % (depending upon purity of available limestone)".* Further, in context of removing the impurities it has been stated that *"The filter shall be designed with cake washing equipment. This equipment shall be capable of reducing the concentration of dissolved solids in the process liquor (primarily chloride) to levels that meet the commercial gypsum quality specifications*."

The following options may be explored by industries for utilization of FGD Gypsum:

i. **Use of FGD Gypsum for Co-Processing in Cement Manufacturing:**

As per estimate, cement production capacity in the country is about 545 Million tons at FY 2020 and producing about 295 million MT of cements. About 4 to 5% of natural gypsum is used in cement making, which makes a requirement of 12-15 million MT. Thus, if the natural gypsum is replaced by FGD Gypsum, whole FGD Gypsum generated can be consumed by the cement industry alone in the country.

Further, no trial runs would be necessary for obtaining authorization for co-processing of FGD Gypsum in cement industries.

However, the utilization of FGD gypsum in the cement plants may depend upon its characteristics. The generators of the FGD gypsum may take necessary steps to ensure that the quality of the FGD gypsum produced is in line with the requirement of the Cement Plants. Primarily, the FGD gypsum may achieve following characteristics for utilization in cement plant i.e. pH>5; Free Moisture (at 45 ˚C) upto 8%; $CaSO_4.2H_2O$ > 70% and Soluble P_2O_5 <0.5%.

As per requirement of cement plants the above characteristic can be relaxed. In order to facilitate effective utilization in cement plants, suitable product specifications and standards such as BIS for FGD gypsum may be developed.

ii. **Use of FGD Gypsum in plaster, blocks or gypsum board manufacturing industry:**

Plaster, Blocks or Gypsum Boards manufacturing industry shall utilize FGD Gypsum as raw material for manufacture of plaster, putty blocks or gypsum boards after reduction in impurities to the specifications as given in Indian Standards IS: 12679-1989, Reaffirmed 2010 (Requirement of By-product Gypsum for Use in Plaster, Blocks and Gypsum Boards).

The generators may explore the option for washing the FGD gypsum to reduce the Chloride content and other impurities in order to make it much suitable for utilization in Board manufacturing.

The following are the preferred specification of Synthetic Gypsum for production of Gypsum boards:

S. No.	Parameter	Unit	FGD Gypsum Characteristics
1.	Moisture	%	< 10
2.	Calcium sulfate dihydrate	%	> 95
3.	pH		5 - 9
4.	Odour		neutral
5.	Magnesium salts		
6.	Water soluble	ppm	< 1000
7.	Total	ppm	Not Applicable
8.	Sodium salts		
	Water soluble	ppm	< 600
	Total	ppm	Not Applicable
9.	Potassium salts		

S. No.	Parameter	Unit	FGD Gypsum Characteristics
	Water soluble	ppm	< 600
	Total	ppm	Not Applicable
10.	Chloride	ppm	< 100
11.	Calcium sulphite	%	< 0.5
12.	Aluminum oxide	ppm	< 3000
13.	Iron-III-oxide	ppm	< 1500
14.	HCl-insoluble	%	< 5.0
15.	Calcium carbonate (out of CO_2)	%	< 3.0
16.	P_2O_5		
¤	Water soluble	ppm	NIL
	Total	ppm	NIL
17.	Fluorides		
	Water soluble	ppm	Nil
18.	$CaSO_4$	%	<2
19.	Radioactivity	I	Not Applicable
20.	Blaine value	cm^2/g	-
21.	Asbestos		Zero
22.	Toxicity		Non Toxic
23.	Ag		Zero
24.	Quartz	%	≤ 1
25.	Sulfur (elemental)	ppm	≤ 10

iii. **Preparation of composite binder**:

Global studies indicate positive results for utilization of FGD gypsum in manufacturing of composite binder. R&D and trial studies may be conducted for Indian Gypsum, binder quality requirements and feasibility of said utilization technique.

Pre-Feasibility study shall be conducted on a case to case basis for the specific application of FGD Gypsum and focus shall also be given on studying potential environmental impacts associated with such utilization.

iv. **Gypsum in Agriculture:**

Potential for utilization of FGD Gypsum for soil needs to be studied and such utilization may be adopted once BIS or any such standards for such utilization are evolved.

v. **Mine Backfilling:** Research reports indicates that FGD gypsum can also be utilized as one of the filler medium for backfilling of the mines. Proper studies are required to be undertaken in the Indian context for the same.

However, Pre-Feasibility study to be conducted on a case to case basis (location to location) by considering potential Environmental.

Note: The Pre-feasibility studies shall be further submitted to obtain necessary approvals from Ministry/Department of Environment, Department of Mines, SPCBs/PCCs and as may be necessary.

For carrying out Study/R&D within the country, no prior permission of SPCB/PCC shall be required for transporting samples of FGD Gypsum up to 2000 kg in individual cases and up to 20 MT per year. The unit shall maintain records of the same.

9. Utilization Target

FGD Gypsum generating units shall utilize minimum 25% of its annual generation in the first year that should be gradually increased to 100% over the in subsequent years. For opting any other utilization options not mentioned in this document, the proponent may submit a proposal along with relevant details to CPCB through the respective SPCB/PCC with their assessment for permitting the same by SPCB/PCC.

The generators shall submit the status report to CPCB & SPCB/PCC by 30th June every year.

10. Monitoring protocol for assessment of environmental impacts in and around the FGD Gypsum plant:

Monitoring of Environmental matrices and the FGD gypsum plays an important role in environmental impact assessment and operation efficiency of FGD system respectively. The same can help in easy and rapid detection of impact and conditions which can help in taking corrective measures and operate on optimum standard operating conditions.

Ambient Air Quality, ground water, Surface water and Soil Monitoring shall be carried out on regular basis to identify any adverse impact on environment.

Further, weekly monitoring of FGD Gypsum shall be carried out for pH, purity, SiO_2, Chloride, free moisture, Fe_2O_3, Al_2O_3, CaO, $CaCO_3$, SiO_2 and other relevant parameters as per the utilization plan.

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