Environmental impacts of Thermal Power plants in India and its Abatement measures

Mohsin Anwer[1*], M.Tech Student (Environmental Engineering), Dept. of Civil Eng., Aligarh Muslim University, Aligarh, India (mailsyed078@gmail.com)

Gulafshan Tasnim[1], M.Tech Student(Environmental Engineering), Dept. of Civil Eng., Aligarh Muslim University, Aligarh, India (afshan.tasnim.nm@gmail.com)

Abstract: Air pollution is one of the major concerns for people all around the world, with various sources contributing to the menace globally. Among these, Thermal power plants is one of the chief point sources of air pollution all over the world. Unfortunately, with the ever-growing capacity of these power plants, our country is also witnessing extreme contaminations of air around their vicinities. Release of these hazardous emissions in the atmosphere contributed by the electricity generation in the thermal power plants is a serious concern and possesses threat to a large percentage of human life, biodiversity and environment. The present study focuses on the various types of anthropogenic emissions that are emitted from these thermal power plants and also sheds light on its negative impacts on environment and human health. Several solutions have been presented to prevent, control and mitigate these impacts and possible alternatives have also been suggested. Furthermore, this study highlights the prevailing problems in the policy making and legislations regarding air pollution in the country and also addresses the shortcomings in the management of the pollution at the plant level. Stringent actions for the compliance of the emission standards, more transparency regarding the air quality data between the stakeholders and general public, regular monitoring of air quality, enforcing new and stricter policies as well as revision of the existing Environmental Impact Assessment (EIA) procedures are some of the key takeaways for dealing with the environmental impacts of thermal power plants in the long run.

Keywords — Coal, Thermal power plants (TPPs), Air pollution, Fly ash, Emissions, Remedial solutions

I. INTRODUCTION

India is one of the fastest developing countries across the globe. It is also the second most populous country in the world having a population of about 1.38 billion which comprises of 17.7% of the world population [1] [2]. It is expected to reach the population of 1.72 billion around 2060 [3] at an average growth rate of about 1.344% [4]. Increase in population is closely followed with increase in people's demand which in turn serves as a motivation for drastic growth in industrialization and urbanization. Development and expansion of Power sector plays a critical role in the welfare and economic growth of any nation. Over the years, electricity has emerged as one of the biggest blessings for modern life as well as the most basic necessity for development of every other sector. At present, India is the world's 3rd largest consumer as well as 3rd largest producer of electricity. The per capita consumption of electricity in the country has seen a gradual increase from 15 kWh in 1950 to about 1,181 kWh in the year 2018-19[5]. Similarly, the overall electricity generation saw a significant growth from about 5.1 Billion units in 1950 to 1390.467 Billion units during 2019-20 [6].

Electricity in India, is largely generated by Coal based Thermal power plants (TPPs) [7]. Globally, India ranks 5th in installed thermal power capacity. A/c to reports of Central Electricity Authority, total all India thermal power plants capacity is 2,30,600 MW, as on 31March,2020 [8]. The installed capacity of Power Plants has surged to 370,106 MW (as on 31 March, 2020) from a meagre 1,713 MW in 1950 over the years [8]. More than 267 TPP Projects have been running in India, owned by different Private companies & NTPC. Fossil fuel and in particular coal, dominates India's electricity sector. It accounted for more than 80 percent of the total electricity produced in the country in 2019–2020. Coal produces 88% of the thermal power in the country and the rest is obtained from other fossil fuel sources like diesel and gas [9].

Although, Coal is the most abundantly available fossil fuel for producing electricity but there is also this reality that the coal available in India is of very low quality and has a very low calorific value [10].High ash content of the available coal and use of inefficient technologies are some of the major culprits for the particulate matter emissions in India. When this coal undergoes combustion in thermal power plants, large amount of heat energy and pollutants are emitted which are extremely hazardous for the environment. They have various serious impacts like acid-rain, Green house effects and global climate change, etc [11]. These emitted pollutants include noxious gases like oxides of carbon, Sulphur and nitrogen, CFCs (greenhouse gases), other trace gases and air borne organic matter like fly ash and suspended particulate matter [12]. These numerous and

 DOI : 10.35291/2454-9150.2020.0668

increasing number of environmental impacts by the thermal power plants are a cause of great concern for our government and the local people residing in the area. Not only they adversely affect our environment and harm our surrounding habitats but also create a series of very serious health issues among human beings [13]. Sadly, the dependency on coal and the repercussions of its overuse will keep increasing in India until other renewable and nuclear power sources are explored more.

The present study focuses on the major atmospheric emissions that are emitted from the TPPs in India and does a thorough analysis of its environmental and health impact. Moreover, the solutions of these impacts is reviewed and the corresponding alternatives are suggested. This study elaborates the present problems in the system and points out the shortcomings in the adopted pollution control measures for the Thermal Power Plants in India. It also highlights the immediate need of some concrete steps from the government like, tighter emission standards, transparency in the monitoring process, immediate need of revision of present EIA procedures and strict policy making, among other recommended solutions.

II. AIR POLLUTION SCENARIO IN INDIA

India has been struggling with pollution for a long time. In fact, in February, the World Economic Forum published a report in which it was stated that India was home to 6 out of 10 of the world's most polluted cities. Not only India, pollution of the air is a very serious problem across the globe as this affects billions of the lives every year [14][15]. As per World Health Organization (WHO) database, air pollution is responsible for about 25% deaths across the world [16]. Thus, it is safe to say that as compared to the other modes of the pollution like water, lead, soil etc., it is indeed the most detrimental type of pollution [17]. The given **Table 1** shows shocking figures related to pollution related deaths in India where India ranks at 10 right now.[17]

Table 1. Deaths rates in India caused by different types of pollution

Type of Pollution related deaths	Death rates
Pollution Death Rate	174
Death ranking	10
Total Pollution Deaths	2,326,771
Air Pollution Deaths	1,240,529
Water Pollution Deaths	698,597
Occupational Pollution Deaths	153,528

Continuous emissions of these deleterious elements in the atmosphere from different sources are leading to increasing number of pollution related deaths day by day. Automobiles and Industries are biggest culprits when it comes to air pollution. As per a research study, the pollution contributed by vehicles is about 60% and industries is about 20-30% in urban areas [18]. Leading American news channel CNN reported that 21 of the world's 30 cities experiencing the worst air pollution lie in India. Out of 640 districts in India, about 27% exceeded the annual standard value i.e 40 µg/m3 in 1998 and almost 45% exceeded it in 2010 [19]

According to the data released by WHO of the 10 most polluted cities in the world, nine out of ten cities are from India while Delhi occupies the 6TH position on the list, having a pretty high concentration of the PM10 [20][21]. These reports are a clear indication that the menace of air pollution in India needs to be addressed as soon as possible and emerging and potential techniques must be used to maintain the air quality level in the country. **Figure 1** below shows the concentrations of PM2.5 and PM10 in some majorly polluted countries of the world where China is currently topping the list with PM concentrations of 405 ppm and 63 ppm, respectively [19].

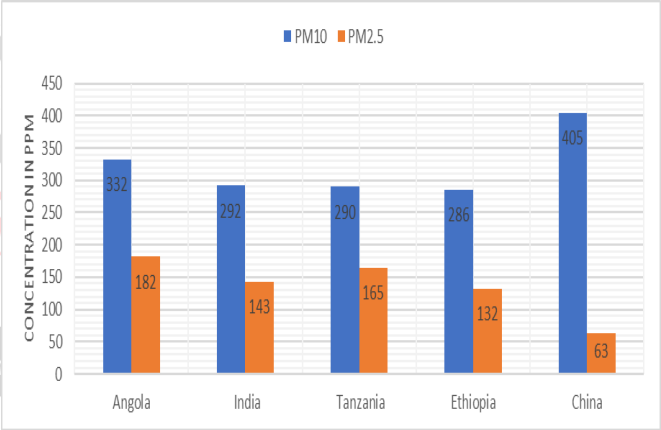

Figure 1. Concentration of PPM in major polluted countries

The **fig.2** and **fig.3** below show the global death rates due to different causes and total deaths from the individual pollution risk factor, respectively [17].From these 2 bar graphs, we can have a clear idea of how pollution and specifically, air pollution is one of the major cause of deaths all around the world.

 DOI : 10.35291/2454-9150.2020.0668

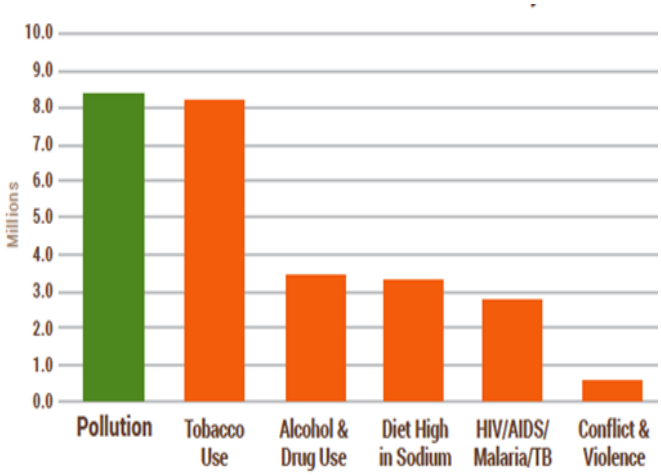

Figure 2. Deaths due to different causes

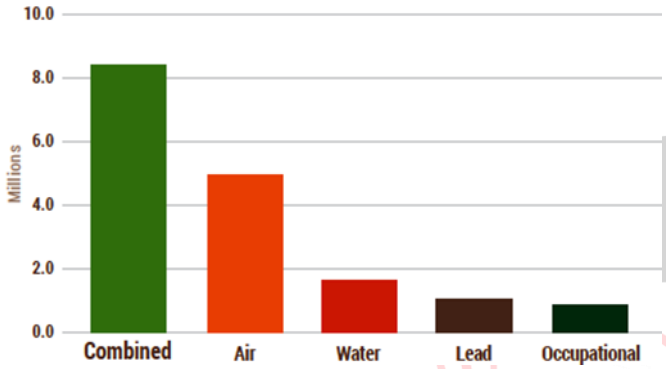

Figure 3. Deaths due to different sources of pollution

III. ROLE OF THERMAL POWER PLANTS (TPPS)

The power sector in India has flourished considerably since we got our independence in 1947.The reason why this sector is considered so important is because, it plays a key role in the development across all the others sectors of the economy, for example : infrastructural, agricultural, commercial , Industrial and railways etc. Through the enactment of Electricity Act, 2003, revolutionary changes have been brought to every area of the sector, favorable environment has been created to promote the participation of private sector and enhance the competition in the sector. The result of these efforts has led to noteworthy investment in generation, transmission and distribution areas.

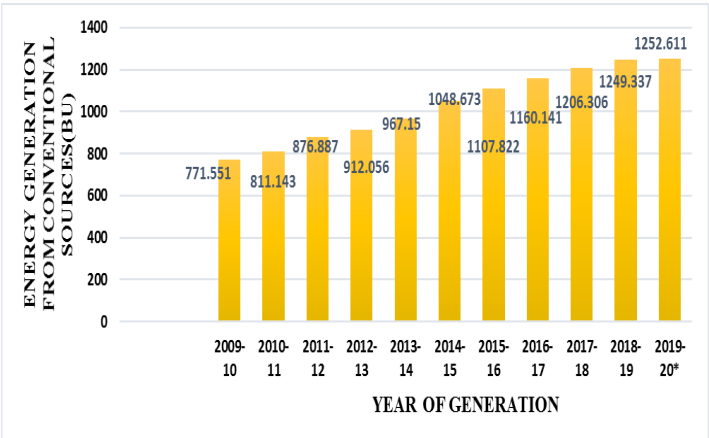

Figure 4. Electricity Generation by conventional sources in the country during 2009-10 to 2019-20

The per capita consumption of electricity in the country has also seen a gradual increase from 15 kWh in 1950 to about 1,181 kWh in the year 2018-19[5].Similarly, the overall electricity generation (Including generation from grid connected renewable sources) saw a significant growth from about 5.1 Billion units in 1950 to 1390.467 BU during 2019-20 [22]. During the 2018-19 fiscal year, about 1,547 TWh of total electricity generation (utilities and non-utilities) was done in the country [5].The figure given below shows the growth in electricity generation by conventional sources in the country over the decade [22].

TPPs are power stations in which heat energy is converted to electric power. They generate electricity by using fossil fuels like Coal, gas and oil and work on the principle of Rankine cycle. In TPPs, the solid fuel (usually coal) undergoes combustion to produce heat energy which is then used to convert water into steam. This high pressure and temperature steam rotate the turbine blade. After that, the turbine shaft connected to the generator then converts the kinetic energy of the turbine impeller into electrical energy. So basically, the chemical energy of fuel converts into the heat energy in the boiler. The turbine converts this heat energy into kinetic energy which is then further converted into electrical energy with the help of an alternator (Synchronous generator). On the basis of the fuel that is used to generate the steam, mainly 3 different types of TPPs are running in India:

Table 2. Types of TPPs in India and major features

S.No	Type of TPPs in India	Features
1.	**Coal based**	These TPPs act as the backbone of Indian power sector. Luckily, India has vast coal reserves that are able to meet more than 75% of India's electricity demand [23]. These plants are generated by Public sector undertaking National Thermal Power Corporation (NTPC) and several other state level powers generating companies. The total installed capacity of Natural gas-based power plants in India, in 2020, is nearly 1,98,525 MW.
2.	**Gas based**	The total installed capacity of Natural gas-based power plants in India, in 2020, is nearly 24,956 MW [24].
3.	**Diesel based**	The total installed capacity of diesel-based power plants in India, in 2020, is about 510 MW [24].

As shown in **Table 3**,the installed capacity of Power Plants (Utilities) has surged to 370,106 MW (as on 31 March, 2020) from a meagre 1,713 MW in 1950, over the years [8].A/c to reports of Central Electricity Authority, total all India Thermal power plants capacity is 2,30,600 MW, as on 31March,2020 [8].Globally, India ranks 5th highest in installed thermal power capacity .More than 267 TPP Projects have been running in India, owned by different Private companies & NTPC, each of which project in turn comprises of a number of units. As shown in **Figure 5**, Coal produces 88% of the thermal power in the country and the rest is obtained from other fossil fuel sources like diesel and gas. About 45.2% of India's thermal power is generated by

 DOI : 10.35291/2454-9150.2020.0668

private sector alone whereas States and Centre have a share of approximately 24.6% and 30.2%, respectively [9].

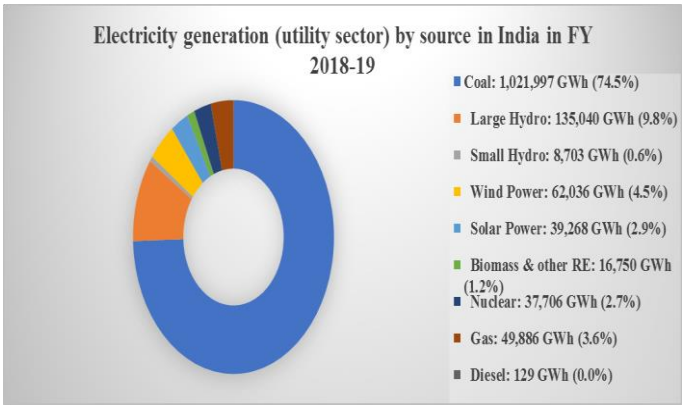

Figure 5. Contribution of all the different major and minor sectors in Electricity generation in India.[23]

Table 3. Total sector wise Installed Capacity as on 30 April, 2020[24].

Fuel used for power generation	Installed Capacity (MW)	% of Total
Total Thermal	2,30,600	62.8%
Coal	1,98,525	54.2%
Lignite	6,610	1.7%
Gas	24,956	6.9%
Diesel	510	0.1%
Hydro (Renewable)	45,699	12.4%
Nuclear	6,780	1.9%
RES* (MNRE)	87,028	23.5%
Total	**370,106**	

IV. HEALTH AND ENVIRONMENTAL IMPACTS OF THERMAL POWER PLANTS

As per TERI analysis, of the total environmental pollution in 2016, power sector reportedly accounted for 51% of SO2, 43% of carbon dioxide (CO2), 20% of oxides of nitrogen (NOx), and 7% of PM2.5 emissions. Coal based Thermal power plant is one of the major contributors in the contamination of the air. The major emissions from thermal power plants are NOx, SOx, CO2, fly ash, SPM, soot and other trace gas species. A/c to Garg et al., Coal and lignite Fired TPPs are among the Largest Point Sources of air pollution. They contribute significantly in the total LPS emissions in India i.e. about 47% each for SO2 and CO2 [25]. The coal used, not only generates power but also produces hazardous substances and anthropogenic emissions like slag and ash as a waste, non-combustible hydrocarbon, heavy metals like As, Cr, Ba, Sr, Zn, Pb, Mo, etc. as well as water contaminated with radio nuclide [26][27][28][29]. However, among all the pollutants SO2 and fly ash are the major pollutants from thermal power plant [30]. These pollutants not only have a massive impact on the biotic and abiotic components of the ecosystem but also have detrimental effects on the world community as a whole [31][32].

Coal Fired thermal plants produce the solid waste in the form of fly ash and bottom ash. The particle size of the bottom ash is relatively coarse and it is disposed of to the waste disposal sites, after collecting from bottom of the boilers, by the wet disposal method in the form of the slurry [33]. Fly ash is the fine-grained fraction is of the particle size of 0.2-90 µm [34] [35]. This fly ash releases into the surrounding atmosphere from the stack because of the unavailability or poor working of the emissions control devices. During the process of combustion, trace elements can be transferred to this waste, especially fly ash, from the coal because of the fine size of the particles and larger surface area absorbs this trace elements from the coal [36].

In the central part of India, states like Jharkhand, Madhya Pradesh, Odisha, Chhattisgarh etc. are highly polluted due to the particulate matter emissions from the large number of coals based thermal power plants in these areas. Other reasons for pollution in such areas is the proximity to coal mines and higher generation capacity of the power plants. The northern part of India including Delhi, Haryana etc. is also struggling with the substantial concentrations of the particulate matter in the atmosphere due to coal fired thermal power plants. Although the inhabitants situated in the coastal areas are relatively suffering less from the PM emissions from power plants because of the land to sea breezes which disperses the pollution over sea but on the other hand, it has become threatening to the water and soil quality in the area due to the pollution from the coal washery and ash dumps. Power plants in inlands are in majority in the country and possesses a very serious concern for the human health and surrounding environment. It has been seen that under normal condition, the impacts of the emission can be seen within 200 km and if the condition is windy, the impacts is in the radius of the 400 km [37].

Table 4. Estimated emissions from TPPs for different states of India in 2014

States	PM2.5	SO2	NOx	CO	CO2
Andhra Pradesh	21	172	160	129	85
Bihar	30	120	107	89	59
Chhattisgarh	57	223	250	166	110
Delhi	12	17	23	13	9
Gujarat	107	309	275	231	152
Haryana	15	124	165	92	61
Jharkhand	28	129	172	97	64
Karnataka	32	93	151	85	56
Madhya Pradesh	30	250	281	186	123
Maharashtra	78	373	449	316	209
Odhisa	36	229	305	171	113
Punjab	11	95	117	71	47
Rajasthan	62	148	167	111	73
Tamil Nadu	40	189	252	141	93
Telangana	17	110	146	82	54
Uttar Pradesh	64	317	423	237	156
West Bengal	56	247	330	185	122
Total	695	3147	3774	2402	1584

 DOI : 10.35291/2454-9150.2020.0668

Table 5. Estimated emissions from TPPs for different states of India in 2030

States	PM2.5	SO2	NOx	CO	CO 2
Andhra Pradesh	94	687	514	513	338
Assam	3	25	34	19	12
Bihar	83	572	560	427	282
Chhattisgarh	149	973	1008	726	479
Delhi	12	17	23	13	9
Gujarat	173	689	557	522	344
Haryana	16	175	170	101	67
Jharkhand	93	553	511	412	272
Karnataka	61	319	317	267	176
Kerala	3	23	11	17	11
Madhya Pradesh	87	673	653	502	331
Maharashtra	144	764	860	622	410
Meghalaya	2	15	20	11	7
Odisha	151	682	810	631	416
Punjab	26	217	228	162	107
Rajasthan	101	282	235	210	139
Tamil Nadu	92	453	461	379	250
Telangana	35	192	197	143	95
Uttar Pradesh	110	699	715	522	344
West Bengal	82	467	558	349	230
Total	1514	8447	8440	6547	4318

The **table 4** and **table 5** above shows the actual emissions and estimated emissions of major air pollutants from TPPs in different states of India for the year 2014 and 2030, respectively [39].From the tables, we can see shocking figures from all the bigger states where most of the major TPPs are based. It also tells us that how the pollution problem from these TPPS needs to be dealt with as soon as possible, otherwise the air in more than half part of the country will become unbreathable by 2030.According to a study of 2011, about 503 million tons of coals was being used in nearly 111 thermal power plant. This enormous consumption of coal leads to production of about 580 kilotons of PM2.5, 2100 kilotons of Sulphur dioxide (SO2), 2000 kilotons of NOx,1100 kilotons of CO and 100 kilotons of volatile organic compounds [37]. It has also been seen that huge quantity of the fly ash is generated as a waste material from the TPPs due to burning of the coal. Nearly about 131 million tons of fly ash is generated in India per year [38].

Another study reported that about 115 thousands premature deaths and about 21 millions of asthma cases were reported in India because of the exposure of the fly ash and coal dust during 2010 and 2011[40].The **Table 6** below shows the present and forecasted data of the number of premature deaths and Asthma attacks that are expected to come up due to breathable PM 2.5 in air that is released from the TPPs. The estimated cost incurred by the government and the public due to these health impacts were about 16000 crore and 23000 crore rupees, respectively which is an absolutely crazy figure. Epidemiological studies conducted in India, have regularly demonstrated higher rates of respiratory and cardiovascular diseases in population due to the exposure of PM, NOx and ozone pollution. [41]. The **table 7** below lists all the harmful health impacts of these anthropogenic and hazardous emissions ,ranging from mild symptoms of nausea and headache, etc. to serious cases of respiratory diseases and even cancer.

Table 6. Anticipated health impacts due to ambient PM2.5 pollution from the planned coal-fired TPPs in India [43]

Year	Premature mortality	Asthma attacks (millions)
2017	112,500-126000	23.4
2020	132,500-153,500	28.4
2025	164000-197,500	36.7
2030	186,500-229,500	42.7

Table 7. Associated health impacts of the emitted pollutants [42]

Pollutants	Associated health hazards
Sulfur dioxide	Eye burning, pulmonary emphysema, cancer, headache, heart diseases, irritation of the respiratory tract, tract infections, coughing, mucus secretion, causing aggravates conditions like asthma and chronic bronchitis.
Respirable Particulate matter	Heart diseases, chronic bronchitis, asthma
Suspended particulate matter	Asthma, cancer, pneumoconiosis, restrictive lung diseases.
Nitrogen dioxide	Viral infection, lung irritation, airways resistance, chest tightness, inflammation of lining of lungs, causes lung infections, wheezing, coughing, colds, flu and bronchitis
Benzene	Asthma, anemia, unconsciousness, carcinogencity, Immonotoxicity
Ozone	Chest pain, irritation in eyes and nose, coughing, impaired lung functions
Lead	Anemia, reduces synthesis of haemoglobin, damage the nervous and renal system
Carbon monoxide	Asphyxiation, cherry lips, nonconsciousness.

Major environmental impacts of the emissions from the TPPs are as:

1) ***Changes in the characteristics of soil***: - The sites having the high pollution load increases alkalinity of the surrounding soil due to deposition of the fly ash emitted from TPPs. These plants also have emissions of the larger and heavy solid particles which results in the increases of bulk density and consequently decreases the porosity of the soil. It has been found that concentration of the total nitrogen and bicarbonate extractable phosphorus contents of the soil were low at the polluted sites. The total S, sulphate S, and organic S accumulation in the soil were greater at the sites receiving higher annual SO2, concentrations as compared to those sites having low annual SO2, averages. Due to pollution of the soil, trace elements like Fe, Cd, Cu, Pb and Ni significantly decrease in concentration [44]
2) ***Accumulation of the heavy metals/metalloids in vicinity of the power plant*:** Some volatile heavy metals/metalloids like Pb, Fe, Cr, Cd, Zn, Ni, V, Co and Cu etc. are released from the combustion operation in the power plant and associated with fly ash after the

 DOI : 10.35291/2454-9150.2020.0668

condensation. This fly ash accumulates these heavy metal and metalloids in the surrounding area and makes the soil contaminated. Fly ash deck is another source, present in the vicinity of the plant, of the polluting surrounding soil by these heavy elements where this get contaminated with these elements and move through wind and storm.[45]

3) ***Generation of the Solid Waste*****:** Coal based TPPs all around the world, generate huge amount of the solid waste in the form of fly ash, bottom ash, and gypsum (produced from FGD cleaning process). The properties of the solid waste generated from plant depend on the type of the coal used and technology used for handling and storing. The Solid waste of the thermal power plant usually contains valuable metals and hence metals can be extracted by using the suitable technology. For analyzing the extraction efficiency of the metals from solid waste, and in order to classify the waste or to know the next step of utilization, many countries has established different standards for their test studies.[11]

4) ***Effects of fly ash on vegetation*****: -** Fly ash generation has huge impact on the vegetation in many ways.

- The deposition of the fly ash on the surface of the leave may causes the stomatal opening close and hence effects the respiration and photosynthetic rate.
- Under the certain humidity, the fly ash dust may stick to the surface of the leaves and fruits and causes the chemical and physical injuries and leave the necrotic dark brown spot on surface on many vegetables. [46]
- Transpiration rate of the plant is also get effected due to the foliar deposition of the fly ash.
- The deposition causes the creation of the thicker layer on surfaces of the leaves and may also affect photosynthetic rate of the plant due the in adequate receiving of the light.
- Microbial activity and root growth of the plant may be affected by changing the property of the soil due to fly ash.
- If the fly ash deposition is very high in the sowing season of the seeds, germination and growing of the seeds gets reduced.
- Due to high amount of fly ash, contains the soluble elements, may induce the hazardous effects on the roots and rhizosphere.
- Fly ash increases the pH of the soil and the increased pH may loss the applied and indigenous N.

5) ***Contamination of the ground water due to heavy metal*****:** Fly ash contains various heavy metals and these heavy metals may percolate down to the groundwater through soil (unlined pond) when fly ash present in the slurry form. The concentration of the heavy metals is found very high in the rainy season [47].

6) ***Radioactive elements in the vicinity of Thermal Power Plant:*** - Coal contains radioactive elements like uranium, thorium and ^{40}K. When coal burns in the thermal power plant, it releases the radionuclides into the surroundings and enhances the natural radiation in the vicinity of the thermal power plants [33]. The radiation emitting from the coal are carcinogenic and may have developmental effects causing impaired functions of brain and even severe mental retardation due ionization of the radiation, if emitting at higher percentage [48]. Lungs and bones are the most targeted organs of the body of the nuclides U and Th. Radiotoxicity of thorium causes severe health effects like leukemia, bone sarcomas and chromosomal aberrations, etc.

7) ***Acid Rain*** - Oxides of the Sulphur and nitrogen reacts with the moisture present in the atmosphere and form weak solutions of the sulfuric and nitrous acids which is responsible for the acid rain [49].

8) ***Greenhouse Effect and Climate change*** - The ozone in the atmosphere that protects us from the harmful ultraviolet radiations of the sun, can be depleted due to increase in the concentration of the nitrogen oxides. Furthermore, chlorine, fluorine and their derivatives, generally toxic and carcinogenic in nature are emitted from the thermal power plant from the combustion products [50]. The carbon dioxide and carbon monoxide is also released in the atmosphere which causes the green houses effect and also leads to the climate change [51].

V. GOVERNMENT INITIATIVES AND LEGISLATIONS OF INDIAN AIR QUALITY

The Air Prevention and Control of Pollution Act was approved by the Indian parliament in 1981 with the objective to work for the prevention, control, and abatement of air pollution. The Central Pollution Control Board (CPCB) of India, established in 1974, has been given powers and duties under the same act. This constitutional body works under the Ministry of Environment, Forest and Climate Change (MoEF & CC). CPCB has set National Ambient Air Quality Standards (NAAQS) for all major air pollutants like PM10, PM2.5, SO2, NO2 and other greenhouse gases for different types of areas, be it commercial, industrial, residential or ecologically sensitive ones [52].The MoEF & CC issued some directives in 1999 under the Environment (Protection) Act of 1986 which include: utilization of Pulverized Fuel Ash by the thermal power plants in all sorts of construction activities in and around the plant. Under an amended notification issued on 3rd Nov-2009, the MoEF, Govt. of India has made it mandatory to utilize fly ash in various construction projects that occur within 100 Km radius of any TPP [53].

Ministry of Environment further issued a notification titled 'Environmental Protection' in December, 2015 setting air pollution standards for TPPs with the aim to reduce suspended particulate matter (SPM) emissions, Sox, NOx and mercury at TPPs. This order has made installation of FGD (Flue gas Desulphurization) system and NOx burner as compulsory in all the existing and upcoming thermal power plants. As shown in **Table 8,**under the new norms introduced in 2015, power plants commissioned between 2003 and 2016 which account for 65% of India's total coal capacity will have to cap their NOx emissions at 300 mg/Nm3 ('N' refers to standard temperature and pressure) while the new plants commissioned from 2017 onwards that comprise 5% of total coal-based thermal power capacity must limit NOx emissions to 100 mg/Nm3.In a surprising move in May 2019, the Ministry of Environment has approved to dilute the emission limit of nitrogen oxides from 300 mg/Nm^3 to 450 mg/Nm^3.The move to increase the standards comes after the government of India has already shifted the implementation deadline for NOx norms in power plants by five years to 2022. The deadline had been further pushed to December 2022 for all

 DOI : 10.35291/2454-9150.2020.0668

the power stations in the country citing complexity of the whole implementation process and the critical need of continuous and smooth electricity supply.

Table 8. Emission norms for coal based thermal power plants applicable from December 2017 onwards (Source: Centre for Science and Environment, New Delhi, India)

Concentration of pollutants (mg/Nm3)	Unit size	Installed before 2003	Installed between 2004 and 2016	Installed 2017 onwards
PM	All	100	50	30
SO2	Less than 500 MW	600	600	100
SO2	Greater than or equal to 500MW	200	200	100
NOx	All	600	300	100
Hg	All	0.03	0.03	0.03

Despite adjournment of timelines for compliance of the new norms from December, 2017 to December 2022 for all TPPs, power stations are still lagging behind in the pace of implementation of emission control systems. To this date, there are no specific pollution standards for individual power plants. Although, the extent of air pollution and quality of emitted pollutants is different for every type of industry but still the ambient air quality standards for all industrial areas is same. This reason is the major culprit in compromising the govt. efforts to control any pollution. There is an immediate need to regulate the standards at the level of plant source. After we are able to ensure that, then we can proceed to our second step of monitoring the pollutants and then to our final step of enforcing rules and reducing the environmental and health impacts of the power plants [54]. Prayas health group stated in his study that unless good alternatives are found, power generation through coal will remain high through the 2030s and so will be the environmental and health impacts due to the pollution emitted by it [55].

VI. REASONS FOR NON-COMPLIANCE OF STANDARDS

The Emission rates of the emissions produced from thermal power plants varies due to different factors like age of the plant, quality of raw material (coal mixture & oil) used, quantity of raw material (coal mixture & oil) required for per unit generation, maintenance standard of the plants and amount of excess air fed into the furnace[56]. These variations make abatement of air pollutions very difficult. Although it's difficult to list all but some of the major reasons can be specified as, namely [54].

- Delay in coal and air pollution control devices supply.
- Inefficient operation and maintenance of air pollution control devices (e.g ESPs, Cyclone separators, bag filters, etc.)
- Huge amounts of generation of ash.
- Lack of efficient management of ash ponds

VII. REMEDIAL MEASURES

A. *Fly Ash*

Fly ash is produced as a residue by combustion of coal in burning chamber of the TPPs. The fine particles in fly ash rise with the flue gases and contribute to air pollution. Apart from that, it also has significant impact on human health. Due to its fine nature, it acts like a cumulative poison for humans by getting deposited in the pulmonary region of the lungs for long periods of time. Talking about the structure of fly ash, it is a spherical fine glass powder whose estimated particles size lies in the range of 0.5 to 100 μm. The major constituents include - silicon dioxide, aluminum oxide and iron oxide. On the basis of its chemical composition, it can be divided into 2 classifications i.e Class F and Class C [57].Class F - composed of Bituminous coal and Anthracite. Class C – composed of sub-bituminous coal or burning lignite

Fly ash mitigation measures

As per the hazardous waste management and handling rule of 1989, fly ash is regarded as non-hazardous because of which, it is often disposed of in Landfills. Disposal of fly ash is done in either wet state or dry state. The concerning point about this type of disposal is migration of metal into the soil which eventually leads to contamination of ground/surface water as well as the soil. Unlike other organic wastes, Heavy metals in the fly ash are persistent and do not degrade easily through biological treatments [10].

Other concerning aspect for this type of disposal is the fact that the present approach for disposal of fly ash in ash ponds as a slurry requires extensive areas of lands. Increasing population and their need for electricity has put a strain on the present sources of power. This has led to the increase in number of thermal power plants which need huge areas for ash disposal. A recent study stated that, at an estimated 0.6 hectare per MW of electricity produced, the total requirement of land for disposal of ash would be around 82,200 ha by the year 2020, which is huge. Hence, it is important to treat Fly ash more as a by-product rather than waste [58].

During the last 30 years, extensive research has been carried out to utilize fly ash in various sectors [59][60]. Right now, Fly ash is majorly utilized in construction works, as a fertilizer, in mine backfilling, as sub-base in roads, as a light weight aggregate, and so on. However, researches in the ongoing years have found that fly ash can also be useful in removal of organic compounds, heavy metals, dyes, etc. through adsorption as well as in zeolite synthesis. With careful execution of these research ideas, they can help great deal in reducing environmental degradation caused due to fly ash [61].

Following are some of the potential areas of use of fly ash:

i. Fly ash bricks:

The utilization of fly ash for brick manufacturing first came into play as a result of research study done at Central Fuel Research Institute, Dhanbad. Nowadays, a major percentage of generated fly ash is being utilized in building bricks.

 DOI : 10.35291/2454-9150.2020.0668

Apart from being environment friendly, fly ash bricks also possesses several advantages over conventional burnt clay bricks. They are much lighter in weight and comparatively, less costly than Clay bricks. Then there are fly ash-clay fired bricks which are basically composite mixture of fired clay and Pulverized fly ash. They can also be utilized to make unglazed tiles for footpaths or pavements. Addition of fly ash improves the physicochemical characteristics of the bricks like high compressive strength, low water absorption, no cracking due to lime, no frost and high resistance to frost-melting while simultaneously saving approximately 20-30% energy [62].

Several fly ash brick manufacturing units have been set up at Korba, both owned by Government and private entrepreneurs and are producing over 60000 bricks/day. Many other ash brick units are also set to be started by several other entrepreneurs to prioritize and boost ash brick manufacturing [63]. Administrative Building of Greater Noida Industrial Development Authority (GNIDA) and NTPC's own Buildings are some of the recent projects where fly ash bricks have been utilized. Fly ash bricks are also being used for construction of residential complexes by the Private real estate developers in various metro cities. NTPC Ramagundam has conducted a research study for use of fly ash in flux bonded bricks/tiles

ii. Fly ash in cement and concrete

Fly ash is quite suitable for use in Portland cement, mostly as a partial replacement of pozzolana. When moisture is present at room temperature, Fly ash reacts chemically with Ca $(OH)_2$ to form cementitious materials. High amounts of reactive elements like Alumina and Silica complement the chemistry of hydration of cement. Cement produces Calcium Hydroxide and C-S-H gel through hydration. This C–S–H gel imparts binding and strengthening properties to the concrete. Fly ash converts the problematic free lime into durable concrete [64].

When compared to ordinary Portland cement, the spherical shape of fly ash particles facilitates their free blending in mixtures. The property of Easy flowability and blending makes fly ash desirable to be used as a concrete admixture. There are several advantages of using fly ash in cement and concrete which are as mentioned below:

- ✓ Imparts strength and minimizes water demand.
- ✓ Less heat of hydration, thus reduced thermal cracking.
- ✓ Reduced bleed channels.
- ✓ High density and enhanced durability.
- ✓ low permeability and minimized sulfate penetration.
- ✓ Increased corrosion resistance.
- ✓ Saves cost on cement.

Previous investigations reported that 15% to 25% fly ash replacement of cement can help in lowering the porosity of concrete and plain cement mortars [63]. It has also been noted that Fly ash can be substituted for up to 66% of cement in the dam constructions. A/c to a Japanese study, Global cement production is proving to be a major curse for sustainable development. The study states that barren lands which are approximately 1.5 times of the size of Indian Territory need to be afforested to compensate for the total global accumulation of carbon dioxide discharged into the atmosphere. Hence, utilization of fly ash in cement concrete becomes more important as it also minimizes the carbon dioxide emission problem to some extent.

iii. Fly ash based distemper

Distemper manufactured with fly ash can be used as a replacement for white cement. Cost of this distemper is less than half when compared to commercial distempers available in the market. This innovative idea of a fly ash based distemper has been already applied for several buildings in Neyveli, Tamil Nadu and the performance has been noted as satisfactory.

iv. Fly ash based polymer products

One of the new studies on fly ashes have deemed them effective to be used a substitute for woods. Regional Research Laboratory, Bhopal collaborated with Building Materials and Technology Promotion Council (B.M.T.P.C) and TIFAC to develop this innovative technology [60].The idea is to use fly ash as the matrix .The Jute cloth which is used as the reinforcement of the matrix is laminated by passing through a polymer fly ash matrix and then cured. The required thickness is achieved by increasing the number of laminates. This polymer product possess a lot of advantages like stronger, more durable, resistant to corrosion and cost effective as compared to wood. This fly ash based polymer product has several applications. It can be used in door shutters, ceiling, for wall and partition panels as well as for floor tiles too. A commercial plant has been set up based on this technology near Chennai, India.

v. Fly ash-based ceramics

This innovative idea evolved at the National Metallurgical Laboratory, situated at Jamshedpur. They developed a process to manufacture ceramics from fly ash.[58].A composite mixture of Fly ash and plastic clays from the Teruel power station (NE Spain) and Teruel coal mining district, respectively were used to manufacture ceramic products. These especially developed ceramics contain up to 50 % of mullite and 16 % of feldspars (by weight) and hence, show superior resistance to abrasion [65]. Firing tests were done for both fly ash and ceramic products to determine their firing behaviour. This was done to understand the effect of heating on the mineralogy of these materials. It also determines the extent of influence that heating has on the physical and chemical properties like colour, bulk density, water absorption capacity and shrinkage due to heating, etc., of these materials [66]. Their physicochemical properties deem them to be fit to be used for manufacturing paving tiles, bricks and stoneware, etc.

vi. Fly ash as a fertilizer

Fly ash utilization has limited but huge potential in Agriculture. It is considered as a potential growth improver and can serve as a good fertilizer. Being a good soil modifier, fly ash enhances the fertility, moisture retaining capacity and overall crop yield. It facilitates the uptake of vital minerals and nutrients (Ca, Mg, Fe, Zn, Mo, S and Se) by crops and vegetation which can lead to an average of 20 to 30 percent improvement in the Crop yield. It can be achieved by supplying varying fly ash dosages of 20 to 100 tonne for each hectare of land area [67]. New studies have

 DOI : 10.35291/2454-9150.2020.0668

also suggested that, using fly-ash as an alternative of lime in agriculture can contribute to reduction in net CO_2 emissions. Thus, in the long run, this also reduces global warming.

However, even after possessing so many advantages, utilization of fly ash is fairly limited in agriculture due to their heavy metal contents and radioactivity. Studies and researches are working in this direction to provide solutions to handle this problem.

vii. Fly ash in road and flyover embankments

This is another area which has huge potential for utilizing large volumes of fly ash. Fly ash can be used as a good quality stabilized base course and as borrow material for the construction of structural fills and embankments. A /c to U.S Federal Highway Administration, Fly ash can also be utilized in asphalt pavements, in grouts for pavement sub-sealing and as flowable fills too.For use of fly ash in road or flyover embankments, demonstration projects at Raichur (Karnataka),NTPC Dadri (U.P.) and NTPC Badarpur (New Delhi) have been successfully completed. Using the fly ash in large quantities for making the road base and surfacing can result in low value–high volume utilization [63]. This ultimately leads to reduction in earthwork costs due to commendable amount of savings in excavation & transportation costs [67].

In the recent few years, CRRI in collaboration with other agencies has provided several consultancy services for fly ash utilization in many roads and embankment projects. For many Fly ash based embankment projects, Reinforced Embankment Technique was adopted. Some of these projects include: Okhla flyover , Delhi (In collaboration with Delhi PWD);Hanuman Setu flyover , Delhi (In collaboration with Badarpur Thermal Power Station, Delhi and Delhi PWD);Sarita Vihar flyover ,Delhi (In Collaboration with Delhi Development Authority and Badarpur Thermal Power Station, Delhi);Greater Noida Expressway project (In Collaboration with IRCON International and Badarpur Thermal Power Station, Delhi) and second Nizamuddin Bridge in Delhi(In Collaboration with Delhi PWD and Indraprastha thermal power station, Delhi).Construction of embankment)[60].

Many plant roads and rural roads have been constructed by utilizing fly ash for their pavement construction. Some of these projects include: NTPC Dadri (In collaboration with National Capital Power Station, NTPC, Dadri, U.P); Budge thermal power plant (In collaboration with CESC Ltd, Kolkata) and rural roads at Raichur, Karnataka (In Collaboration with Karnataka PWD and Raichur thermal power station)[68].

viii. Fly ash in Railway Embankments

In association with the Central Road Research Institute (CRRI), New Delhi, Research study was carried out to demonstrate use of ash in construction of railway embankment. This design was validated by conducting Centrifuge Model Tests at IIT Bombay. Construction of railway embankment for NTPC's Merry Go-Round (MGR) rail track for coal transportation is planned at NTPC Kahalgaon and NTPC Talcher-Kaniha.

Environmental Impacts of Fly ash Use

Utilization of fly ash not only minimizes the disposal problem but also creates a wonderful opportunity to derive commercial benefits from the wastes by products produced in the power plants thus, decreasing the potential harmful impact that it could have on the environment to a big extent [53].It also saves huge areas of lands which would be otherwise be needed for conventional disposal of fly ash,had these fly ashes were not utilised as a raw material. A/c to a detailed EIA study by UK Quality Ash Association, it is clear that PFA do not possess much environmental risk due to leaching or radiation, when used as a filling material [69]. Leaching of heavy metals is prevented by stopping rainwater seepage into the fly ash core by adopting some simple techniques to ensure safe utilisation of fly ash in Road and Railway embankments. Fly ash, when used in concrete or in stabilization work, reduces any possible kind of leaching by reacting chemically with the cement [61].

B. Emissions

Follow-up Actions needed to Minimize Emissions from TPPS:

To meet the requirements of the increasing demand for power with minimal environmental impacts and sustainable development, government needs to make the following adaptations:

i. **Transparency**-There is an immediate need to introduce new policies for more transparency and efficient distribution of information between the power plant agencies and the public domain. It is absolutely necessary that the real figures and data concerning to the emissions and their mitigation measures adopted by the agency is open to the public and govt. bodies for scrutiny. Lack of transparency is undoubtedly the biggest hindrance in controlling atmospheric emissions from power plants.

ii. **Tighter emission standards**-Following the approach of emerging and developed economies like China, USA, EU, etc., all coal-fired power plants in India should be subjected to tighter emission standards. There is an immediate need to make the emission standards for particulates more stringent, introduce new emission standards for other pollutants and to create awareness among the stakeholders [54]

iii. **Efficiency improvement of existing, older power plants**- Several studies have suggested that efficiencies in many countries can be improved by 10–20% by adopting better technology [70]. Continuous monitoring and mandating technologies that reduce pollution should become a critical component to control the atmospheric emissions. For developing countries like India, average net efficiency for power generation is approximately 26 %.This also means 74% of energy produced is lost in the production and distribution of the electric power[70]

iv. **Revision of EIA procedures**-Its incredibly urgent to enforce the stringent standards by revising the

 DOI : 10.35291/2454-9150.2020.0668

current environmental impact assessment procedures to overcome the critical shortcomings. Present EIA drafts do not consider impact of long-range transport of pollution from the stacks on human health and environment. At present, EIA for an area of only 50 km radius from the plants is considered.

v. **Continuous stack monitoring** -Introducing and enforcing continuous stack monitoring at all the large and small power plants such that the real time data is available in the public domain. Since, stack emissions are point sources so, its relatively simple to monitor them when compared to non-point sources.

vi. **FGD systems**- Encouraging and monitoring implementation of FGD systems (Flue Gas Desulfurization) for reduction in emissions of multiple pollutants like particulates and sulphur oxide[71]

vii. **Clean coal Technology**-Adoption of clean coal technologies (CCTs) can play a major role in mitigating the environmental impacts of increasing atmospheric emissions.

viii. **IGCC technology** -Researches and Experiments are ongoing for use of the IGCC (Integrated coal gasification combined cycle) technology too and it has a lot of scope in the coming years. They are new generation thermal power systems with considerably enhanced efficiency of power generation and excellent environmental performance. They are flexible with the quality of coal, have high power generation efficiency, have much lower emission, hot wastewater and slag generation as compared to conventional power plants.

ix. **Fuel switching** –The idea behind the process is that dirty, pollution causing non-renewable fossil fuels can be replaced with low carbon intensity fuels which are both clean and renewable. This is a much-needed alternative especially for battling bigger issues of global warming and climate change due to the various atmospheric emissions. India has a huge potential for renewable energy but at present, a very minute portion of it is utilized for producing electricity. Non-conventional fuel sources like solar, wind, biomass, hydro, geothermal, tidal energy etc. require high initial investment and are also expensive to establish and operate. Despite that drawback, in the coming years these fuels can certainly replace coal or fossil fuel fired power generation partially to some extent. Waste to energy options can lead to significant decrease in Greenhouse emissions too [72].

x. **Carbon Sequestration**:- Another excellent idea that has been gaining attention in the recent years for controlling CO2 emissions from TPPs is Carbon sequestration. The idea is to capture, store and utilize the atmospheric CO2 which eventually helps in reduction of Greenhouse emissions in the atmosphere. Storage can be done in aquifers, oil or gas fields or on the ocean floor, etc. Researches of International Energy Agency on Greenhouse Gases have declared Carbon capture utilization and storage or CCUS as an important emission reduction technology with huge potential in the coming future [56]

xi. **Promoting Afforestation and Increasing the number of forest and carbon dioxide Sinks** [56]
Sathaye et al. in his researches has suggested that Afforestation, Regeneration and Protection of forest are undoubtedly the best and fastest alternatives to reduce Greenhouse emissions [73]. India has large areas of available wastelands (i.e 5,57,66.51 Sq.Kms,16.96% of Total Geographical Area of the country) which can be used for forestation[74].
Forests as sinks-Controlling deforestation and planting more trees helps in enhancing the planet's terrestrial biomass sink, which eventually helps in slowing down CO2 build-up in the atmosphere. At present, Forests, shrubs and grasslands, etc. all over the world are absorbing an estimated 5.5 Gt CO2/year.
Carbon dioxide sinks- Globally, there are large number of natural carbon dioxide sinks that work to remove the gas from the planet's atmosphere. But of course, naturally occurring sinks have limited capacity so, disposal of carbon dioxide into sinks through artificial sinking can be the best mitigation option [75].

At the plant level, several simple air pollution control measures can be implemented during the planning and operation stages in the power plants to minimize the negative impacts [76].

1) Fly ash generation can be kept down by using washed coal or beneficiated coal.
2) With the aim to restrict the dust emission to a minimum, sprinkler systems should be installed at all coal transfer, tipper, crushing, and screening points, etc.Partial enclosure of coal unloading, transfer and conveying equipment and use of baghouses during coal storage and handling processes[76].Simple methods of dust abatement like wetting soils, using covers for storage piles, and restricting operations during stormy and windy periods can also help in minimizing the dust emission and the resulting impacts. Before processing of coal, a dust extraction system should be used. Chemical Wetting agents like Calcium chloride solutions, etc. can be used to reduce the water demand and increase the efficiency of dust suppression.
3) Use of efficient pollution control systems like ESPs, Bag filters, Cyclones, etc. and monitoring their proper use and maintenance.
4) New generation Emission control systems like Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR) and Flue Gas Desulphurisation (FGD), etc. need to be

 DOI : 10.35291/2454-9150.2020.0668

implemented at all the major power plants as soon as possible. For a typical coal-fired power station, FGD can effectively remove more than 90% of the Sulphur dioxide in the flue gases.

5) Besides installation of the above given latest technologies, it is also necessary to adopt some pre combustion modifications such as use of over-fired air, in-situ modifications in boiler and Low NOx burners installation.
6) For reducing NOx emissions, combustion modification measures like reducing the combustion temperature, adopting low nitrogen fuel, and installing exhaust gas denitrizers can be adopted to minimize NOx emissions and to remove them.
7) Since Electro-Static Precipitators (ESPs) are largely responsible for particulate matter control in TPPs, their retrofitting from time to time is very essential to keep the emissions within the limits specified by MoEF & CC.
8) All boilers burning heavy oil, crude oil, and coal as fuel should be fitted with electric bag filters to eliminate soot particles from exhaust gas.
9) Installing an exhaust gas desulfurizer to remove SOx from exhaust gas and thus controlling SOx emissions through both input and output measures. Encouraging the use of low sulfur fuel like sulfur-free LNG and low-sulfur heavy oil and crude oil.
10) Use of high-temperature, high-pressure filters within the gasification process to collect more than 99.9 percent of PM from the syngas. Use of a reactor containing alumina-based metal sulfide or sulfide-activated carbon to remove more than 92 percent of mercury from the syngas. Mercury abatement from the emission can be achieved as co-benefit of reduction of NOx, SOx and dust.
11) Green belts with recommended flora of tall and fast-growing trees can be created around the coal washery plants and tailing dumps areas.
12) Taking appropriate measures for proper handling and utilization of the waste and by products produced.
13) Central government should encourage use of fly ash based manufactured products (tiles, bricks, ceramics, fertilizers, etc.) by the concerned local government agencies and the power plant managements. Government also needs to provide special incentives to encourage these kinds of sustainable and eco-friendly approaches [77].

Other Alternatives

In one of his researches, Arun et al. reported that the implementation of World Bank Emission Guidelines (1998) for TPPs can lead to significant reduction in concentration of Total suspended particulates thereby, bringing the particulate concentration within the NAAQ standards as specified for industrial areas in India (CPCB,2001). The study estimated decrease in Thermal power plant emissions by about as large as 56% to 82% [78]. The guidelines stated the following points for achieving acceptable levels of site–specific emission standards i.e following maximum plant emission levels to reduce pollution levels, using commercially proven and widely used technologies and follow the current regulatory and technological trends.Dmitrienko et al.'s feasibility studies have revealed that Coal-water slurries containing petrochemicals (CWSPs) is a very cost effective option for using as a fuel[79].When compared to conventional options of fuel like high ranking coal, CWSPs can help in saving over 40 to 75 million euros in just fuel costs. Their superior energy and environmental performance makes them a multipurpose fuel. Using CWSPs can result in reduced fly ash production by 20%.,low combustion temperature leading to longer no-failure operation period, reduction in key expense items by 30–40%, high energy performance indicators and last but not the least, lower payback period for countries like India, etc. The concentration of atmospheric emissions can be decreased severe fold by varying the concentration and type of waste used in the CWSP [79]

Landscaping and green belts: Plants play a significant role in monitoring and keeping the environmental balance in check[80].Not only they play an active role in recycling of gases and nutrients in the nature but their metal trapping capacity allows them to collect heavy metals (i.e. mercury, lead, etc.) from the surrounding air too [81][82][83] Plant have enormous surface area available for impingement which allows absorption, adsorption and trapping of emitted pollutants[84].Through extensive research and case studies done around several thermal power plants, Nandita et al. and her group concluded that Green belts around the close surroundings of power plants and dumping spots of fly ash can play an important role in decreasing pollution to a considerable extent at the pollution source itself [85]. Not only these belts will enhance the natural beauty of the landscape but more importantly, they will act as a protective shield for the local population by acting as a buffer zone. For ensuring effective trapping of the particles during the whole year, the green belts should include mix of indigenous perennial, deciduous and evergreen type of fast-growing subshrubs, shrubs as well as trees [85]. Plantations should be done closely to ensure interception of particulate matter and to accommodate large number of trees in less area. Santosh et al. studied Heavy metal speciation of soil around thermal power plant area and gave the idea of landscaping for controlling the pollution in the area. He reported in his studies that some species of plants (in his study, Calotropis procera) have the property to adsorb/absorb and accumulate heavy metals to a significant extent. He further stated that landscaping based on Air pollution tolerance index of plant species can be used to minimise the soil contamination and pollution in the ambient air [86]

VIII. CONCLUSION

With 5th highest installed thermal capacity globally, Thermal Power Plants in India are one of the most pivotal industries that provide electricity and support expansion and development of all the other sectors. Coal is the most carbon intensive fossil fuel and most emissions from coal are emitted from the electricity sector. Despite its innumerable and detrimental environmental and health impacts, it is still the most extensively used fossil fuel for power generation in India with about 88% thermal power plants running on coal and remaining by other sources.

 DOI : 10.35291/2454-9150.2020.0668

Heavy Metals, Particulate matter, Greenhouse gases, Polycyclic aromatic hydrocarbons, Sulfur dioxide, Nitrogen oxide, Volatile organic compounds are just some of the major emissions from these power plants. Every year, over thousands of premature deaths and millions of cases of cardiovascular and respiratory diseases as well as asthma cases are being witnessed because of these hazardous emissions. Not just that, it also has severe harmful impacts on the physicochemical components of the environment like quality of ground water, land use pattern, surface quality and temperature, fertility of soil, biodiversity (flora, fauna &wildlife). Other socio-cultural aspects like rehabilitation, loss of lives due to accidents, aesthetics, etc. also require our immediate attention.

Acid rain, greenhouse effects and generation of huge amount of the sewage, fly ash, etc. are some of the few other reasons why coal is losing its popularity all over the world and countries are opting for cleaner alternatives of energy. Major nations like Belgium, Canada, Germany, UK and European countries such as Austria, Hungary, etc. have made official commitments to stick to the phase-out deadlines for getting rid of the fossil fuel altogether. While completely phasing out coal altogether is not an option for a developing country like ours but there is certainly an alarming need for tougher regulations for the power plants, investment in more renewable sources for electricity generation and gradual and partial phasing out of coal in the country.

From the extensive study of whole thermal power plant-based air pollution scenario, we can conclude that although TPPs generate electricity but they are also quite troublesome for the environment. Following is a gist of the abatement measures mentioned in our literature that can be utilized for achieving our objective of sustainable development:

- **i.** The Government of India should bring newer and stricter legislations and revise them from time to time to deal with the menace of air contamination by these TPPs,
- **ii.** Government should also discourage the overuse of coal in the industries and encourage investment in available sources of other alternatives like renewable and nuclear energy,
- **iii.** Using better quality of coal and retrofitting of the Emission control systems of TPPs can also reduce emissions from the plant and enhance the electricity production in the country,
- **iv.** Govt. should provide incentives and encourage mass utilization of emitted by products like fly ash, etc. for different engineering purposes,
- **v.** Govt. should ensure that the air quality standards and permissible limits regarding air pollution are strictly complied,
- **vi.** There should be transparency and easy accessibility of air pollution monitoring data from the TPPs,
- **vii.** EIA procedures should be revised from time to time to deal with the challenges in the current scenario and should be implied strictly,
- **viii.** Activities like Afforestation, Landscaping and Green belts should be encouraged in the near and far surroundings of the TPPs.

REFERENCES

[1] World population prospects: the 2019, United Nations, Department of Economic and Social Affairs Population Dynamics. Available at:https://population.un.org/wpp/Download/Standard/Population/

[2] James, K. S. (2011). India's Demographic Change: Opportunities and Challenges. Science, 333(6042), 576–580. doi:10.1126/science.1207969.

[3] United Nations, World Population Prospects: The 2010 Revision (United Nations Population Division, Department of Economic and Social Affairs, New York, 2011); available at http://esa.un.org/unpd/wpp/index.htm.

[4] People Facts- Population Charts and Tables, World Statistics-India, Population Changes between1970-2050. Available at:https://os-connect.com/pop/pc/IND/

[5] Growth of Electricity Sector in India from 1947-2019"(PDF), Central Electricity Authority, May 2018

[6] Central Electricity Authority, Ministry of Power, Govt of India,May 2020, Retrieved from https://powermin.nic.in/en/content/power-sector-glance-all-india.

[7] Sarkar, A., Rano, R., Udaybhanu, G., & Basu, A. K. (2006). A comprehensive characterization of fly ash from a thermal power plant in Eastern India. Fuel Processing Technology, 87(3), 259–277. doi:10.1016/j.fuproc.2005.09.005

[8] "All India Installed Capacity of Utility Power Stations (As on 30 March,2020)"(PDF), Central Electricity Authority, GOI, March 2020.

[9] Invest India, National Investment Promotion & Facilitation Agency. Retrieved from https://www.investindia.gov.in/sector/thermal-power on 15 May,2020.

[10] Ahmad Shamshad, Fulekar M.H., and Pathak Bhawana, " Impact of Coal Based Thermal Power Plant on Environment and its Mitigation Measure" International Research Journal of Environment Science ,ISSN 2319–1414 Vol. 1(4), 60-64, November (2012)

[11] Meawad, A. S., Bojinova, D. Y., & Pelovski, Y. G. (2010). An overview of metals recovery from thermal power plant solid wastes. Waste Management,30(12), 2548–2559. doi:10.1016/j.wasman.2010.07.010

[12] Puste, A. M., & Das, D. K. (2001). Water, Air, and Soil Pollution, 130(1/4), 843 848. doi:10.1023/a:1013874628761

[13] Sengupta, I. (2007). Regulation of suspended particulate matter (SPM) in Indian coal-based thermal power plants: A static approach. Energy Economics, 29(3), 479–502. doi:10.1016/j.eneco.2006.01.004

[14] Louati A, Son LH, Chabchoub H (2018) Smart routing for municipal solid waste collection: a heuristic approach. J,Ambient Intell Humaniz Comput,10:1865–1884. https://doi.org/10.1007/s12652- 018-0778-3

[15] Son LH, Louati A (2016) Modeling municipal solid waste collection: a generalized vehicle routing model with multiple transfer stations, gather sites and inhomogeneous vehicles in time windows. Waste Management, 52:34–49. https://doi.org/10.1016/j.wasman.2016.03.041

[16] Amal L, Son LH, Chabchoub H (2018) SGA: spatial GIS-based genetic algorithm for route optimization of municipal solid waste collection. Environ Sci Pollut Res 25:27569–27582. https://doi.org/10.1007/ s11356-018-2826-0

[17] IHME Global Health Data Exchange Tool. http://ghdx.healthdata.org/ gbd-results-tool (accessed Aug 21, 2018).

[18] Cement factories, Air pollution and Consequences by Syed sana mehraj and Dr. g.a bhat, Department of Environmental Science & Centre of research for development, University of Kashmir, Jammu and Kashmir, India, 190006, Retrieved from: http://www.sciencepub.net/book/00065_book_1_65.pdf

 DOI : 10.35291/2454-9150.2020.0668

[19] World's most and least polluted cities, ©2015 GlobalResidenceIndex.com Available at: https://globalresidenceindex.com/world-most-least-polluted-cities/

[20] YudaM(2019) Asian countries rush to fight toxic air pollution. Accessed from https://asia.nikkei.com/Economy/Asian-countries-rush-tofight- toxic-air-pollution. Accessed 24 Jan 2019

[21] Donkelaar A et al (2016) Global estimates of fine particulate matter using a combined geophysical-statistical method with information from satellites, models, and monitors environmental. Sci Technol 50: 3762–3772. https://doi.org/10.1021/acs.est.5b05833

[22] Central Electricity Authority, Ministry of Power, Govt of India, May 2020, Retrieved from https://powermin.nic.in/en/content/power-sector-glance-all-india

[23] Central Electricity Authority, Ministry of Power,Govt of India, April 2020,Retrieved fromhttps://powermin.nic.in/en/content/generation-reports

[24] "Location wise regional summary of all India installed capacity (IN MW) of power stations as on 30/04/2020(PDF)",Published reports, National Power Portal Retrieved from https://npp.gov.in/public-reports/cea/monthly/installcap/2020/APR/capacity1-2020-04.pdf

[25] Garg, A.; Kapse, M.; Shukla, P.R.; Ghosh, D., "Large Point Source (LPS) emissions from India: regional and sect oral analysis", Atmospheric Environment (2002), 36, 213-224

[26] Chen, P., Kang, S., Li, C., Rupakheti, M., Yanb, F., Li, Q., Ji, Z., Zhang, Q., Luo,W., Sillanpää,M., 2015. Characteristics and sources of polycyclic aromatic hydrocarbons in atmospheric aerosols in the Kathmandu Valley, Nepal. Sci. Total Environ. 538, 86–92.

[27] Deng, S., Shi, Y., Liub, Y., Zhang, C., Wang, X., Cao, Q., Li, S., Zhang, F., 2014. Emission characteristics of Cd, Pb and Mn from coal combustion: Field study at coal-fired power plants in China. Fuel Process. Technol. 126, 469–475.

[28] Noli, F., Tsamos, P., 2016. Concentration of heavy metals and trace elements in soils, waters and vegetables and assessment of health risk in the vicinity of a lignite-fired power plant. Sci. Total Environ. 563-564, 377–385.

[29] Pandey,V.C.,Singh,J.S.,Kumar,A.,Tewari,D.D.,2010.Accumulation ofheavymetals by chickpea grown in fly ash treated soil: effect on antioxidants. Clean – Soil Air Water 38(12),1116–1123. http://dx.doi.org/10.1002/clen.201000178

[30] Qadir, S. U., Raja, V., & Siddiqui, W. A. (2016). Morphological and biochemical changes in Azadirachta indica from coal combustion fly ash dumping site from a thermal power plant in Delhi, India. Ecotoxicology and Environmental Safety, 129, 320–328. doi:10.1016/j.ecoenv.2016.03.026

[31] Yuan, X., Zhang, M.,Wang, Q., Wang, Y., Zuo, J., 2014. Evolution analysis of environmental standards: effectiveness on air pollutant emissions reduction. J. Clean. Prod. 149,511–520.

[32] Adiansyah, J.S., Haque, N., Rosano, M., Biswas, W., 2017. Application of a life cycle assessment to compare environmental performance in coal mine tailings management. J. Environ. Manag. 199, 181–191.

[33] Mandal, A., & Sengupta, D. (2003). Radioelemental study of Kolaghat, thermal power plant, West Bengal, India: possible environmental hazards. Environmental Geology, 44(2), 180 186. doi:10.1007/s00254-002-0744-3.

[34] Baba (2002) Assessment of radioactive contaminants in byproducts from Yatagan (Mugla, Turkey) coal-fired power plant. Environ Geol 41:916–921

[35] J. Tomeczek, H. Palugnoik, Fuel 81 (2002) 1251–1258.

[36] Gulec N, Gunal (Calci) B, Erler A (2001) Assessment of soil and water contamination around an ash-disposal site: a case study from the Seyitomer coal fired power plant in western Turkey. Environ Geol 40(3):331–344.

[37] Retrievedfrom:http://www.urbanemissions.info/wpcontent/uploads/docs/2015- 01-EPW-Regularting-Coalfired-TPP-Pollution-India.pdf

[38] Singh, R. K., Gupta, N. C., & Guha, B. K. (2014). pH dependence leaching characteristics of selected metals from coal fly ash and its impact on groundwater quality. International Journal of Chemical and Environmental Engineering, 5, 218–222.

[39] Retrievedfrom:http://www.indiaairquality.info/wcontent/uploads/docs/Air%20Pollution%20from%20India%20Coal%20TPPs%20-%20LowRes.pdf

[40] Guttikunda, S K and P Jawahar (2013): "Coal Based Thermal Power Plants in India – An Assessment of Atmospheric Emissions, Particulate Pollution, and Health Impacts", Urban Emissions. Info, New Delhi, India

[41] Balakrishnan, K., Ganguli, B., Ghosh, S., Sambandam, S., Roy, S., Chatterjee, A., 2013. A spatially disaggregated time-series analysis of the short-term effects of particulate matter exposure on mortality in Chennai, India. Air Qual. Atmos. Health 6, 111e121.

[42] Yadav, S., & Prakash, R. (2014). Status and Environmental Impact of Emissions from Thermal Power Plants in India. Environmental Forensics, 15(3), 219–224. doi:10.1080/15275922.2014.930937

[43] Sarath K. Guttikunda, Puja Jawahar, Evaluation of Particulate Pollution and Health Impacts from Planned Expansion of Coal-Fired Thermal Power Plants in India Using WRF-CAMx Modeling System, Aerosol and Air Quality Research, 18: 3187–3201, 2018, doi: 10.4209/aaqr.2018.04.0134.

[44] Singh, J., Agrawal, M., & Narayan, D. (1995). Changes in soil characteristics around coal-fired power plants. Environment International, 21(1), 93–102. doi:10.1016/0160-4120(94)00035-6

[45] Santosh Kumar Prajapati, Neelima Meravi. "Heavy metal speciation of soil and Calotropis procera from thermal power plant area" Proceedings of the International Academy of Ecology and Environmental Sciences, 2014, 4(2): 68-71

[46] Tripathi, R.D., P. Vajpayee, N. Singh, U.N. Rai, A. Kumar and M.B. Ali, 2004 Efficacy of various, amendments for amelioration of fly ash toxicity growth performance and metal composition of Cassia siamea lamk. Chemosphere, 54: 1581-1588

[47] Verma, C., Madan, S., & Hussain, A. (2016). Heavy metal contamination of groundwater due to fly ash disposal of coal-fired thermal power plant, Parichha, Jhansi, India. Cogent Engineering, 3(1). doi:10.1080/23311916.2016.1179243

[48] Otake M, Yoshimaru H, Schull WJ (1987) Severe mental retardation among the prenatally exposed survivors of the atomic bombing of Hiroshima and Nagasaki: A comparison of the old and new dosimetry systems. Radiation Effects Research Foundation RERF Technical Report, pp 16–87

[49] Ge, B., Wang, Z., Gbaguidi, A.E., Zhang, Q., 2016. Source identification of acid rain arising over Northeast China: observed evidence and model simulation. Aerosol Air Qual. Res. 16 (6), 1366–1377.

[50] Chen, W., Xu, R., 2010. Clean coal technology development in China. Energy Policy 38 (5), 2123–2130.

[51] Pan, S.-Y., Wang, P., Chen, Q., Jiang, W., Chu, Y.-H., Chiang, P.-C., 2017. Development of high-gravity technology for removing particulate and gaseous pollutant emissions: principles and applications. J. Clean. Prod. 149, 540–556

[52] Ankica Rađenović1; Gordana Medunić2; Binoy K. Saikia3, Comparative review of Croatian and Indian air pollution studies with emphasis on pollutants derived by coal combustion, The Mining-Geology-Petroleum Engineering Bulletin, 2017, pp. 33-44,DOI: 10.17794/rgn.2017.1.5

[53]]NTPC, AshUtilization, Copyright © 2015 NTPC Ltd. Retrieved from: https://www.ntpc.co.in/en/environment/ash-utilisation

[54] Sudhir Yadav & Rajiv Prakash (2014) Status and Environmental Impact of Emissions from Thermal Power Plants in India, Environmental Forensics, 15:3, 219-224, DOI: 10.1080/15275922.2014.930937

[55] Sarath k. guttikunda,puja jawahar, Atmospheric emissions and pollution from coal fired thermal power plants in india, , Atmospheric Environment 92 (2014) 449-460.

 DOI : 10.35291/2454-9150.2020.0668

[56] Raghuvanshi SP, Chandra A, Raghav AK. Carbon dioxide emissions from coal based power generation in India, Energy Conversion and Management 47 (2006) 427–441 439, 2005 Elsevier Ltd. doi:10.1016/j.enconman.2005.05.007

[57] Norshahrizan Nordin1, Mohd Mustafa Al Bakri Abdullah2, 3, Muhammad Faheem Mohd Tahir3, Andrei Victor Sandu4,5, Kamarudin Hussin3, Utilization Of Fly Ash Waste As Construction Material , International Journal of Science and Conservation 7, 1, Jan-Mar 2016: 161-166 162

[58] Senapati Manas Ranjan, Fly ash from thermal power plants – waste management and overview current science, 100, 17911794 (2011)

[59] Palit, A., Coal ash utilization in India. Urja J., 1992, 32, 39–44.

[60] 'Fly Ash Mission', Technology Information, Forecasting and Assessment Council (TIFAC), Department of Science and Technology, Ministry of Science and Technology, Government of India, Technology Bhawan, New Delhi, 1994.

[61] Ahmaruzzaman, M.(2010). A Review on the Utilization of Fly Ash. Progress in Energy and Combustion Science. 36. 327-363. 10.1016/j.pecs.2009.11.003.

[62] NTPC,Copyright © 2015 NTPC Ltd.Retrieved from:www.wealthywaste.com/fly-ash-utilization-in-india (2012)

[63] korba.gov.in/kwflyash.htm (2012)

[64] Cement Manufacturing Association, (1999)

[65] Ignasi Querlt,XavierQuerol ,Angel Lopez-Solar ,Felicano Plana ,Use of coal fly ash for ceramics ;a case study for large Spanish power station, fuel,8 , 787-791, (1997)

[66] SaikatMaitra, Cremic product from fly ash global prospective. In preceding of the national seminar on fly ash utilization, February 26-27, NLM jamshedpur India,(1999)

[67] Kumar Vimal and MathurMukesh, Clean environment through fly as utilization. Cleaner Technology, Impacts/12/2003-2004, MOEF-CPCB, Govt. of India, 235-255, (2003)

[68] www.crridom.gov.in/techniques-facilities/10.pdf (2012)

[69] www.ukqaa.org.uk

[70] Raghuvanshi SP, Chandra A, Raghav AK. Carbon dioxide emission inventory from power sector. In: Proceedings Energy and Environment—International Conference on Energy and Environment: Strategies for Sustainable Development (ICEE-SSD) 2004: 369–78

[71] Sarath Guttikunda, Puja Jawahar, Debi Goenka,Regulating Air Pollution from Coal-Fired Power Plants in India, january 3, 2015, vol l no 1 ,EPW Economic & Political Weekly (62 -67)

[72] Frederick MD. Voluntary reporting of GHGs emissions reduction achieved in 2000. Air Pollution Constants (Aspen Pubs Inc.) 2002;12(5):19–113

[73] Sathaye JA, Makundi WR, Andrasko K, Boer R, Ravindranath NH, Sudha P, et al. Carbon mitigation potential and cost of forestry options in Brazil, China, India, Indonesia, Mexico, The Philippines and Tanzania. Mitigat Adapt Strat Global Change 2001; 6:185–21

[74] Wastelands atlas of India -2019, Department of Land Resources Ministry of Rural Development Government of India, 2019, New Delhi-110011.Available from: https://dolr.gov.in/documents/wasteland-atlas-of-india.

[75] Energy facts sheet: Greenhouse Gases [online]: Available from: http://www.iclei.org/efacts/greengas.htm

[76] S. K. Banerjee R. K. Dhar M. K. Ghose*, Air Pollution Due To Coal Washery Projects And Its Abatement Measures, Environmental Management Vol. 20, No. 2, Pp. 235-240

[77] Senapati Manas Ranjan, Fly ash from thermal power plants – waste management and overview current science, 100, 17911794 (2011)

[78] Arun Kansal, Mukesh Khare, Chandra Shekhar Sharma,Air quality modelling study to analyse the impact of the World Bank emission guidelines for thermal power plants in Delhi,Atmospheric Pollution Research,Volume 2, Issue 1,2011,Pages 99-105, ISSN 13091042,https://doi.org/10.5094/APR.2011.012.

[79] Margarita A. Dmitrienko , Pavel A. Strizhak , Coal-water slurries containing petrochemicals to solve problems of air pollution by coal thermal power stations and boiler plants:An introductory review (2017) Elsevier, Science of the Total Environment 613-614(2018)1117-1129

[80] Tripathi, A., Ren, Y., Jeffrey, P. et al. Structural characterization of Tip20p and Dsl1p, subunits of the Dsl1p vesicle tethering complex. Nat Struct Mol Biol 16, 114–123 (2009). https://doi.org/10.1038/nsmb.1548

[81] Shannigrahi, Ardhendu & Sharma, Ramesh & Fukushima, Takehiko. (2003). Air Pollution Control By Optimal Green Belt Development Around The Victoria Memorial Monument, KOLKATA (INDIA). International Journal of Environmental Studies. 60. 241-249. 10.1080/0020723022000008202.

[82] Prajapati, Veena & Tripathi, Abhijeet & Khanuja, Suman & Kumar, Sushil. (2008). Anti-insect Screening of Medicinal Plants from Kukrail Forest, Lucknow, India. Pharmaceutical Biology. 41. 166-170. 10.1076/phbi.41.3.166.15092.

[83] Brack, C.L.(2002). Pollution mitigation and carbon sequestration by an urban forest. Environmental pollution (Barking, Essex: 1987). 116 Suppl 1. S195-200. 10.1016/S0269-7491(01)00251-2.

[84] Nowak, David. (2009). Spatial heterogeneity and air pollution removal by an urban forest. Landscape Urban Plan.90. 10.1016/j.landurbplan.2008.10.021

[85] Sarah Jamil, P.C. Abhilash, Amita Singh, Nandita Singh∗, Hari M. Behl, Fly ash trapping and metal accumulating capacity of plants: Implication for green belt around thermal power plants, Landscape and Urban Planning ,92 (2009), 136–147

[86] Manju Sharma, Neeraj Panwar, Pooja Arora, Jyoti Luhach and Smita Chaudhry*, Analysis of biological factors for determination of air pollution tolerance index of selected plants in Yamuna Nagar, India, Journal of Environmental Biology, Vol. 34, 509-514, May 2013

 DOI : 10.35291/2454-9150.2020.0668