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ASH GENERATION FROM COAL CONSUMPTION IN THERMAL POWER AND ITS UTILIZATION FOR SUSTAINABILITY

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Abstract**:** Fly ash is a by-product of power generation with coal. Sustainable ash utilisation is one of the key concerns at thermal power stations. As with policies governing collection and disposal, practical implementation of fly ash intended to stimulate is often slow. A characteristic advantage of fly ash utilization is its pozzolanic reaction with lime formed during the hydration of cement. The fly ash with active aluminosilicates reacts with lime-based chemically active compounds to form additional C–S–H or similar hydrated phase. Taking advantage of this blended cements have been formed using fly ash and lime-based slag or other similar compounds. The fly ash generated from coal based thermal power station like NTPC and others can be utilized for sustainable products using good manufacturing practices.

Keywords**:** Ambient Air; Fly Ash; National Green Tribunal.

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INTRODUCTION

Coal-based power is one of the most resource-intensive and polluting industries, and contributes significantly to ambient air pollution in India. Currently, coal and lignite-based utility power plants account for 77% of the country's total electricity generation (Soundaram *et al.,* 2020). The sector consumes about 65% of the total coal consumed in India. In order to meet the growing electricity demand, a huge capacity addition has occurred to the Indian coal-based power sector in the past 10 years. Around 64% (132 GW) capacity was added in the last 10 years, which has also led to a surge in coal consumption in the sector. Between 2009–2010 and 2018–2019, annual coal consumption rose from 367 million tonnes to about 629 million tonnes, an increase of almost 71%. Fly ash is the by-product or unburnt residue formed during combustion of coal in a furnace. It is emitted along with the flue gases and collected either by mechanical separators or electrostatic precipitators in the dry form. The collected fly ash is normally stored in silos. Heavier unburnt ash, collected at the bottom of the furnace, is called bottom ash and constitutes around 20% of the total ash generated at a power plant. Unused fly ash and bottom ash from plants is generally transferred in the wet slurry form to ash ponds with the help of ash slurry supply lines.

A rise in coal consumption naturally increases the production of fly ash as a by-product or residue, which not only requires large tracts of land for disposal but also leads to significant pollution. This problem is particularly severe in India, because Indian coal is low-grade, with high ash content (of the order of 30–45 per cent) and low calorific value (3,500–4,000 kcal/kg). Annual fly ash generation from Indian coal power plants rose from 123 million tonnes in 2009–2010 to 217 million tonnes in 2018–2019, an increase of almost 76% (Anon, 2019). Fly ash is ultra-fine, prone to becoming air borne

in the dry state. This significantly affects air quality near coal-based plants. Long-term exposure to fly ash in the air can lead to serious pulmonary illnesses like bronchitis, silicosis, fibrosis, pneumonitis, etc. The ash contains toxic heavy metals that are known carcinogens. Ash disposed of in the wet form in ash ponds can be equally harmful if not handled in an environmentally sound manner. Several cases of contamination of nearby surface water bodies and groundwater due to ash pond overflows or leakages have been reported. This may even lead to accumulation of heavy metals beyond permissible limits in the contaminated water bodies. Naturally, fly ash has been under the regulatory scanner for quite some time now. The effort has been to convert potentially harmful waste into a resource. The notification on fly ash utilization first came into force in 1999. Over the years, it has gone through several amendments in 2003, 2004, 2009 and 2016, in order to move towards the goal of 100% utilization of fly ash produced by all coal- and lignite-based plants. As the quantity of coal consumed in India increased, and fly ash generated increased proportionally, Ministry of Environment, Forest and Climate Change (MoEF&CC) brought in several other policy measures and reforms to increase utilization of residual ash. Currently, fly ash is utilized in India in cement, brick and tiles manufacturing, filling up abandoned mines, reclamation of low-lying areas and construction of roads and flyovers. The ministry has also set certain limits, in terms of geographical area, within which fly ash is to be compulsorily used for manufacturing bricks or in the construction industry. Yet, 21 years after the notification first came into force, many plants have still not been able to achieve the target. As per a December 2019 report submitted to the National Green Tribunal (NGT), the quantity of unused ash from the coal power sector is 1,647 million tonnes (as on 31 March 2019). This is almost eight times the current annual ash generation. Ash is piling up in the wet form as slurry in ash ponds and in the dry form in open fields. Fugitive emissions and leakages have increased substantially. The severity of the problem was exemplified by the major coal ash pond accidents that occurred between 2010 and 2020 (Anon, 2020a). This risk of overabundance of ash has been further aggravated with the recent government orders of doing away with mandatory coal washing and opening the coal sector for commercial mining by private players, which will lead to increase in ash generation. Improper maintenance and lining of ash ponds continues to be a problem. This particular area does not have any regulatory oversight. In recent years, National Green Tribunal (NGT) has passed several orders pertaining to non-compliant plants for depositing environmental compensation towards damage caused by ash accidents. However, after pleas filed by power producers stating that NGT had not analysed the situation on a plant-to-plant basis and end users like cement plants and other agencies that can utilize ash should also be made accountable for it, Supreme Court put a stay on a few such orders. This has been continuing, derailing the regulations and the enforcement system. While end users like cement and construction agencies should be made accountable to some extent, it is primarily the responsibility of the power producers to make efforts for effective utilization of waste generated by them, whether it be coal ash or any other hazardous waste. Power producers must ensure disposal of ash in an environmentally sound manner that does not cause harm to the surrounding areas. With so many ash breach incidents, it is clear that power plants have been negligent on their part and must be dealt with strictly by regulatory bodies. Therefore, in order to tackle the growing concerns and impacts associated with overabundance of ash, and to clear the huge stockpile of legacy ash, urgent interventions; in terms of policy measures, technologies and practices; are needed to enhance fly ash utilization.

India's total power generation capacity (as on 31 March 2020) stood at 370 gigawatts (GW), 4 of which thermal power capacity alone is about 230 GW. Coal- and lignite-based power stations continue to be the bulk energy providers, making up 205 GW (89 per cent) of the total thermal power capacity. Significant coal-based capacity has been added in the last 15 years. Around 64% (132 GW) of the capacity is less than a decade old. About 74% (152 GW) is less than 15

years old. Huge capacity additions have led to a gradual increase in coal consumption over the years, thereby also leading to an increase in fly ash generation. Moreover, Indian coal has high ash content (about 30–45 per cent), which leads to generation of large quantities of fly ash at coal- and lignite-based thermal power stations. Trends in coal consumption and ash generation in a span of ten years (i.e. from 2009–2010 to 2018–2019), coal consumption in the power sector increased by almost 71% and the corresponding ash generation increased by almost 76 per cent. At present, the power sector currently consumes about 623 million tonnes of coal and generates about 217 million tonnes of ash, 94 million tonnes up from the 2009 ash generation figures. This is a significant increase.

TRENDS IN ASH UTILIZATION AND RESIDUAL ASH GENERATION

Tremendous increase in coal consumption by the power sector in the past decade has ballooned fly ash generation and resulted in large quantities of unused ash. As per Central Electricity Authority's (CEA) 2018–2019 annual report on fly ash, 103 thermal power stations were able to achieve the target of 100% ash utilization. However, 83 power stations have not been able to achieve this target. Though the all-India average fly ash utilization percentage from TPPs has jumped from 63% (77 million tonnes) in 2009 to 78% (168 million tonnes) now, the major cause of concern is the amount of residual or unutilized ash that has gradually accumulated over the past many years due to the low utilization percentage. For about five years (between 2012–2013 and 2016–2017), the quantity of fly ash utilized has remained stagnant at around 100 million tonnes; however, during the same period, annual generation has been above the 150 million tonne mark, which indicates a huge pile up. Only in the last two years (i.e., 2017–2018 and 2019– 2020) has there been an additional 30 million tonnes increase in utilization each year. Average ash utilization percentage between 2009 and 2019 has been about 62 per cent. During the period, on an average, almost 60 million tonnes of fly ash has remained unutilized annually.

State-wise ash utilization and residual ash generation Coal-based power plants are spread over 17 states in India. They are heavily concentrated in Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Maharashtra, Odisha, Uttar Pradesh and West Bengal. Substantial quantities of coal are consumed in these states, generating humongous quantities of ash. Uttar Pradesh and Chhattisgarh have had the highest ash generation, followed by West Bengal, Maharashtra, Andhra Pradesh, Madhya Pradesh and Odisha. All these states have large coal-based power capacity. High generation and low utilization percentage in many states indicate pile up of unused ash in those states. Chhattisgarh and Uttar Pradesh have accumulated the most ash in this decade. Madhya Pradesh, Andhra Pradesh, Maharashtra and Odisha also have a huge ash backlog. States with large coal-based capacity and limited ash demand in nearby areas have low ash utilization rates. West Bengal is the only state that produces a sizeable quantity of ash but manages to clear the stock. It has utilized 131 million tonnes out of the total of 157 million tonnes of ash it produced in the past decade. Fly ash is used extensively in cement manufacturing in the state. It is also used in construction of roads and highways. Some fly ash is even exported to Bangladesh for manufacturing Pozzolana Portland Cement (PPC) cement. Ash is transported pneumatically through pipelines to silos located on jetties by the riverside. Ash from the silos is loaded into covered barges and exported to Bangladesh (Anon, 2020b).

A few states, notably Haryana, Gujarat, Punjab and Rajasthan, utilized as much ash in 2018–19 as they produced in that year, but no state has been able to completely utilize its accumulated stock of legacy ash. Jharkhand, Punjab and Rajasthan are the only states that have achieved an average fly ash utilization rate of 90–100 per cent. In fact, Gujarat, Haryana, Punjab and Rajasthan do not have any plants with a poor ash utilization rate.

Concentration of large capacity coal power plants in a region

Regions where many power plants are in close proximity tend to have lower utilization rates as

there is overabundance of ash and the demand cannot keep up with it, due to limited number of cements, brick or construction agencies present within a 300 km radius of such regions. Singrauli–Sonebhadra, spread across parts of Uttar Pradesh and Madhya Pradesh, is one such region. The two states together account for about 51 GW of power generation capacity in India, half of which is generated in the Singrauli–Sonebhadra region. Nine major power plants operate in this region, with a combined capacity of around 21,270 MW. More than half of the capacity (11,180 MW) is less than 10 years old and was added by construction of either new power plants or addition of stages to existing plants in the region. Due to a skewed demand–supply ratio, the two states are in the top four in terms of fly ash generation and in the bottom four in terms of utilization rates.

Distance from cement and brick manufacturing and construction units

Transportation and settlement play an important role in determining the ash utilization rate. States with more cement or brick manufacturing units, that are in proximity to power plants, tend to have higher utilization rates. Andhra Pradesh, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu together account for about 60% of total cement production capacity in India. These are also the states with the highest ash utilization percentages. On the other hand, in states like Chhattisgarh, demand for ash is limited due to minimal presence of businesses that utilize ash.

NOTIFICATION ON FLY ASH UTILIZATION

In order to minimize environmental pollution caused due to fly ash, Ministry of Environment, Forest and Climate Change (MoEF&CC) has come up with several notifications in the past. These notifications have sought to promote utilization of fly ash produced by coal- or lignite-based thermal power plants, including captive power plants and co-generation plants. They have also sought to restrict excavation of top soil for manufacture of bricks.

• The notification on fly ash utilization came into force in September 1999. It stipulated targets for utilization of fly ash produced at thermal power plants by construction companies falling within the prescribed radius. The notification was subsequently amended in 2003, 2009, 2016 and 2019. With each subsequent amendment, the radius around coal- and lignite-based thermal power plants for which the said norm is applicable was increased to enhance use of fly ash.

• The August 2003 amendment mandated the use of 100% fly ash by construction agencies in a phased manner in five years by August 2007.

• Following this, the November 2009 amendment revised and extended the timelines and the period of implementation for achieving 100% utilization in a phased manner to 2014.

• In January 2016, another amendment extended the area within which fly ash was to be utilized from 100 km to 300 km. The time period to comply with the requirements of 100 %utilization of fly ash was extended to 31 December 2017.

• In September 2020, a draft fly ash amendment has for the first time introduced a penalty framework based on polluter pays principle. The draft specifies a fine of Rs 1,500 per tonne of unused ash if the plant does not achieve at least 80 % ash utilization annually or is unable to utilize, on an average, 100 %of ash in a three-year cycle. There is also a fine of Rs 2,000 per tonne for non-utilization of legacy ash. User agencies within 300 km radius of a power plant have also been made accountable through imposition of a fine of Rs 2,000 per tonne of nonutilized ash. The draft amendment is out for comments, and is likely to face criticism and objections, especially from the power sector, because, if notified, it will definitely lead to huge penalties on the large number of non-compliant plants, and especially those with poor ash utilization rates.

The deadline for complying with the notification has already passed. However, even after 21 years since the first notification came into force, many power plants are still not able achieve the target of 100% utilization. As per CEA's latest report, the number of such power plants is 83. Management of fly ash has been a matter of concern for coal and lignite-based power plants due to the requirement of a large area for its disposal and its adverse impact on the environment and health of the people living

nearby due to its hazardous nature. Non-utilization and improper disposal of fly ash leads to severe air and water pollution. Apart from lime, silica and alumina, fly ash contains toxic heavy metals like lead, mercury, arsenic and hexavalent chromium, all of which are known carcinogens. Several health studies conducted in communities living near thermal power plants have clearly established health problems associated with fly ash. Several major coal ash pond accidents have been reported across the country in the last ten years, from utility thermal plants as well as captive power plants. Minor fly ash incidents which occur on a regular basis are not even reported. At times, these incidents have led to loss of life and property in nearby settlements. Since many power plants are located close to surface water bodies serving as a source of freshwater for the plant, leaking or overflowing slurry from ash ponds often finds its way into these surface water bodies leading to their contamination.

NGT has recently come down harshly on non-compliant power plants and those facing litigation due to ash dyke breaches or ash leakages, by way of imposing penalties on them. However, penalties imposed on plants in the last two–three years have not been an effective deterrent as many of them are far from meeting the 100 %utilization rate and continue to pollute their immediate surroundings with ash. A good illustrative example of continuous non-compliance is the North Chennai Thermal Power Station (NCTPS), where fly ash leaked from a busted pipeline in August 2020 and flooded the nearby village. The residents of the village have been battling against this issue (and the plant) for many years. At times, ash slurry enters their houses and there are high levels of ash in the air and nearby waterbodies which affect the health of residents. River and borewell samples show high rates of contamination with heavy metals. Back in 2017, NGT had warned that the plant would be completely shut down if discharge of fly ash was not contained. Later, a committee was appointed to observe the plant for violations. In January 2020, NGT even imposed a penalty of Rs 8.34 crore on the plant. Despite all these measures, the plant continues to pollute the area. Over the last few years, such incidents have increased. To ensure better compliance, stricter penalties, shutting down non-complying plants and stricter monitoring are the need of the hour.

There have been cases where power plants have expanded without obtaining land for additional ash ponds and continue to dump huge quantities of ash in the existing ponds. At times, ash overflows in these ponds or the boundary walls are breached. A major fly ash breach incident occurred on 10 April 2020 at the Sasan ultra-mega power plant (owned by Reliance Power in Singrauli– Sonebhadra region). It resulted in human causalities and spread of toxic slurry in the surrounding areas (up to six kilometres), destroying agricultural fields. In 2019, similar incidences of ash dyke breaches had occurred at the Essar Mahan Power plant and NTPC Vindhyachal plant located in the same region. Three instances of fly ash breach within a year have raised concerns regarding the management of fly ash at coal power plants. A committee appointed by NGT to look into the breaches at ESSAR thermal power plant and NTPC, Vindhyachal found that no sincere efforts had been made for ash disposal by these plants since their commissioning in the early 1980s. There are also issues with improper maintenance and lining of ash ponds. Environmental clearances granted to thermal power plants set up after 2006 made it mandatory for plants to have impervious lining at the bottom of ash ponds. This requirement was to avoid any leaching of toxic heavy metals present in ash slurry into the groundwater. No monitoring agency exists to ensure that plants put in place impervious lining before disposing of ash slurry into the ponds. There is gross mismanagement and unsafe disposal, evident from the high levels of contaminants and heavy metals found in groundwater samples taken from the vicinity of ash ponds.

The following section covers recent NGT orders and committees formed on fly ash utilization:

i) January 2018: NGT passed an order directing states to submit action plans for fly ash use (Anon, 2020c).

• States and Union territories were directed to furnish their action plans for 100 %utilization of

fly ash generated by thermal power plants in accordance with the 2009 amendment to the notification.

• Following this order, in August 2018, 20 states submitted their action plans—13 of them were incomplete and not unsatisfactory. MoEF&CC was directed to monitor compliance and submit a status report on them.

• Thereafter, MoEF&CC submitted a status report to NGT in September 2018 wherein it was noted that the states had sought further extension of time by two to five years, i.e. upto 2023, for 100% fly ash utilization. Moreover, a few plants had not even submitted action plans for 100% utilization.

ii) November 2018: NGT passed an order on forming a joint committee and imposing penalty on defaulters.

• NGT directed MoEF&CC to constitute a committee comprising of representatives from MoEF&CC, CPCB, IIT Roorkee and any other members considered necessary for implementation of the action plan to achieve 100 %fly ash utilization by power plants in an environmentally sound manner. The committee was also required to assess the amount of damages to be paid for non-compliance with the notification. Following this order, MoEF&CC constituted a joint committee comprising of member secretary, CPCB and representatives from IIT Roorkee, Ministry of Power, Ministry of Coal, Ministry of Housing and Urban Affairs, National Highway Authority of India (NHAI) and Odisha SPCB.

• Until the committee can assess the damages, thermal power plants that failed to utilize 100 % fly ash by the end of 2017 have to deposit specified environmental penalty.

If the penalty was not deposited with CPCB within one month, an interest of 12% per annum would be payable.

• Following the November 2018 NGT order, the joint committee filed its report on December 2019 on the progress made on action plans and compensation assessment. The report states that the quantity of unused ash was as high as 1,647 million tonnes as on 31 March 2019. The committee recommended a maximum of two years' time for 100% utilization. It also recommended that compensation should be obtained only from non-pit-head power plants. Construction of fly ash dykes and their maintenance was not found technically sound at many plants.

iii) February 2019: Supreme Court stayed environmental compensation imposed by NGT on non-compliant plants of NTPC and MPPGCL. The Supreme Court stayed NGT's November 2018 order of imposing fines on NTPC and MPPGCL plants. These fines ranged from Rs 1–5 crore, depending on the power plant's capacity. NTPC mentioned in its plea that NGT did not take into consideration the reluctance of end use industries, like cement and brick manufacturing plants, for taking fly ash from power plants as the 2016 notification had made it obligatory for user industries to uptake fly ash. The plea further mentioned that power plants only have to facilitate transportation of fly ash but cannot force user agencies to uptake fly ash.

iv) February 2020: NGT passed an order on directing all power plants to take steps for scientific disposal of fly ash (Anon, 2020c).

• Following three fly ash breach incidents in Singrauli region in 2019–2020, in February 2020 NGT directed thermal power plants to take prompt steps for scientific disposal of fly ash, warning that failure to do so would lead to penalty. The tribunal stated that non-compliant plants will have to pay environmental compensation which would be determined from the cut-off date of 31 December 2017 as stipulated in the notification issued by the Union environment ministry (Anon, 2020d).

• In the same order, NGT asked CPCB to compute and levy environmental compensation with respect to individual plants in accordance with the law and submit a compliance report to the tribunal.

Supreme Court issues a stay order on recovery of environmental compensation imposed by NGT on non-compliant plants.

• On 14 September 2020, Supreme Court stayed the recovery of fines imposed by NGT through its February 2020 order against noncompliant thermal power plants (that have not achieved the target of 100% fly ash utilization and disposal). CPCB had issued notices to various

non-compliant power plants after NGT's February order.

• The plea was filed by power producers stating that due to COVID-19 pandemic, there has been disruptions in fly ash utilization and disposal. The plea also mentioned that no case-by-case analysis was done while determining the environmental compensation for each plant.

Thus, it is clear that proper enforcement of regulations is lacking, both at the level of power plants and at the level of end users. The blame game has been continuing with NGT passing orders for environmental compensation against non-compliant plants and Supreme Court staying those orders after hearing pleas from power plants.

UTILIZATION OF FLY ASH FROM THE POWER SECTOR

Andhra Pradesh, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu together account for about 60% of the cement production capacity of India. These are also the states utilizing the most fly ash, especially Haryana, Punjab, Rajasthan and Tamil Nadu, all of which have ash utilization percentages between 70–99 per cent. Though fly ash utilization in the cement sector has increased over the last few years due to several government interventions and policy measures mandating its use, the uptake has not been commiserated with the tremendous growth in the production of cement. Between 2009 and 2019, cement production in India increased from 187 million tonnes to 334 million tonnes, an increase of almost 78 per cent. Currently, India produces about 334 million tonnes of cement annually and the production is expected to reach 400 million tonnes by 2025, owing to continuously rising demand. In 2017, MoEF&CC formed a committee, with representatives from the Ministry of Mines, Ministry of Power, CEA, Department of Industrial Policy and Promotion (DIPP) and Ministry of Coal, to examine the possibility of building cement plants near power plants to enhance utilization of fly ash. But utilization of fly ash in the cement manufacturing industry is hindered by several factors, chief among them being lack of or costly transportation, lack of awareness among cement manufacturers, and poor implementation and monitoring by government agencies. Fly ash bricks are made from fly ash, lime, gypsum and cement. Use of fly ash in the manufacture of fly ash bricks is a technically well-established practice. However, average ash utilization percentage in the brick manufacturing sector has only been a low 7 per cent. Bureau of Indian Standards (BIS) has formulated standards for fly ash bricks. IS 12894: 2002 establishes specifications for fly ash–lime bricks. Fly ash can be easily used as a building material in place of red clay bricks and save precious top soil as well. Moreover, producing fly ash bricks is a relatively cleaner process as it does not require firing. India is currently the second largest producer of bricks in the world and with the rising demand for bricks, there is immense potential for utilization of fly ash in the brick sector. The major fly ash brick producing states are Andhra Pradesh, Bihar, Delhi, Maharashtra, Odisha, Tamil Nadu and West Bengal.

To enhance utilization in this sector, MoEF&CC had issued the following directions through its 2016 notification:

• Mandatory use of fly ash-based products for construction activity within a radius of 300 km from coal- and lignite-based power plants.

• Power plants to bear transportation cost of fly ash up to a radius of 100 km. Beyond the radius of 100 km (up to 300 km), transportation cost shall be borne equally by fly ash users and power plants.

• MoEF&CC also issued a draft amendment to the notification in February 2019 inviting public comments, wherein the following proposals were made:

- No new red clay brick kiln shall be established within a radius of 300 km of a thermal power plant.
- Existing red clay brick kilns within a radius of 300 km of thermal power plants shall be converted to fly ash brick, block or tile manufacturing units.

To enhance utilization, a few state governments have started providing incentives to fly ash start-ups, made use of fly ash bricks compulsory in construction near coal power plants, and mandated use of fly ash bricks in construction of government buildings. Despite

government policies, fly ash utilization in the brick manufacturing sector remains poor in many states because:

• Brick kiln contractors still prefer clay bricks over fly ash bricks.
• There is no quality control system in place to ensure that fly ash production units comply with BIS standards.
• Lack of incentives to fly ash start-ups in many states.
• The process of making fly ash bricks requires more training and knowhow in the hands of the workers, which is missing.
• There is also an absence of an existing market for fly ash bricks as adequate initiatives have not been taken by Central and state governments in this direction.
• Transportation of fly ash from power plants to brick units and costs involved in transportation also act as a hindrance to its utilization.
• A robust monitoring system in missing.

Use of Fly Ash

- *Reclamation of low-lying areas:* Soil or sand can be substituted with fly ash in reclamation of low-lying areas. This helps save precious top soil. Average ash utilization from power plants for reclamation activities is only around 8.45 per cent. About 21 million tonnes (out of 217 million tonnes) of fly ash generated was utilized in 2018–2019 in reclamation of low-lying areas.
- *Backfilling of Mines:* Traditionally, river sand has been used as mine backfilling material, but its continued availability is suspect. Fly ash offers a viable alternative. Average ash utilization rate as mine filling has been around 6 per cent. About 0.65 million tonne of fly ash was used in backfilling and stowing of open cast and underground mines during 1998–1999, which increased to 10 million tonnes by 2018–2019.
- *Construction of roads and fly overs*: Road networks are expanding in India. New roads, highways and flyovers are coming up and existing ones are being widened. Fly ash can be used in this sector as well. Fly ash is pozzolanic and can enhance the strength of road structures. However, average ash utilization in this sector has only been 3.6%.
- *Manufacturing blocks and tiles for walls and floors*: Fly ash is also used to manufacture floor and wall tiles (with fly ash content not exceeding 50%). Fly ash-based blocks and tiles are as good as conventional clay-based building tiles.
- *Agriculture*: Several studies proclaim the benefits of using fly ash in agriculture. However, there are risks associated due to presence of toxic heavy metals in the ash which can find their way into the food chain.

MEASURES TO BE ADOPTED

It is clear that coal will remain the mainstay of energy generation in India in the near future, which will further aggravate the problem of fly ash management. A proper disposal and utilization framework are vital in view of the growing environmental concerns associated with its generation. Along with the current emphasis on meeting emissions standards, ash utilization must also be made a priority area as its improper disposal significantly contributes to air pollution. Although there is a well-defined policy and regulatory framework for 100% fly ash utilization, thermal power plants have failed to achieve the targets due to one or the reason discussed in this report. Ash lying around will always be a hazard despite the best disposal measures.

Figure 1: Paver blocks using Fly Ash at NTPC and its utilization within premises

Ensuring its 100% utilization by converting it into a variety of useful products or using it in construction activities is the only way forward. Concerted efforts are required at the plant level as well as by agencies that utilize ash to make this possible. Only if all thermal power plants consistently utilize 100% of the ash they generate in the coming years, while also clearing the ash backlog from previous years, will the adverse environmental impacts created due to ash be minimized. Instead of utilizing ash in batches, its continuous utilization should be made possible. User agencies within a stipulated radius of thermal power plants must be made accountable and should be strictly monitored for use of ash in their products. Thermal power capacity additions should work in tandem with the capability in any region to ensure 100% utilization of ash in an environmentally sound manner. Coal power plants should explore avenues to ensure 100% utilization, and the government can regulate this with stricter monitoring and stringent penalties, and by creating a conducive fly ash-product market. Thus, power plants, regulatory bodies as well as the government need to take definite measures to improve fly ash utilization. Some suggestions on the same as follows:

1) Discourage expansion or installation of coal capacity in regions where it is already heavily concentrated. Doing so will ensure that there is no overabundance of fly ash in such regions and reduce the chances of serious fly ash pollution.
2) Capacity addition should not be allowed in plants with limited ash pond capacity. There have been several instances where plants have undertaken capacity addition without assessing the carrying capacity of their ash ponds. This should be strictly discouraged.
3) Power plants not utilizing 100% of their ash should not be given approval to expand capacity.
4) It must be made mandatory for non-compliant power plants to set up fly ash depots in regions with high ash demand. In particular, plants with capacities exceeding 2,000 MW and also those with low ash utilization rates must set up such depots in urban areas.
5) Monitor periodically and take strict action against plants not meeting the 100% utilization target. Government must come up with strict policy measures in the form of penalties and disincentives against such plants. Power stations should be asked to determine their availability only after accounting for their ability to utilize 100% of the ash they produce, before committing to scheduling their stations to state load dispatch centres.
6) Make disclosure of fly ash data by power plants mandatory to ensure better transparency. It must be made mandatory for each power plant to put its annual ash generation and utilization (including of legacy ash) data on its official website for better transparency. Power plants must also disclose their fly ash procurers along with the amount utilized by each.
7) Reduce plant load factor (PLF) of plants not meeting the 100% target. A low PLF will lead to lesser coal consumption and fly ash generation. The reduced amount can then be easily utilized to the extent of 100 per cent, solving the problem of its disposal.
8) Provide guidelines on proper construction of ash dykes and appoint dedicated government- or SPCB-appointed authorities or officials in each state for periodic monitoring. Capacity building of such officials is also needed.
9) Provide adequate transport infrastructure for bulk transfer of ash through roads, railways or waterways from power plants to utilizing agencies.
10) Ensure strict monitoring of the mandated use of fly ash. State governments must come up with stricter regulations and enforcement systems to ensure mandatory use of fly ash in the making of cement, bricks and roads. Noncompliance with such a mandate should be dealt with strictly.
11) Encourage setting up of new cement and fly ash-based brick manufacturing units in close proximity to power plants. State governments must provide suitable incentives and support to start-ups,

agencies or power plants willing to establish fly ash-based units in the vicinity of power plants.

12) Establish a market for fly ash-based products. States should make use of fly ash products compulsory in construction activities near power plants. Use of fly ash bricks and cement should be made mandatory in construction of all government buildings.
13) Strict enforcement of already existing policies. MoEF&CC had mandated 100% utilization of fly ash by power plants by end of December 2017. Regulations were passed on transportation cost bearing and mandatory use of fly ash by user agencies located within 300 km radius of power plants. However, on ground enforcement and monitoring has been poor. Stricter enforcement is required.
14) Replication of success stories for higher ash utilization rate. Success stories (whether intra-country of global) must be replicated.

MEASURES TO BE TAKEN BY COAL AND LIGNITE BASED POWER PLANTS

1) Ensure dry extraction of ash to the maximum extent possible by building sufficient storage silos. Dry ash is more suitable for making cement, bricks and for other uses. After a proper assessment of monthly fly ash generation, plants should ensure that they have at least one month's fly ash storage capacity within their premises. Power plants should also create facilities for faster loading of ash onto vehicles.
2) Every power plant must have a dedicated ash management cell working for proper management, safe disposal and utilization of ash. The cell must ensure the quality of fly ash supplied to user agencies. It must also inspect ash ponds periodically for leakages and other maintenance issues.
3) For bringing in more transparency, power plants must disclose their annual ash generation and utilization figures, including of legacy ash, on their official website and also in the annual environment statements they submit to pollution control boards.
4) Every power plant with a low ash utilization rate must install fly ash depots in regions with high demand for fly ash.
5) Power plants must explore the possibility of building fly ash-based brick or cement units adjacent to the plant or selling fly ash for nearby construction activities.

MEASURES TO BE TAKEN BY REGULATORY BODIES AND POLLUTION CONTROL BOARDS

1) Regulatory bodies must devise a clear penalty mechanism as environmental compensation for damage and should impose strict penalties on plants mismanaging fly ash. The collected money should be spent on restoration of the environment and in compensating the people affected by such incidents.
2) Closure notices should be issued and heavy penalty must be imposed on plants with poor ash utilization rates.
3) Pollution control boards should renew consent to operate only for stations that demonstrate adequate fly ash management and submit proper action plans for its 100% utilization.
4) State and regional pollution control boards must periodically inspect and assess the condition of ash dykes. Ash ponds must be monitored for leaks or overflow. Appropriate action should be taken against power plants through show cause notices, closure notices or by imposing penalty on defaulters, in case of mismanagement and unsafe disposal of ash in dykes or overflow of ash dykes.

CONCLUSION

India's total power generation capacity (as on 31 March 2020) stood at 370 gigawatts (GW). Coal and lignite-based power stations continue to be the bulk energy providers, making up 205 GW (89 per cent) of the total thermal power capacity. Significant coal-based capacity has been added in the last 15 years. Around 64% (132 GW) of the capacity is less than a decade old. About 74% (152 GW) is less than 15 years old. Huge capacity additions have led to a gradual increase in coal consumption over the years,

thereby also leading to an increase in fly ash generation. Moreover, Indian coal has high ash content, which leads to generation of large quantities of fly ash at coal and lignite-based thermal power stations. Transportation and settlement play an important role in determining the ash utilization rate. States with more cement or brick manufacturing units, that are in proximity to power plants, tend to have higher utilization rates. Andhra Pradesh, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu together account for about 60% of total cement production capacity in India. Ash ponds must be monitored for leaks or overflow. Appropriate action should be taken against power plants through show cause notices, closure notices or by imposing penalty on defaulters, in case of mismanagement and unsafe disposal of ash in dykes or overflow of ash dykes.

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