Chapter 3
A Review on Pollutants from Coal Based Power Sector

Shashi Kant Verma, S. L. Sinha and D. K. Chandraker

Abstract Pollutants management techniques in thermal power station could be a key issue to contemplate once analyzing environmental deterioration. The release of harmful pollutants from warm power plants into water bodies as well as our surrounding atmosphere would bring about unsafe effects on the environmental life. This chapter gives an overview of various types of emitted pollutants from various fuel base based power plant and their measurement and control techniques, both past and present using various approaches. Various opportunities in power sector along with key challenges and issues related to climate change mitigation in the power sector would be discussed. In this chapter, some of the good correlation with their conclude remarks have been discussed. Stack Height for Small Boilers with emission limits as suggested by Central Pollution Control Board have also been discussed. Different theories and application for measurements and control of such hazards pollutants such as CO_2, SO_2, NO_2 and mercury have been presented. This chapter will include the some of the new emerging areas for thermal pollution control. The undesirable outputs of various fuel base thermal power plants not only affect the environmental laws but also have negative impacts on the water quality and ecological life. At the end, some of the good models with solutions and recommendations will be presented.

Keywords Thermal pollution · CO_2 · SO_2 · NO_2 · PM · Control techniques

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3.1 Introduction

Power is the most fundamental needs in the everyday existence of each one in this dynamic world. As the world population increases, the demands of electricity have also being increased. Due to this, the difference between energy source and demand is forever present and it requires primary concern. At the same time, pollutants from the various thermal power plants increase. To defeat the situation of the distinction between the supply and demand, the effectiveness of the current power plants should be taken care and furthermore the newly power plants should be built up with the supercritical innovation. This increases the global temperature of the world. The substance that unconstructively affects the atmosphere, animals as well as human being, due to emission into the environment is called pollution. The air/water temperature rises so that it becomes unsafe to human being and other organisms. Table 3.1 shows the different pollutants from thermal power plants and

Table 3.1 Different thermal pollutants and their effects

S. No.		Types of pollutants	Effects
1.	Particulate types	Suspended particulate matter/dust	Depends on specific composition, reduces sunlight and visibility, increases corrosion, pneumoconiosis, asthma, cancer, and other lung diseases
2.		Fly ash	Settles down on vegetation, houses. Adds to the suspended participate matter (SPM) in the air. Leachates contain harmful material
3.	Gaseous pollutants	Carbon compound (CO and CO_2)	Respiratory problems, Green house effect
4.		Sulphur compounds (SO_2 and H_2S)	Respiratory problems in humans, Loss of chlorophyll in plants (chlorosis), acid rain
5.		SPM (Suspended particulate matter) (Any solid and liquid) particles suspended in the air, (flush, dust, lead)	Poor visibility, breathing problems, Lead interferes with the development of red blood diseases and cancer, Smog (smoke and fog) formation leads to poor visibility and aggravates asthma in patients
6.	Primary pollutants	NO_x	Lung irritation (e.g. inflammation, respiratory cell damage, premature ageing) Increased susceptibility to respiratory infection, Respiratory and cardiac diseases, Asthma attacks

their effects. There are different sources of thermal pollution like Petroleum refiners, Thermal power station, and Nuclear power plants. Over the last few years the energy part/area has come up against new challenges about the reduction of its effect on the surrounding conditions or on the health of the Earth. The higher types of amphibian life require oxygen for survival. The high temperature diminishes the grouping of oxygen in water. Thus, it is critical to weaken the warm fixation into water bodies and limit it into little territories to keep up the suitable furthest reaches of oxygen required for the oceanic life. Because of global atmosphere commitments, there may be a need to restrict the measure of unmitigated CO_2 outflows being radiated into the climate. Alleviation of such discharges at coal terminated power plants offers an effortlessly controllable method for lessening such outflows.

Wang et al. (2018) used Life cycle carbon emission modelling for coal-fired power plant in Chinese case. They analyse the carbon emissions from coal mining, processing and transport to coal-fired plant with the help of life cycle accounting model. They concluded that the availability and quality of data play a major role in Life Cycle Assessment (LCA) for developing the models.

3.2 Insight from Previous Study

Hassim et al. (2014) have studied Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) emissions measured from a coal-fired power plant. They established emission factors for each combustion condition using the following Eq. (3.1), modified from U. S. EPA (1997):

$$\text{Emission factor} = \frac{\text{Pollutant concentation}\left(\frac{\text{ng}}{\text{N m}^3}\right) \times \text{Flue gas flow rate}\left(\frac{\text{N m}^3}{\text{h}}\right)}{\text{Coal feeding rate}\left(\frac{\text{kg}}{\text{h}}\right)} \tag{3.1}$$

The emission factors range from 0.08 to 0.11 ngI–TEQ/kg, which is depends on country. Hassim et al. (2014) also summarized the emission factors for different country i.e. in Taiwan for coal-fired power plant this value is 0.133, in Poland for Coal-fired circulating fluidized bed (CFB) (7.51–46.4). They concluded that due to the high combustion efficiency, most probably the emissions of PCDD/Fs were low. Figure 3.1 shows the schematic block diagram of thermal power plant.

Kadali et al. (2017) used optimum thermal generation schedule using new fangled grey wolves optimization (GWO) technique for emission operation. The emission objective function defined as follows:

$$\text{Minimize}\, E\left(P_{\text{gi}}\right) = \sum_{i=1}^{N} \alpha_i + \beta_i P_{\text{gi}} + \gamma_i P_{\text{gi}}^2 \tag{3.2}$$

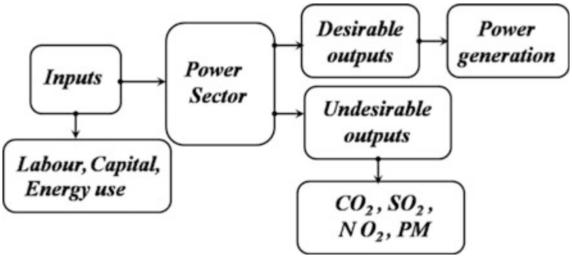

Fig. 3.1 Schematic diagram of thermal power plant

Equation (3.2) expresses the emission release (ER) incurs during generation which is estimated as the sum of quadratic function of real power generation. Where E denotes the total emission release (kg/h), P_{gi} is lower limits of ith unit generation, α_i, β_i and γ_i are express the emission coefficients of the ith unit. They concluded that the numerical results would be helpful for authoritarian bodies as the cleanliness environment to the society.

Fu et al. (2014) used Linear Programming (LP) algorithm for determination of the cost of achieving emission reductions with the help of Multi-pollutant emission model.

They assuming that if there are N power plants and M types of control technologies for pollutant j, the mathematical formulation for emission control can be written as:

$$R_{j,k} = E_{j,k}\left(1 - \sum_{i=1}^{M}\left(EFF_{i,j}X_{i,k}\right)\right) \tag{3.3}$$

Equation (3.3) shows the remaining emission of pollutant (j) after installing control technology (i) at power plant (k).The original emission of pollutant (j) at power plant (k) is expressed by $E_{j,k}$ ton. Where $EFF_{i,j}$ denotes the removal rate of control technology for pollutant in terms of percentage and $X_{i,k}$ (set of integers 0 and 1) express the degree to which the control technology is useful to reduce the emission from power plant. They found that LNB (Low-NO_x Burners) reduced the NO_x emission by 64.7% on the selected region as compared to combination of Selective Catalytic Reduction (SCR) and LNB. They also discuss the application of control technologies for different thermal pollutants in the selected region for the base year (2010).

Mao et al. (2014) defined an air pollutant equivalence (AP_{eq}) indicator by combines all the pollutants (i.e., SO_2, NO_x, and CO_2) as one in the study. The reductions on SO_2, NO_x, and CO_2 for a specific technology have been represented by S, N and C with their weight factor α, β, and γ respectively.

The air pollutant equivalence (AP_{eq}) indicator is defined mathematically as follows by Eq. (3.4).

$$AP_{\mathrm{eq}} = \alpha S + \beta N + \gamma C \tag{3.4}$$

where

$$\begin{gathered} 0 \le \alpha \le 1 \\ 0 \le \beta \le 1 \\ 0 \le \gamma \le 1 \\ \alpha + \beta + \gamma = 1 \end{gathered}$$

As per the requirement other pollutants such as particulate matter and mercury can be consider into the equation as shown in Eq. (3.4). The higher weight pollutants reflect the higher pollutant priority according to pollution prevention scheme. They concluded that the multi-pollutant reduction co-control routes are always better to single-pollutant reduction routes.

Duan et al. (2017) defined Mercury Emission Factor (MEF) by Eq. (3.5) for comparing the mercury emissions in different power plants or at different loads (100, 85, 68% output). They used different types of coal and test has been conducted in a 350 MW pulverized coal combustion power plant. They utilized different types of thermal pollutant control devices such as Selective Catalytic Reduction (SCR), Electrostatic Precipitator and Fabric Filter (ESP + FF), and Wet Flue Gas Desulfurization (WFGD).

$$\mathrm{MEF} = \frac{\text{Ultimate mercury emitted to the atmosphere}}{\text{Heat value coming from the feeding coal}} \tag{3.5}$$

They concluded that the elemental mercury (Hg^0) taken a huge proportion (70.3–74.8%) in the stack. The calculated MEF was 0.92–1.17 g/10^{12}J, which is lower than the average value of both Chinese and US power plants.

Wang et al. (2017) established a high-resolution inventory of thermal pollutants from coal-fired power plants by using two unit-level approaches. The annual emissions of each species have been calculated by using Eqs. (3.6) and (3.7) as follows:

$$Q_i = \sum_{j=1}^{m} M_j \times GF_{i,j} \times \frac{\left(1 - \eta_{i,j}\right)}{1000} \tag{3.6}$$

$$Q_i = \sum_{j=1}^{m} M_j \times \frac{EF_{i,j}}{1000} \tag{3.7}$$

where, Q_i denotes the annual emission of the species i (ton).The annual amount of coal consumption is expressed by M in ton and GF express the generation factor in g/kg of coal. η is the overall decontamination efficiency. Equation (3.6) can only be applicable, if generation factor and the overall decontamination efficiency are known. Otherwise, select Eq. (3.7). Subscript i, j and superscript m represent the emission species, individual unit and unit number, respectively. They found that coal quality play a major role for emission of SO_2 and PM, respectively. They have been discussed various types of decontamination technologies along with their corresponded removal efficiencies and applied percentages for different pollutants. For SO_2 the used decontamination methods are Wet Flue Gas Desulphurization (Wet FGD), Dry/semi-dry FGD, 0 Desulfurization during combustion with average decontamination efficiency (75%) along with average applied percentage (13.3%). For NO_x the used decontamination methods are Low Nitrogen Burners (LNB), Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), combined SCR-SNCR and ammonia desulphurization with average decontamination efficiency (39.6%) along with average applied percentage (37.56%). Similarly for fine particulate matter ($PM_{2.5}$) and inhalable particulate matter (PM_{10}), the used decontamination methods are ESP, high effective ESP, Fabric filters, ESP combined with fabric filters, Wet scrubbers, Cyclones machinery and ESP combined with wet-FGD with average decontamination efficiency (89.3%) along with average applied percentage (14.13%).

3.3 Continuous Emission Monitoring System

Continuous Emission Monitoring System (CEMS) involves analysers and related things for estimation of SO_x, NO_x, CO_2, Mercury and Particulate emission supervision for chimney emission monitoring. Vent gas analyzers should be accommodated stack consistent outflow checking framework (CEMS). The stack emission observing framework includes SO_x, NO_x, CO_2, stack gas flow and mercury analyzer. All flue gas analyzers at stack should be situated at a height or according to contamination control board standards and might be open for repairs and maintenance work. Figure 3.2 shows the schematic of continuous emission monitoring system.

3.4 Stack Height for Small Boilers with Emission Limits (Central Pollution Control Board)

A stack is a type of chimney or similar structure through which combustion product gases called flue gases are exhausted to the outside air.

The stack or chimney takes part in a significant role for the abatement and control of such air contamination emissions. Stacks are used to diminish the ground level concentration of a pollutant by emitting the process gas at immense height at which the scattering of pollutants over a greater area reduces their concentrations in ambient air to retain the air quality in fulfilment with different regulatory limits.

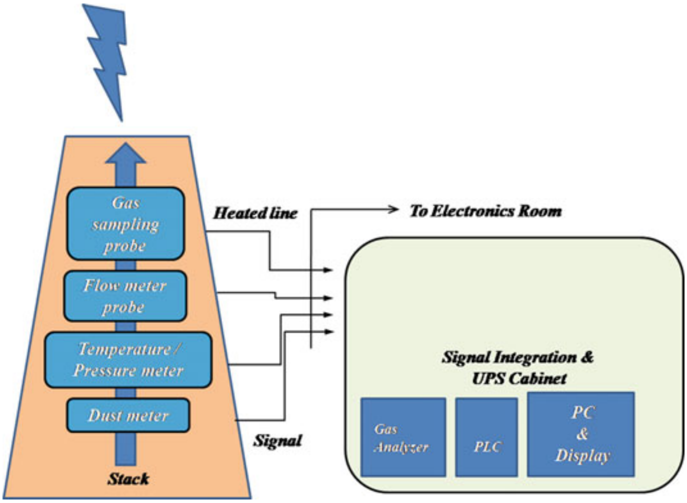

Fig. 3.2 Schematic of continuous emission monitoring system

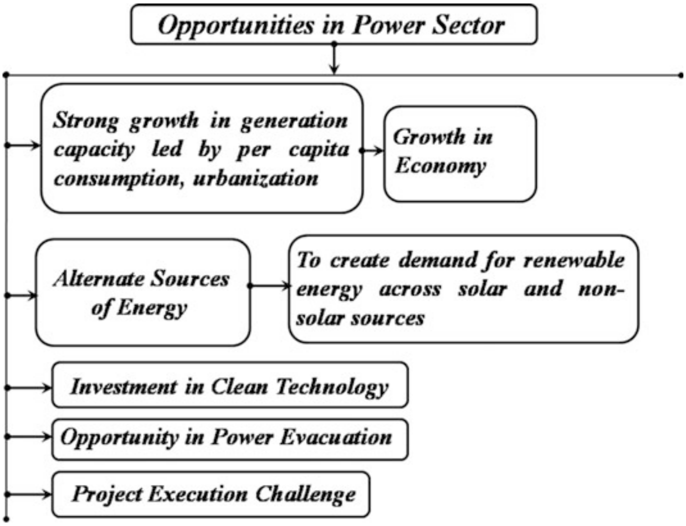

Fig. 3.3 Opportunities in power sector

For a thermal power plant fitted with Flue Gas Desulphurisation (FGD), the required size of the stack is administered by quantum of SO_2 being transmitted from the chimney. Figure 3.3 shows the different opportunities in power sector.

For 100 MW power generation capacity, the stack height (H) is calculated based on following equation as given below:

Table 3.2 Emission limit for small boilers

S. No.	Steam generation capacity (tph)	Pollutant	Emission limit (mg/Nm^3)
1	Less than 2	Particulate matter	1200[a]
2	2 to less than 10	Particulate matter	800[a]
3	10 to less than 15	Particulate matter	600[a]
4	15 and above	Particulate matter	150[b]

[a] To meet the individual norms, cyclone/multi-cyclone is suggested as control equipment with the boiler

[b] To meet the individual norms, bag filter/ESP is suggested as control equipment with the boiler

$$H = 6.902(Q \times 0.277)^{0.555} \quad \text{or} \quad 100\ \text{m whichever is high} \tag{3.8}$$

For less than 100 MW power generation capacity, the stack height is calculated based on following equation as given below:

$$H = 6.902(Q \times 0.277)^{0.555} \quad \text{or} \quad 30\ \text{m whichever is high} \tag{3.9}$$

where Q is the emission rate of SO_2 in kg/h and H is the physical stack height in m. The SO_2 emission depends upon the size and number of units associated to a chimney (CEA 2017). Table 3.2 shows the emission limit for small boilers according to central pollution control board.

3.5 Guidelines for Pollution Prevention in Small Boilers (Central Pollution Control Board)

Figure 3.4 shows the key challenges in power sector. Figure 3.5 shows the issues related to climate change mitigation in the power sector.

3.6 Control Techniques for Different Pollutants

The thermal power plants generated pollutants such as carbon monoxide, nitrogen oxides, sulphur dioxide, thermal radiation, particulate matters, noise and vibration, which deteriorate the atmosphere. Figure 3.6 shows the pollutant emission, as discussed by Hogetsu (2005). Some of the micro-pollutants like Cl_2, Cu, Cr, Pb, and F which cause a severe risk to the environment.

These toxins, if not checked and controlled, change the photosynthesis procedure of plants which diminish the significant supplement in plant, lessen soil ripeness, dis-structure the dirt strata, and encourages offices erosion and assault man

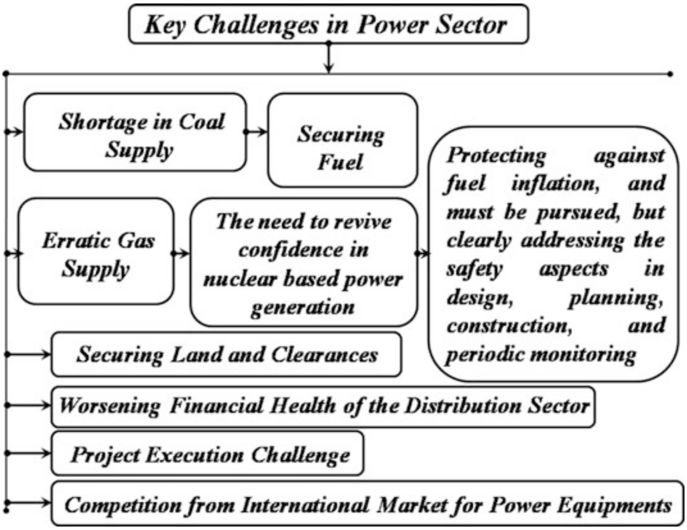

Fig. 3.4 Different key challenges in power sector

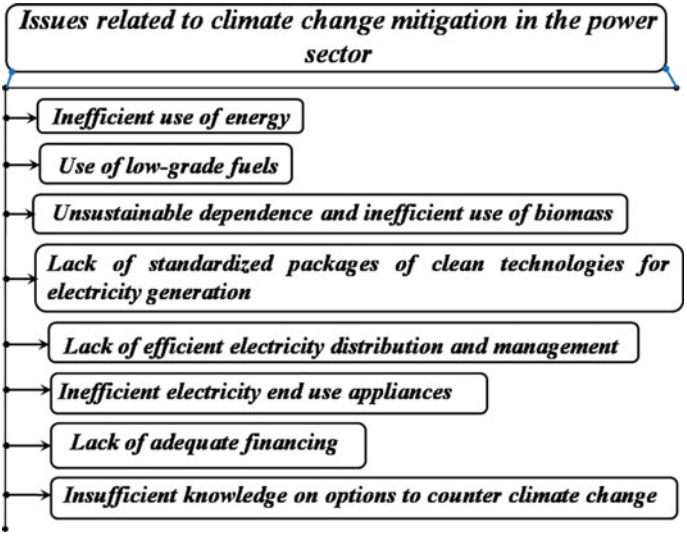

Fig. 3.5 Issues related to climate change mitigation in the power sector

and creature specifically. Electrostatic precipitators, Low NO_x burners, Flue gas stack and Dry ash extraction are the devices or technique used for air pollution controls.

Some control methods as observed were set up to diminish these poisons. Figure 3.7 shows the pollutants and pollution control in coal fire power plant.

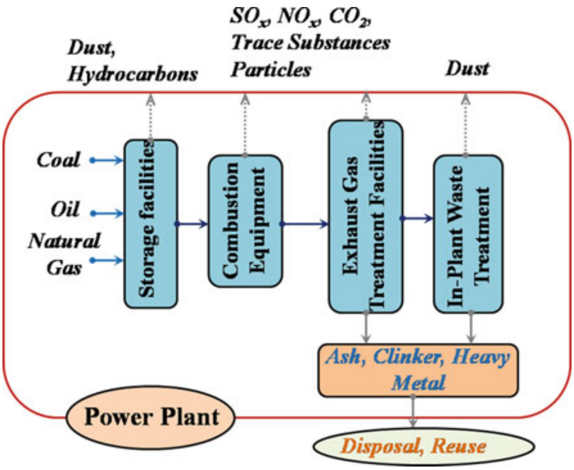

Fig. 3.6 Pollutant emission, Hogetsu (2005)

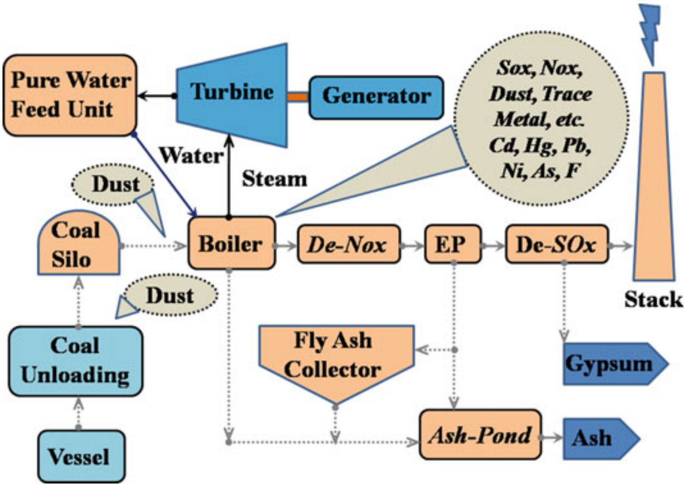

Fig. 3.7 Pollutants and pollution control in coal fire power plant, Hogetsu (2005)

Figure 3.8 shows the pollutants and pollution control in oil fire power plant. The amount of emitted dust is very less in the case of oil fired power plant as compared to coal-fired power plant. Figure 3.9 shows the pollutants and pollution control in gas fire power plant.

Figure 3.10 shows the way to modify the existing power plant for low carbon emission. NO_x is the dominated pollutant in gas-fired power plants, following which nickel and cadmium are emitted from oil-fired power plants. Fig. 3.11 shows the prevention and control of thermal pollution. Figure 3.12 shows the NO_x control system.

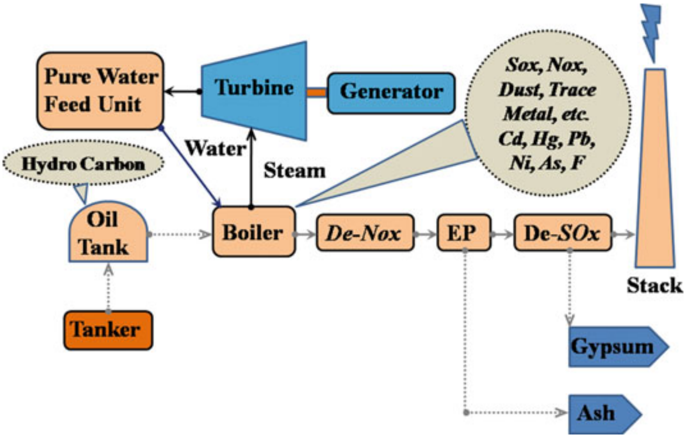

Fig. 3.8 Pollutants and pollution control in oil fire power plant, Hogetsu (2005)

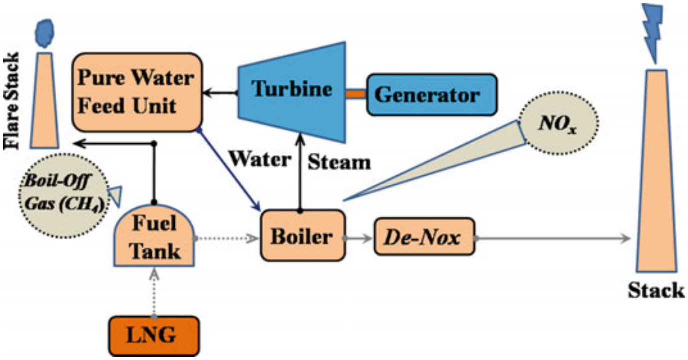

Fig. 3.9 Pollutants and pollution control in gas fire power plant, Hogetsu (2005)

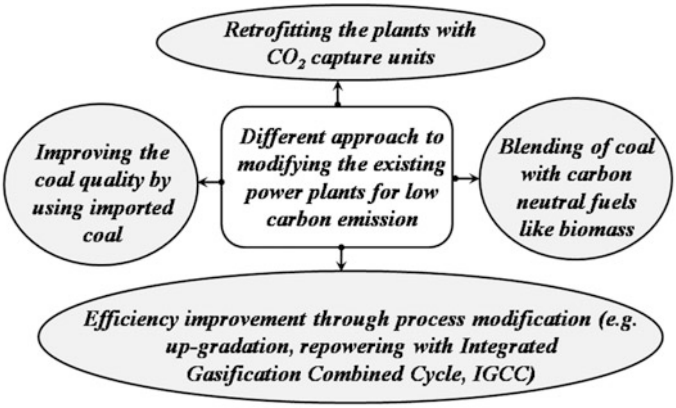

Fig. 3.10 Way to modify the existing power plant for low carbon emission, Singh and Rao (2016)

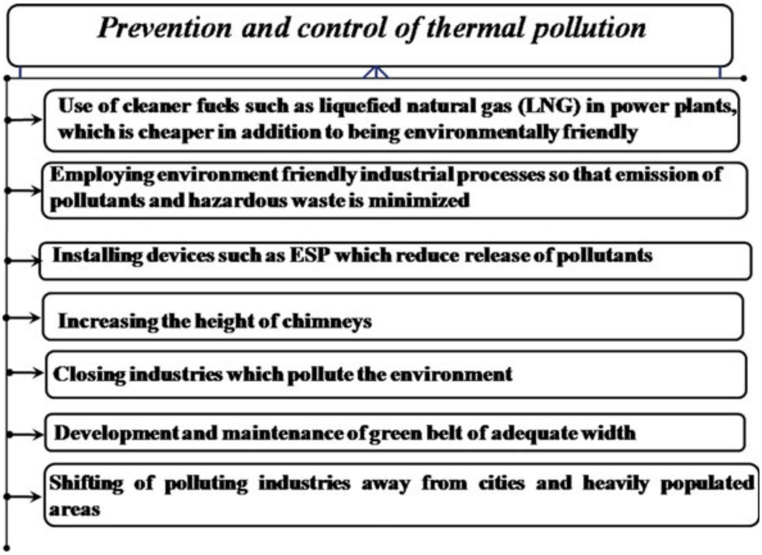

Fig. 3.11 Prevention and control of thermal pollution

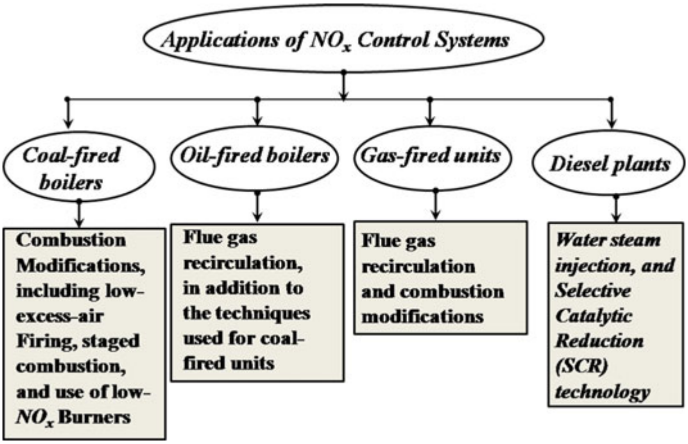

Fig. 3.12 NO$_x$ control system

3.7 Recommendations

The "Emerging pollutants" (EPs) and "emerging contaminants" (ECs) utilized reciprocally that are not usually checked in the earth be that as it may, which can possibly enter the earth and cause known or suspected unfavourable biological and human health effect. Figure 3.13 shows the control devices for mercury emissions.

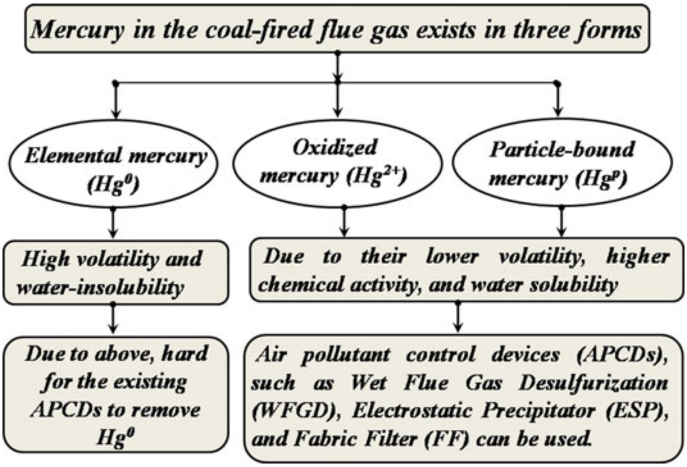

Fig. 3.13 Emission of mercury and their control devices

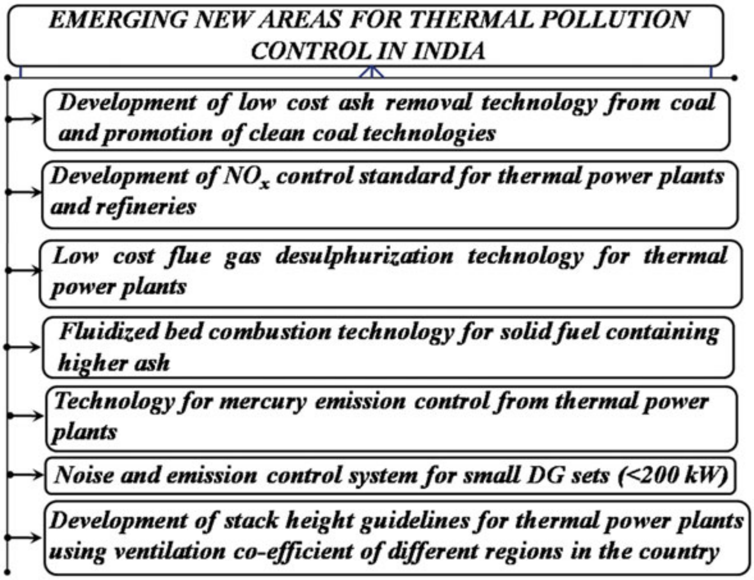

Fig. 3.14 Emerging new areas for thermal pollution controls

Different types of model have been suggested by the investigators and it has been found that the high power generation demand could be achieved by applying different control techniques with a lesser amount of emission of pollutant into our surroundings. Some researcher suggest flue gas desulfurization (FGD) technique for the reduced of emission of PCDD/Fs. Figure 3.14 shows the Emerging new areas for thermal pollution controls. The emission of NO_x can be reduced by the use of low-NO_x burners and low nitrogen fuels (natural gas). The overall removal efficiency of mercury can be increased by the installation of a Wet Electrostatic Precipitator (WESP) in the coal-fired power plants. The measurement of annual emissions of each species with the help of unit-level approaches could offer scientific sustain for strategy makers to extend valuable emission control programs.

3.8 Conclusion

A few nations and even individual states and regions require restricts on releases that prompt warm contamination of getting waters. Direction may adopt altogether for different strategies; in a few laws, a best practice is required, for example, the utilization of cooling lakes or cooling towers for waste warm release. Specialists need to create associations with other segments to recognize and execute need intercessions for pollution control. Advances to decrease air contamination at the source are settled and ought to be utilized as a part of all new mechanical improvement. Retrofitting of existing power plants is additionally advantageous. The ideology and practices of sustainable improvement, united with local research, will help contain or eliminate health risks resulting from thermal pollution. Universal joint effort including both legislative and non-governmental associations can guide this highly interdisciplinary and intersectional area of disease control.

3.9 Emerging New Areas

Further research should be based on improving the control of carbon emission along with eco-friendly fuels. So that it can minimize the Green House Gasses (GHG) into the atmosphere. Some of the technological substitutions like hydro, nuclear and wind energies are significant way to minimize GHG. A comprehensive coal emission boundary should be clearly defined for the controls of direct emissions of CO_2, CH_4 etc. prior to use in coal-fired plant. These boundaries include coal mining, processing, transportation and fugitive emissions. Further Research needs to be focused on Gangue utilization (Wang et al. 2018) which has a great significance for saving energy and reducing environmental pollution.

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