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Critical Review and Analysis of General Pollutants associated with Thermal Power Plants in Nigeria and Control Techniques

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ABSTRACT

Pollutants control techniques in thermal power plant is a key factor to consider when analyzing environmental deterioration. This environment deterioration affects man and environ, and is usually associated with pollutants arising from the operation of thermal power plant such as noise and vibration, sulphur dioxide, carbon monoxide, nitrogen oxides, thermal radiation, particulate matters and some micro-pollutants such as Cl_2, Cu, Cr, Pb, and F which pose a serious threat to the environment. These pollutants are emitted into the atmosphere, settles and discharge negative impact on the environment. These pollutants, if not checked and controlled, alter the photosynthesis process of plants which reduce the major nutrient in plant, reduce soil fertility, dis-structure the soil strata, facilitates facilities corrosion and attack man and animal directly. Some control techniques as seen were put in place to curtail these pollutants.

INTRODUCTION

McGraw Hill dictionary defines thermal power plant as a facility that produces electrical energy from thermal energy released by combustion of a fuel or consumption of a fissionable materials. Thermal Power Plant is an electrical facility using any source of thermal energy with a nominal electric generating capacity of 25 megawatts or more for electricity generation and distribution. Wikipedia sees a thermal power plant as a plant in which the prime mover is steam driven, water is heated, turns into steam and spins a turbine, which drives an electrical generator.

Power is a key factor towards economic development of any nation. It requires generating units usually sited as mega projects and involves huge capital. However as critical as it is, so are issues attached with power generation. The word thermal power plant is associated with power generation through heat generated with coal, gas and steam power plants, solar, nuclear, internal combustion engines or waste incineration plant and so on. The production of power from a fuel can be direct such as burning wood in a fire place to create heat or by converting chemical energy to mechanical energy for power generation in heat engine [1]. Heat engines work on the principle of heating and pressurizing a fluid, the performance of mechanical work and the rejection of unused or waste heat to a sink.

Fossil fuels bear chemical energy, which are usually transformed into power. This is done directly through a process for releasing the chemical energy of fossil fuels known as combustion. Emission from power generation constitutes a major contribution to anthropogenic pollution [2]. The energy efficiency of a conventional thermal power plant considered salable energy produced as a percent of the heating value of the fuel consumed and is typically 33 % to 48% [3]. Currently in Nigeria, there are two main types of power plants operating in the country, which are hydro electric and thermal power plant. Of all the thermal power plants operating in Nigeria [4], the sources are coal fired and natural gas fired. As at December 2013,the total installed maximum capac-

ity of the power plants was 6953 MW, with available capacity of 4598 MW and actual average generation of about 3800 MW. In December 2014, the total installed capacity rose to 7445 MW with available capacity of 4949 MW and actual available generation less than 3900 MW. Currently, Nigeria electric energy output is very low with current installed capacity of energy generation at about 6800 MW and actual average generation between 2500 MW to 3200 MW [5]. Consider the population size of Nigeria at 160 million and to compare between countries showed that Sweden with population of 9 million generates 32,000 MW, South Africa with a population of about 42 million generates 36,000 MW and Lithuania with a population of 3 million generates 3000 MW [6-8].

Igbokwe et al. presented the facts from the Federal Ministry of Power, which showed that the national grid generates 4389 MW, and sent out 4038 MW at December 2014 [9]. This is a far cry of the energy requirement, which is put at 31,210 MW at an optimistic GDP growth rate of 11.5%. Currently, Nigeria is suffering acute power poverty with only 47% having access to electricity and 10% not connected to the grid. Measures to improve the performance indices of the plant have suggested in various fora but little or nothing has been said about the increasing discharge of pollutant that will find their way into our environment as concerted efforts are channeled towards realizing the national energy requirement of 31,210 MW. Pokale (2012) thermal power plant contributes to over 60% of SO_2, 20% of NO_x, 25% of manmade mercury and over 30% of excess CO_2 to the environment.

Igbokwe et al. [9] opined that fossil-fueled thermal power plants have been identified to be among the major contributors of environmental pollution, which has a lot of impact to human health. The pronounced fuel utilized in about 80% of thermal power plants in Nigeria is natural gas. The epileptic power situation in Nigeria is currently giving rise to mini thermal power plant in the form of single cylinder internal combustion engines. These have in no small way bring closer the pollutants to man and environment [10].

The land requirement per mega watt of installed capacity for coal, gas and hydroelectric power plants is 0.1-4.7 ha, 0.26 ha and 6.6 ha respectively. In case of coal-based power plants, the land requirement is generally near the area to the coalmines. While in the case of gas-based, it is any suitable land where the pipeline can be taken economically. Land requirement of hydroelectric power plants is generally hilly terrain and valleys [11]. 321 ha, 2616 ha and 74 ha of land were used to dispose fly ash from the coal based plants at Ramagundam, Chandrapur and Gandhinagar respectively. The primary effects of thermal pollution are direct thermal shocks, changes in dissolved oxygen, and the redistribution of organisms in the local community. Because water can absorb thermal energy with only small changes in temperature, most aquatic organisms have developed enzyme systems that operate in only narrow ranges of temperature [12].

DISCUSSIONS

Control Techniques of Pollutants

Carbon monoxide (CO)

Carbon monoxide has a strong affinity for hemoglobin. This means that inhaling CO reduces the oxygen needs by the vital tissues. This indirectly will induce headache, reduce mental stability, vomiting, collapse and possibly death. It has been observed that measures taken to minimize the formation of NOx during combustion prevent complete combustion and incomplete lead to an increase emission of CO due to insufficient oxidation.

The pronounced control technique for CO is known as catalytical oxidation, it is a post combustion measure for CO reduction. It oxidizes CO to CO_2 with the help of catalyst. This catalyst is usually installed at the discharge section of a gas turbine.

Nitrogen Oxides (NOx)

Basically, high combustion temperature promotes the production of NOx. The American lung association in 1990 estimates that nearly 50% of USA inhabitant lives in countries that are not at ozone compliance. Acid rain formation is not far from NOx reactions. NOx exposure leads to swelling of throat and reduces oxygen intake, reacts with aerosols to form respiratory problems, visual impairment and so on.

However, possible NOx control technique in thermal power plant can be grouped into two namely: Combustion

Modification Technique and Post Combustion Modification Technique

Combustion modification technique

Burners out of service (BOOS): This technique involves taking one or more burners out of function to lower the potential flame temperature.

Boiler derating (BD): Boiler Derating is a reduction of steam demand at certain process phase out. In other way round, it simply means reduction in firing rate.

Oxygen and combustible trim: This technique limits the influent air quantity allowed into the boiler, thereby reducing the boiler efficiency and combustible trim reduces combustible concentration to a required level.

Steam injection (SI) and water Injection (WI): Steam Injection is commonly applied to gas turbine to limit NOx emission. Steam Injection reduces the potential flame temperature by diluting oxygen near the burner front and directly removing heat from the burner flame. Water Injection removes more heat from the burner through it heat of vaporization.

Stage combustion (SC): Stage Combustion involves partitioning of air or fuel to create fuel rich zone followed by air rich zone to enhance complete combustion at a lesser temperature.

Other Combustion modification feasible for pollutant control technique are use of alternate fuel with low nitrogen content, flue gas recirculation which involves withdrawing some portion of the flue gas from the boiler stack and sending it back to the combustion air to reduce the oxygen.

Post Combustion Modification Techniques

Selective Catalytic Reduction (SCR): This reduces NOx to N_2 and water using ammonia (NH3) at about 540°F to 840°F using a base metal as catalyst. However, NH_3 can be injected without a catalyst and this is known as Selective Non Catalytic Reduction (SNCR).

Wastewater Purification

A well-detailed plan for water purification should be keyed into the process of developing any power plant. Wastewater management system should be design for optimum overall plant availability, reliability, ease of operation and maintenance and compliance to environmental regulation. Water treatment can be before or after the use of the water, this is done to prevent corrosion and scale deposit in the boiler and turbine system [13]. Waste water treatment control measures includes waste water suspended solid removal, waste water filtration, oil separation and removal, neutralization, solid dewatering, dechlorination, heavy metal reduction, waste water volume reduction, membrane processes, evaporation and distillation processes.

Settling Pond is perceived to be the oldest method to capture suspended solids through clarifier. Clarifier is a steel or concrete basin specifically designed to remove suspended solids in wastewater. However, pretreatment of water is a critical aspect of thermal power plant [14] pollutant control techniques and this is usually achieved using methods such as sedimentation and clarification, aeration, softening, filtration, iron/manganese removal, and deminerization. Wastewater discharges encourages thermal water pollution, which affects aquatic life.

Particulate Matter (PM) and Ash

EPA defines PM as a complex mixture of extremely small particles and liquid droplets. EPA further grouped PM as inhalable coarse particles and fine particles.

Inhalable Coarse Particles are those found near roadways and dusty industries. They are larger than 2.5 μm and smaller than 10 μm in diameter. Fine Particles are those found in smoke and haze and are less or equal to 2.5 μm(EPA). Control Techniques associated with PM are use of mechanical collector (cyclone), scrubber, fabric filter and electrostatic precipitators. Mechanical collector (cyclone) is the most widely use collector and its efficiency gets up to 80-89% with PM of 10 μm size. Scrubbers separates solid or liquid particles from a gas stream and exists in various design and types such as centrifugal, packed, venture, semi dry injection and so on with efficiency as high as 95%. Fabric filter collects solid particles by passing gas through cloth bag, which most particles cannot penetrate. As the gas flows, a layer of PM builds up on the fabric, which causes a change in pressure of the flowing gas stream. Electrostatic precipitators use a voltage source, which create a negatively charged area from the suspended wires in the gas flow path. The precipitator applies the controlling force only to the particles of interest and not on the whole gas stream. This is efficient and capable of achieving 99% PM removal. The collecting plates capture the electrically charged suspended particles and are disposed off by mechanical periodic vibration, rapping and rinsing. Ashes are produced in large quantity, making it imperative that proper ways of control should be adopted. Ash handling system could be manual handling, mechanical, steam jet, pneumatic (conveyor or hydraulic system).

With manual handling, ashes are collected directly from the ash outlet and are most suitable for smaller thermal power plant. Steam jet system uses jets of high-pressure steam blow in the direction of the conveying pipe. Pneumatic conveyor system is suitable for handling abrasive and fine dusty substances. It usually consists of airtight receiver, airtight discharger gate, air washer and exhauster, and storage bin for discharge gate.

Noise and Vibration

Wikipedia presented types of noise to be thermal noise, shot noise, flicker noise, burst noise, transit-time noise, coupled noise, intermodulation noise, crosstalk, interference, atmospheric noise, industrial noise, solar noise, and cosmic noise.

However, noise of interest in thermal power plant is the industrial and thermal noise. Bies et al. [15] presented three approaches to noise control which are: Noise controlled directly at the source, Noise controlled along path, Noise controlled at the receiver.

Vibration is usually caused by forcing mechanism such as oscillating, rotating or reciprocating component. Use of vibration-

energy absorbing material to surfaces will curb the amplitude of vibration and prevent excitements. Usually acoustic booths are provided for workers within a thermal power plant site to mitigate the effects of noise. The most common noise control techniques in thermal power plant includes use of mufflers, enclosures, lagging and wrapping, damping, isolation, equipment selection and improved maintenance.

CONCLUSION

As the need for more quantity of power generation increases in Nigeria, it is also imperative to strictly consider the pollution associated with such demand and the control techniques adopted to mitigate and cushion the rising effects of the pollutants emitted from thermal power plants spread across Nigeria. A critical review of various control technique was carried out with a view to curb the effects of these pollutants to man and environ. It was observed from the review that complete oxidation process lowers the formation of CO while lowering the combustion temperature favours low emission of NOx. In addition, wastewater purification, particulate matter and ash, and noise and vibration control techniques are detailed in the discussion. If the control techniques are strictly adopted, the high power generation demand in Nigeria can be achieved with less emission of pollutant into our environment.

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