Government of Pakistan
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Sectoral guidelines for environmental reports—
Major thermal power stations

Contents **Page**

1 INTRODUCTION

1.1 Scope of guidelines

These guidelines deal with major thermal power plants which will be defined as those producing electrical energy from fossil fuels (coal, gas or oil).

The guidelines will assist proponents to identify the key environmental issues that need do be assessed as well as mitigation measures and alternatives that need to be considered in the actual EIA. Readers are advised not to apply a mechanistic approach based on the guidelines. Thoughtful consideration should be given to the proposal, its siting and the physical and cultural environment in which it is proposed; and no technique can replace this.

The environmental issues discussed in these guidelines are typical of the issues that a thermal power plant development should address. The degree and relevance of the issues will vary from proposal to proposal. The specific power sector EIA should only deal with issues relevant to the particular proposal and focus on key environmental issues.

1.1 Context

This guideline is part of a package of regulations and guidelines which include:

- The Pakistan Environmental Ordinance 1997
- Policy and Procedures for filing, review and approval of environmental assessments
- Guidelines for the preparation and review of Environmental Reports
- Guidelines for public participation
- Guidelines for sensitive and critical areas
- Pakistan environmental legislation and the National Environmental Quality Standards (NEQS)
- Sectoral guidelines for environmental reports: ***Major Thermal Power Stations***

This guideline should not be read on its own, but in the context of the overall package.

2. INDUSTRY AND PROCESSES

Thermal power plants can generate significant impacts on the surrounding natural environment. The major impacts on the natural environment concern aquatic resources threatened by cooling water discharge and air quality.

The major components of thermal power plants include the power system (i.e., power source, turbine and generator) and associated facilities, which may include the cooling system, stack gas cleaning equipment, fuel storage and handling areas, fuel delivery systems, solid waste storage areas, worker housing, electrical substations and transmission lines. The type of facility, size of the project, and its location, will determine the type and size of these associated facilities.

Conventional thermal power plants generate electricity through a series of energy conversion stages;

- fuel is burned in boilers to produce high-pressure steam
- the steam expands and drives a turbine
- and the mechanical energy of the turbine is converted to electrical energy by a generator.

Newer processes include;

- combined cycle units (with turbines driven both by direct fuel combustion and by steam for gas-fired plants)
- fluidized bed combustion
- coal gasification
- and cogeneration units (with recovery of waste heat) from an individual process to generate electricity.

These newer processes offer improvements in thermal efficiency and environmental performance relative to conventional power plants.

3. WASTES

3.1 Gas-Fired Power Plants

In general gas-fired plants produce negligible quantities of particulates and sulfur oxides. They produce nitrogen oxides, which are at lower concentrations than coal or oil fired

3.2 Coal & oil-fired power plants

Coal and oil burning processes generate wastes which contain particulates, sulfur and nitrogen oxides, and volatile organic compounds. The particulates include heavy metals present in the fuel. Primary attention needs to be focused on gaseous emissions of particulates less than 10 microns in size (PM_{10}), sulfur dioxide (SO_2) and nitrogen oxides (NO_x) due to the associated health concerns and other environmental damage caused by these pollutants. The concentration of these pollutants in the exhaust gases are a function of the firing configuration, operating practices, and fuel consumption. Alternative methods of emission control are provided in these guidelines.

Ash residues and the dust removed from exhaust gases may contain significant levels of sulfates, heavy metals, and organic compounds in addition to inert materials. Fly ash removed from exhaust gases make up 60-85 % of the coal ash residue in pulverized coal boilers. Bottom ash includes slag and other heavier particles.

Substantial increase in the above mentioned wastes can occur when environmental measures such as coal cleaning, flue-gas desulphurisation (FGD), or fluidized bed combustion are applied (with compensatory reduction in the emissions to the atmosphere).

Steam turbines may require large quantities of water for cooling the steam prior to recirculation to the boiler or steam generator. Water is also required for auxiliary station equipment, ash handling and Fluegas Desulphurisation systems. The characteristics of the waste waters produced depend upon the ways in which water has been used. Waste water contamination is common in thermal power plants and can be due to:

- waste from demineralizers
- lubricating and auxiliary fuel oils, and
- chlorine, biocides, and other chemicals used to manage the quality of water in recirculating systems.

4. POTENTIAL IMPACTS ON THE ENVIRONMENT

Power plant projects can produce significant negative impacts during both construction phase and operation phase.

4.1 Construction Phase

One of the major impacts from power plants involves the influx of workers for construction. Several thousand workers may be required during the years of construction of a large plant.

Construction impacts are related to site preparation activities which include: clearing, excavation, earth moving, dewatering, dredging and/or impounding streams and other water bodies, and developing borrow and fill areas. The large number of workers employed in constructing power plants can have significant social and cultural impacts on local communities.

There is potential for great stress where the host community is small. A “boom town” condition can result with significant negative effect on the existing community infrastructure such as schools, hospitals, transport, police, and so forth. Similarly, the influx of workers from other localities or regions will change local demographic patterns and disrupt local social and cultural values, as well as living patterns of the residents. The purchasing power of the new workers can distort local markets, and lead to economic dislocation for the original community.

Another potential impact is the displacement of the local population because of land requirements for the plant site and associated facilities. Significant disruption of local traffic can occur from the construction and operation of a thermal power plant. Large power plants can also be visually obtrusive and noisy.

A number of impacts can be avoided altogether or mitigated more successfully and at less cost by thoughtful site selection. Section 2.6 on site selection in the *“Guidelines for the preparation and review of environmental reports”* should be read in conjunction with this section.

4.2 Air Emissions

Power plant air emissions can have a major impact on the local and regional air quality. The pollutants can seriously impair human health and damage vegetation and other materials.

The emissions include sulfur dioxide, oxides of nitrogen, carbon monoxide, carbon dioxide, and particulates (which may contain trace metals). The emission levels depend on the following variables:

a) the type and size of facility
b) the type and quality of fuel, and
c) the manner in which it is burned.

The dispersion and ground level concentrations of these emissions are determined by the interaction the following variables:

a) plant stack characteristics
b) physical and chemical characteristics of the emissions
c) meteorological conditions at or near the site during the time the emissions travel from the stack to the ground level receptor
d) topographical conditions of the plant site and surrounding areas

4.3 Cooling Water and Waste Heat

Any cooling system entails some consumptive loss of water, and thereby reduce the available volume for drinking, irrigation, and other uses in water short areas.

4.3.1 Once-Through Cooling Systems

The volume of water for large plants with once-through cooling systems is taken from natural water bodies such as rivers and bays, and there is a risk of mortality to aquatic organisms from entrainment and impingement in the cooling system.

The significance of entrainment of small aquatic organisms and entrapment of fish in the power plant's water intake depends on the water inflow requirements of the plant compared to the total flow of the waterway and on the characteristics of the aquatic ecosystem. A thorough understanding of the ecosystem in a waterway receiving a thermal discharge is necessary to determine potential impacts of a given plant.

Heated water discharges will elevate ambient water temperatures. This can radically alter existing aquatic plant and animal communities by favoring organisms which are suited to higher temperatures. The new communities are then vulnerable to the opposite effect, namely sharp reductions in ambient temperature following plant shut-downs (due to breakdowns or scheduled maintenance).

4.3.2 Evaporative Cooling Systems

Use of evaporative or recirculatory cooling towers reduce the volume of water which must be withdrawn for cooling. However they do require makeup water to off-set evaporation. Water makeup requirements for a cooling tower consist of the summation of:

a) evaporation loss
b) *drift loss* (entrained water in vapors), and
c) *blowdown* (blowdown refers to discarding of a portion of the concentrated circulating water due to evaporation process in order to lower the system solids content)

Thus while cooling towers eliminate thermal discharge, they produce cooling tower blowdown which must be discharged. Various types of chemical compounds are added to the recirculating water for purposes of slime and corrosion control, and usually these contain toxics, especially chromium (which in the hexavalent form is very toxic to people, animals and fish). Hence provision must be made for removal of the toxics from the cooling tower blowdown, and extra special care is needed to ensure that the system will be kept properly functioning to achieve 100 % treatment of all blowdown.

4.4 Other Effluents

Other effluents from thermal power projects are less plentiful but can significantly affect water quality. For instance, liquid effluents from coal-fired power plants include:

- discharges from cooling system blowdown
- boiler blowdown, demineralizer backwash and resin regenerator wastewater
- ash transport wastewater
- run-off from coal stock piles
- ash piles and the site
- other miscellaneous low-volume wastewater and discharges from accidents and spills.

Trace metals, acids, and other chemicals in various combinations are found in these effluents. Oil spills have a negative impact on water quality at oil-fired facilities.

4.5 Global and Transboundary Impacts

4.5.1 Acid Precipitation

Emissions from thermal power plants can act as precursors of acid precipitation, particularly when coal with its high sulfur content is the fuel. Acid precipitation has primarily been related to SO_2 and NO_x deposition. Acid deposition is considered to have a wide range of environmental effects:

- radically alters aquatic ecosystems of lakes, streams and ground waters through acidification
- accelerates the deterioration of buildings and monuments, metal structures and fibers
- damages vegetation in forest ecosystems and sometimes agricultural crops.

When considering the environmental impacts of long-range transport of acid-constituents in the atmosphere, consideration should be given to the actual windflows, the atmospheric chemistry, and the buffering characteristics at the site.

4.5.2 Global Warming

Increase in CO_2 and NO_x in the atmosphere causes global warming.

5. MITIGATION MEASURES

All environmental assessments should include an analysis of reasonable mitigation measures and alternatives to off-set potential environmental impacts due to the project. The analysis may lead to alternatives that are more sound from an environmental, social, cultural, and economic point of view than those originally proposed.

Some alternatives that should be considered and discussed by listing their advantages and disadvantages in all EIAs are:

- no action (i.e., examine the consequences of taking no action to meet the expected demand needs)

- alternative fuels
- energy and load management alternatives
- site location alternatives
- alternative heat rejection systems
- alternative water supply/intake
- solid waste disposal alternatives
- engineering and pollution control equipment alternatives
- management control alternatives
- social structure alternatives including infrastructure and employment

The appropriateness of these alternatives should be addressed as part of the conceptual design process at the feasibility stage and preference should be given to those alternatives that provide cost-effective environmental control.

5.1 Cleaner Fuels

The most cost-effective form of pollution control is to use cleaner fuels. Natural gas plants currently have a decisive advantage in terms of their capital costs, thermal efficiency and environmental performance.

If the availability and price of natural gas rule out this option, then use:

- low sulfur, low ash coal, or
- low sulfur fuel oil, or
- LPG.

Typically such fuels will command a premium price, but the reductions in operating or environmental costs that they permit is likely to outweigh this premium.

In preparing project feasibility an evaluation of alternative fuel options should be carried out to establish the most cost effective combination of (a) fuel, (b) technology, and (c) environmental controls for meeting performance and environmental objectives.

5.2 Clean Coal Technologies

New clean coal technologies offer the possibility of reducing or even eliminating emissions of some pollutants, especially SO_x.

Clean coal technologies are most likely to have an economic advantage when the main fuel option is low quality, high sulfur hard coal, brown coal or lignite.

The new technologies include:

- Integrated Gasification and Combined Cycle (IGCC)
- Atmospheric Fluidized Bed Combustion
- Pressurized Fluidized Bed Combustion

5.2.1 Integrated Gasification and Combined Cycle (IGCC)

Coal is partially combusted in a limited supply of oxygen and steam, preferably at high pressure, to produce a fuel gas at about 400^{o}C. This gas is two thirds carbon monoxide and one third hydrogen. Because the gasifier operates in reducing conditions, sulfur present in the fuel is converted to hydrogen sulfide which is more amenable to removal than sulfur dioxide. Desulfurization using established technology takes place after the fuel gas has been cooled and washed. The chlorine in the coal is removed with the waste liquors and fuel nitrogen is converted during gasification to molecular nitrogen. The clean, dust free gas is then combusted in combined cycle gas turbine generators.

The capital costs for IGCC are claimed to be about the same as for conventional plants, and running costs about 10 % cheaper, mainly due to greater thermal efficiency.

5.2.2 Atmospheric Fluidized Bed Combustion (AFBC)

Fuel combined with either limestone or dolomite is combusted in a medium of coal ash or sand, at a ratio of one part fuel to 99 parts bed material. Combustion air is introduced through the bottom of the bed, making it fluid. The improved combustion efficiency allows the bed temperature to be held at 750-950^oC, significantly lower than the combustion temperature in a conventional coal-fired plant. The lower operating temperature reduces NO_x and SO_2 formation. SO_2 emissions are further reduced by the presence of the calcium-based limestone or dolomite.

Atmospheric Fluidized bed Combustion (AFBC) units are thought to be competitive with conventional coal-fired plants that incorporate a FGD system. AFBC plants generate large quantities of solid waste; approximately twice as much as a conventional coal-fired plant. This technology is likely to be overtaken by pressurized FBC which potentially offers more advantages.

5.2.3 Pressurized Fluidized Bed Combustion (PFBC)

The main difference between Pressurized and Atmospheric Fluidized bed Combustion is that the combustion mixture is fluidized by pressurized air in the range of 4-20 bar in PFBC (atmospheric pressure in AFBC technologies).

In contrast to AFBC, PFBC plants permit the use of deeper combustion beds and slower fluidizing velocities (the rate of flow of air through the bed), which results in longer residence time through the bed. This in turn gives rise to greater combustion efficiency, more effective sulfur capture, and as a result of higher pressures NO_x emissions are lower. As with AFBC, bed temperatures range from 750-950^oC, giving a gas turbine temperature of less than 900^oC.

The lower NO_x emissions result from the lower operating temperature of PFBC compared to conventional plants. All the NO_x produced comes from the nitrogen content of the coal itself, and none from the oxidation of atmospheric nitrogen as is normally the case.

PFBC plants have increased generating efficiency and reduced environmental impact. The costs of PFBC and conventional pulverized coal estimate that the capital costs are 9 % and power generation costs are 6 % lower than for conventional plants. These estimates are without any credit given to environmental benefits of PFBC. In addition, it is expected that commercial markets will be found for the large quantities of ash produced by PFBC plants, which would further reduce power generation costs.

PFBC plants achieve combustion efficiencies of 99 % with a wide range of coals. The net efficiency of plants range around 44 %.

The economic, technical and environmental advantages suggest that the market penetration of PFBC will occur soon. The plants have the additional advantage of being quicker to build than conventional plants because of their more compact design.

5.3 Particulate Removal

Particulate removal from exhaust gases can be achieved with:

1. cyclones
2. fabric filters (or baghouses)
3. and electrostatic precipitators.

5.3.1 Cyclones

Cyclones may be adequate for small boilers but their overall removal efficiency is less than 90 % for all particulate matter and is considerably lower for PM_{10} (which is often associated with respiratory concerns such as asthma etc.).

5.3.2 Fabric Filters Vs Electrostatic Precipitators

Both Fabric Filters and Electrostatic Precipitators can achieve removal efficiencies of 99.8 % or better. The choice between a fabric filter or an electrostatic precipitator will depend upon fuel and ash characteristics as well as operating and environmental factors.

Fabric filters have the potential to enhance the removal of SO_x when sorbent injection or dry-scrubbing systems are used.

Electrostatic precipitators are available in a broad range of sizes for power plants and can be less sensitive to plant upsets than fabric filters, because their operating effectiveness is not as sensitive to maximum temperatures and they have a low pressure drop. On the other hand, electrostatic precipitator performance can be affected by fuel and boiler characteristics as well as poor operating or maintenance procedures, so their actual removal efficiency may be well below their design specification.

Modern baghouses (or fabric filters) can also be designed to achieve very high removal efficiencies for PM_{10} at a capital cost that is comparable to that for electrostatic precipitators when low sulfur fuels are used, but it is necessary to ensure the availability of filters and the appropriate training of operating and maintenance staff.

5.4 Desulfurization Technologies

The range of options for the control of SO_x emissions is wide because of large differences in the sulfur content of different fuels and in control costs. In general the following controls will need to be considered for the respective fuel types.

Less Than 1 % Sulfur:

For low sulfur, high calorific fuels, specific controls may not be required.

1-3 % Sulfur:

For medium sulfur fuels, coal cleaning (when applicable), sorbent injection, or fluidized bed combustion may be adequate.

Greater Than 3 % Sulfur:

For high sulfur fuels, Fluegas Desulfhurisation Units (FGDs) or other clean coal technologies should be considered.

5.4.1 FGD System: Wet Scrubbers

This technology for removing SO_2 from the flue gas arises from the combustion of sulfur-bearing coal or heavy fuel oil. A slurry or solution containing calcium, nitrogen or ammonia-based sorbents absorbs SO_2 to produce an initially wet by-product. Seawater being alkaline is also used by some plants. Systems using a limestone based sorbent can produce gypsum as a byproduct. Gypsum is used in building or can be dumped as it is dry, stable and leachate resistant. Where gypsum is not produced, the sludge by-product is dumped in landfill sites.

5.4.2 FGD System: Dry Scrubbers

SO_2 is removed from the flue gases to produce a dry-product that is usually collected together with the fly ash. The principal type in use is the lime spray dryer.

5.4.3 FGD System: In-furnace Sorbent Injection

Finely pulverized lime or limestone sorbent is injected directly into the furnace to react with the combustion gases. The efficiency of sorbent injection is not equal to other FGD systems and often this process is combined with a further SO_2 removal stage after combustion.

5.4.4 Regenerable FGD Systems

SO_2 is removed from the flue gases by reaction with wet sorbent, sodium sulphite or magnesium oxide. The reaction product is then separated and the sorbent thermally regenerated. The sorbent is recycled, leaving a concentrated stream of SO_2 which can be then processed to produce elemental sulfur, sulfuric acid or liquid SO_2.

Regenerable systems achieve high removal efficiencies (90-98 % removal of sulfur). They produce salable sulfur by-products and no solid waste. They have high capital and annual costs.

5.4.5 Coal Benefication

Coal is often treated physically before being burned in power stations in order to improve its characteristics. This treatment involves a number of physical processes such as crushing, grinding, screening and various washing techniques including froth floatation, hydrocyclones and dewatering. These make use of the difference in specific gravity between the inorganic sulfur compounds and the rest of the coal. The benefits include reduction in ash content (and therefore reduction in volume and transport costs), production of coal with a more uniform heating value, reduction of sulfur content, and more efficient combustion at the power station.

More advanced physical coal cleaning technologies offer higher removal efficiencies of inorganic sulfur and ash. They exploit the differences in physical characteristics such as magnetic susceptibility or of the various components of coal.

5.5 De-nitrification Technologies

The main options for controlling NO_x emissions are combustion modifications:

a) low NO_x combustion modifications, and
b) selective catalytic, and
c) selective non-catalytic reduction.

5.5.1 Low NO_x Combustion Modifications

NO_x forms in a boiler or furnace in one of two ways:

1. Thermal NO formation takes place when atmospheric nitrogen oxidizes at temperatures above 1,300^{o}C. Complex chemical reactions in the atmosphere convert NO to NO_2. This NO_2 may be precipitated from the atmosphere as nitric acid.

2. Fuel NO formation takes place when nitrogen contained in the fuel itself is oxidized at temperatures of 680–1,400^{o}C. The rate of reaction is highly dependent on fuel nitrogen content, partial pressure of oxygen, and temperature.

Unlike SO_2 control, there is potential for No_x control at source through reducing combustion temperature or oxygen concentration. This may be achieved in a number of ways, including the following.

- Finely pulverizing the coal so that 95 % of the particles are less than 0.09 mm diameter and none are greater than 0.2 mm. This reduces the amount of air required in the boiler.
- Combustion with low excess air, allowing just enough to maintain furnace conditions, can reduce NO_x formation up to 30 %, primarily through limiting the oxidation of fuel nitrogen.
- Flue gas recirculation increases the flow rate through the boiler. This is more effective at reducing NO_x formation in oil or gas-fired plants than coal-fired plants.
- Low NO_x burners can reduce NO_x formation by as much as 40 % through introducing combustion air in stages, so converting fuel nitrogen to elemental nitrogen instead of NO_x.
- Fuel staging involves reburning unburned fuel in a secondary stage in low oxygen conditions. NO_x formed in the first stage is then reduced to elemental nitrogen through reaction with hydrocarbons formed in the second stage.

5.5.2 Selective Catalytic Reduction

Nitrogen oxides in the flue gases react with ammonia in the presence of a catalyst to produce water and elemental nitrogen (N_2). At an operating temperature of between 300-400^{o}C the process is selective as other components of the gas mixture, including SO_2, remain unaffected. The advantages of this system are that NO_x removal efficiency is high and that there are no by-products which require disposal.

Titanium oxide is the most commonly used catalyst, others include activated carbon, iron oxides and aluminium silicate (zeolite). Zeolite is a crystalline material which has the advantage of being able to store excess ammonia that may otherwise escape to the environment.

Selective catalytic reduction units can remove 70-90 % of NO_x but involve a high capital cost and significant increase in operating costs, especially for coal-fired plants.

International Energy Agency estimates indicate that the average annual cost for adding a selective catalytic reduction unit to remove only 40 % of NO_x amounts to 9 % for coal-fired plants, 3 % for oil-fired plants, and 2 % for gas-fired plants.

5.5.3 Selective Non-Catalytic Reduction

Ammonia is used to react with NO_x without the aid of a catalyst, at temperatures between 900-1,100^oC, *producing elemental nitrogen.* The process is particularly sensitive to operating temperature, generating excess ammonia or NO_x when outside the optimum range.

Selective non-catalytic units can remove 30-70% of NO_x with relatively small capital and operating costs.

5.6 Fly Ash Removal

Fly ash handling systems may be generally categorized as dry or wet, even though the dry handling involves wetting the ash to 10-20 % moisture to improve handling characteristics and mitigate the dust generated during disposal. In wet systems the ash is mixed with water to produce a liquid effluent with 5-10 % solids by weight. This is discharged by pipeline to settling ponds, which are often used for the disposal of bottom ash and Fluegas Desulphurisation sludges as well.

These ponds may be used as the final disposal site or the settled solids may be dredged and removed for final disposal in a landfill. Where there are heavy metals present in ash residues or Fluegas Desulphurisation sludges, care must be taken to monitor and treat leachates and overflows from settling ponds, and in the safe disposal of the settled solids in landfills.

5.7 Water Usage Reduction

It is possible to reduce the water for cooling systems by installing evaporative cooling systems which may use only 5 % of the water volume required for once-through cooling systems. However, such systems may be more expensive and require careful management to minimize bifouling (discharge of biocides in water vapors and droplet drifts).

Where once-through cooling systems are used, the volume of water required and the impact of its discharge can be reduced by careful siting of intakes and outfalls, by minimizing the use of biocides and anti-corrosion chemicals, and by controlling discharge temperatures and thermal plumes. Wastewaters from other processes can also be recycled, but again this requires careful management and treatment for reuse.

5.8 Water Temperature Reduction

This can be achieved by lengthening the outlet channel.

6.0 EMISSION REQUIREMENTS

The emission requirements for major power plants will be based on the NEQS. Appendix III provides a list of the major environmental legislation and regulatory requirements for Pakistan. Appendix IV provides the following information:

A. National Environmental Quality Standards for Municipal and Liquid Industrial Effluents
B. National Environmental Quality Standards for Industrial Gaseous Emissions
C. National Environmental Quality Standards for Sulphur Dioxide and Nitrogen Oxide Ambient Air Requirements

Some of the NEQS levels are currently undergoing revision and as updates are made available these guidelines will be amended. The following specific requirements must be met for thermal power projects.

6.1 Air Emissions

This assessment should, establish baseline ambient concentrations of PM_{10}, SO_2, NO_x , CO_2 and Ozone without the project as well as identifying the main sources contributing to total emissions of these pollutants within a defined airshed encompassing the project.

An appropriate dispersion model that has been officially recognized by the Responsible Authority should be used to investigate the impact of the project on the ambient concentrations of these pollutants under alternative assumptions about environmental controls. For example when there is a reasonable likelihood that the power plant will be expanded in the medium or longer term, the analysis should take account of the impact on air quality within the airshed of the proposed plant design both immediately and after any probable expansion in capacity.

The costs of installing alternative emission controls should be compared with the costs of other measures designed to reduce pollution exposure within the airshed. If there are significant concerns about the long range transport of acid pollutants, this analysis should be extended to identify least cost options for reducing total emissions of these pollutants from a region.

The emission requirements are specified in sections 6.1.1, 6.1.2 and 6.1.3 respectively within the categories of:

1. Particulates
2. Nitrogen Oxides
3. Sulfur Dioxide.

The requirements represent the basic minimum standards that should apply to all projects. More stringent emission requirements will be appropriate if the environmental assessment indicates that the benefits of additional pollution controls as reflected by ambient exposure levels and by other indicators of environmental damage outweigh the additional costs involved. In particular:

If the environmental assessment establishes, for one or more of the pollutants covered in this document, that:

a) the baseline exposure of significant populations within the airshed exceeds the trigger value for ambient exposure, and

b) the proposed project will result in significant worsening in this exposure level,

then the Responsible Authority may require the project comply with stricter emission requirements, or it may require alternatives to reduce emissions from other sources to mitigate ambient exposures within the airshed.

The environmental assessment should also address other project-specific environmental concerns, such as emissions of cadmium, mercury, and other heavy metals resulting from burning certain types of coal or heavy fuel oil. In such cases, the Responsible Authority will require specific measures to mitigate the impact of such emissions and set associated emission requirements.

6.1.1 Partciulates

For a coal-fired plant, the recommended removal efficiencies from exhaust gases are over 99 % for all particulates (PM) and over 98 % for PM_{10}. These removal efficiencies should be achieved at least 95 % of the time that the plant is operating. For power plants the PM emissions should not exceed 300 mg/m^3 for oil fired plants, and 500 mg/m^3 for coal fired plants.

6.1.2 Nitrogen Oxides

As a general guide, a target reduction in NO_x emissions of 40 % (relative to the case in which no NO_x controls installed) is recommended to be achieved for 95 % of the time that the plant or unit is operating. The specific NO_x emission levels required are:

- 400 mg/m^3 for a **gas fired** power plant
- 600 mg/m^3 for an **oil fired** power plant
- 1200 mg/m^3 for a **coal fired** power plant.

Table 1 below shows the nitrogen oxide ambient air requirements and the criteria that must be satisfied, before the Environmental Approval will be granted from the EPA .

Table 1: Nitrogen Oxide Ambient Air Requirements

NITROGEN OXIDES	
Ambient air concentrations of nitrogen oxides, expressed as NO_2, should not exceed the following:-	
Annual Arithmetic Mean	100 ug/m3 (0.05 ppm)
Emission levels for stationary sources discharges, before mixing with the atmosphere, should be maintained as follows:-	
For fuel fired stream generators, as nanogram (10E-9 gram) per joule of heat input:-	
Liquid fossil fuel	130
Solid fossil fuel	300
Lignite fossil fuel	260

6.1.3 Sulfur Dioxide

The concentration of SO_2 in flue gases should not exceed 1500 mg/m^3. Table 2 below shows the sulphur dioxide ambient air requirements and the criteria that must be satisfied, before the Environmental Approval will be granted from the EPA.

Table 2: Sulphur Dioxide Ambient Air Requirements

SULPHUR DIOXIDE

Sulphur Dioxide Background Levels (ug/m3)

			Standards	
			Criterion I	***Criterion II***
Background Air Quality	Annual Average	Max. In 24 Hour Interval	Max. SO_2 Emission	Max. Allowable Ground Level Increment to Ambient
(SO_2 Basis)	(ug/m3)	(ug/m3)	(tons/day/plant)	(ug/m^3) (One year average
Unpolluted	<50	<200	500	50
Moderately Polluted*				
Low	50	200	500	50
High	100	400	100	10
Very Polluted**	>100	>400	100	10

* For intermediate values between 50 and 100 ug/m3 linear interpolations should be used.

** No project with sulphur dioxide emissions will be recommended.

6.2 Liquid Effluents

For thermal power plants, the following effluent levels should be achieved. These levels have been obtained from the Government of Pakistan 1993 *"National Environmental Quality Standards For Municipal And Liquid Effluents"* (see Appendix III).

Table 3: Permissible effluents levels from thermal power plant

Parameter	Maximum Value
pH	6-10
TSS	150 mg/l
Oil & grease	10 mg/l
Total residual chlorine	0.2 mg/l*
Chromium (total)	1.0 mg/l
Chromium (hexavalent)	0.1 mg/l*
Copper	1.0 mg/l
Iron	2.0 mg/l
Nickel	1.0 mg/l
Zinc	5.0 mg/l
Temperature Increase	less than or equal to 3^{o}C [1]

[1.] The effluent should result in a temperature inreasec of no more than 3 degrees Celsius at the edge of the zone where initial mixing and dilution takes place. Where the zone is not defined , use 100 meters from the point of discharge.

* World Bank Recommendation.

6.3 Solid Wastes

Dewatered ash and chemically stabilized FGD sludges can be disposed of in:

a) land fills sited in areas of low permeability with deep ground water tables; and
b) lined disposal cells where ground water seepage is a concern.

Disposal sites for untreated fluegas desulphurisation sludges should incorporate leachate control and collection systems to minimize the migration of contaminants such as sulfates, chlorides and heavy metals - to ground or surface waters.

7. MONITORING AND REPORTING

The monitoring program should provide the following information

- actual impacts from the project
- early warning information of unacceptable environmental conditions.
- actual impacts compared to predicted impacts

7.1 Baseline Conditions

Monitoring for thermal power plants should begin before design and construction to determine *baseline conditions*. Baseline conditions are distinct from before plant conditions in that they refer to monitoring *without plant* and with other expected development during the plant construction phase.

The length of monitoring during construction and operation phases will depend on the environmental resource that is being affected and the expected duration of the impact. For example, if a continuos cooling water discharge is planned, then weekly or daily water quality monitoring may be needed for the life of the facility. Specific monitoring programs will be required depending on the type of thermal power plant and the type of resources predicted to be affected.

7.2 Air Emission Monitoring

Primary pollutants emitted from a major power plant facility should be monitored on a continuos basis. Monitoring sites should be established to measure emission concentrations and ground level concentrations at predefined air quality receptor locations (e.g., residential areas, agricultural areas, etc.). Meteorological conditions for the site need to be characterized for air modeling purposes. If appropriate meteorological data are unavailable, then monitoring will be necessary.

Air monitoring of the workspace for dust, noise, and levels of toxic gases is also necessary to protect operating personnel.

Systems for continuos monitoring of particulates, SO_x, NO_x, and (where appropriate) other pollutants including heavy metals in the stack exhaust can be installed at a reasonable cost for coal and oil-fire power plants. Direct measurements of the concentrations of PM_{10}, NO_x and SO_x in samples of flue gases should be performed every 12 months and the calibration of the continuos monitor should be checked at the same time. In addition, regular monitoring of fuel ash and sulfur content is recommended.

Automatic air quality monitoring systems measuring ambient levels of PM_{10}, NO_x and SO_x, outside the plant boundary should be installed in at least three locations where there is:

1. least influence of the power plant (background)
2. maximum pollution concentration, and there are
3. sensitive receptors such as protected areas and population centers.

The number of such air quality monitors should be greater if the area in which the power plant is located is prone to temperature inversions or other meteorological conditions which lead to high levels of air pollutants affecting nearby populations or sensitive ecosystems.

7.3 Waste Water Monitoring

The type and nature of the wastewater discharge will determine if surface water monitoring will be required. Expected pollutants should be measured as well as water quality parameters that are important for human health and public welfare.

If not more frequent, seasonal water quality monitoring should be conducted. Groundwater monitoring may be required if contamination of groundwater is predicted. Monitoring should be conducted upstream of the point of discharge, and downstream from the point of discharge in any receiving water body used by the public or considered environmentally significant (i.e., rivers, drinking and irrigation wells).

Geophysical testing of the site may be required to characterize geological conditions under the proposed facility. If groundwater is proposed for cooling, then a pump test will be required to determine ground water quantity and quality at the feasibility stage, and monitoring of the ground water resource will need to be undertaken periodically.

The pH and temperature of the wastewater discharges should be monitored on a continuos basis. Levels of suspended solids, residual chlorine, heavy metals, and other pollutants in wastewater discharges should be measured monthly if treatment is provided.

A biological monitoring program should be designed to provide a scientifically defensible information useful for determining the status of the environmental resources affected by the thermal power project, to provide information to predict future effects, and to provide information for management decisions on possible mitigation if observed or predicted impacts are considered unacceptable. Indicator species should be identified and specified.

7.4 Analysis and Review

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be maintained in an acceptable format and reported to the responsible authorities and relevant parties, as required.

8. MANAGEMENT AND TRAINING

Because of the major environmental considerations involved in the construction and operation of thermal power plants, a team of environmental engineers and scientists need to be a part of the design and management staff for the facility. This group should work with the power plant engineers in all phases of the project that have environmental implications. Depending on the education and experience of the environmental staff, a training program in the environmental management of thermal power plants may be warranted.

A number of environmental discipline specialties that relate to management of thermal power projects need to be understood. They include the following:

- ambient air quality monitoring, modeling, and pollution control
- water resources monitoring, modeling, and pollution abatement
- solid waste management and control and industrial hygiene
- toxic substances control and hazardous waste management
- noise abatement
- natural resource protection and land use planning
- social and economic impact assessment.

Environmental training may be required for:

- general impact assessment concepts
- methodologies
- monitoring theory and methods
- data collection and analysis

- and pollution control strategies.

The training should be done as part of the environmental assessment phase of the project and with assistance from the environmental consultant. If at all possible, the environmental staff should be involved in the environmental assessment study. This will ensure an understanding of the environmental assessment of the project. In particular, staff workers must have an understanding of the rational for the recommended mitigation and monitoring that they will be implementing. Training should be given to the technical staff and supervisory staff who will interface with the power plant engineers and managers.

Staff training in and management enforcement of standard operating procedures, as well as health and safety procedures will be required to minimize environmental and health and safety impacts of the plant once it is in operation.

Provincial and Federal environmental agencies involved in the review, approval, and oversight of the project may also need training to monitor and enforce compliance during the construction and operation of the project.

9 KEY PRODUCTION AND CONTROL PRACTICES

The following list summaries the key production and control practices that will lead to compliance with emission requirements:

- Choose the cleanest fuel economically available (natural gas is preferable to oil which is preferable to coal)
- Give preference to:

  low sulfur oil, or low ash/low sulfur coal,
  consider beneficiation for high ash/high sulfur coal.

- Select the best power generation technology for the fuel chosen to balance the environmental and economic benefits.

The choice of technology and pollution control systems will be based on the site-specific environmental assessment. For pollution control, the following issues should be considered:

- Acceptable levels of particulate matter removal are achievable at relatively low cost.
- NO_x reduction is achieved by low NO_x burners
- Dry sulfur removal systems are preferred over wet systems.
- Ash requires careful disposal and reclamation.
- Use recirculating cooling systems
- A comprehensive monitoring and reporting system is required.

10 REFERENCES

The development of these guidelines rely heavily on the following sources:

- Government of Pakistan EIA Guidelines 1986
- ADB Guidelines 1993
- World Bank EIA Guidelines 1994
- The UNEP EIA Training Resource Manual June 1996
- New South Wales EIS Guidelines 1997
- IUCN EIA Guidelines for Energy Sector in Pakistan 1991
- ADB Environmental Considerations in Energy Development 1991
- Liberty Power Project; Hagler Bailley 1996
- Hub River Power Project; EBASCO Environmental 1993

Illustrative examples of potential negative impacts Vs specific mitigation measures — APPENDIX I

TABLE 4: Potential Negative Impacts Vs Mitigation Measures
Major Thermal Power Projects

Potential Negative Impacts	Specific Mitigation Measures
1. Air emission effects to human health, agriculture, and native wildlife and vegetation	• Locate facility away from sensitive air quality receptors • Use cleaner fuels (e.g., low sulfur coal) • Install air pollution control equipment
2. Increased noise and vibration	• Use low rated equipment • Control timing of noise and vibration to least disruptive periods • Install noise barriers
3. Change in surface water and ground water quality	• Treat discharge chemically or mechanically on-site • Prevent ground water contamination through use of liners • Use deep well injection below potable zones • Construct liners for ponds and solid waste disposal areas
4. Toxic effects of chemical discharges and spills	• Develop spill prevention plans • Develop traps and containment systems and chemically treat discharges on-site
5. Thermal shock to aquatic organisms	• Use alternative heat dissipation design (e.g., closed cycle cooling) • Dilute thermal condition by discharging water into larger receiving water body • Install mechanical diffusers • Cool water on-site in holding pond prior to discharge • Explore opportunities to use waste heat
6. Entrainment and impingement of aquatic organisms	• Select water intake in area that avoids significant impact • Install screens to eliminate entrainment and impingement
7. Change in surface water and groundwater quantity	• Develop water recycling plan
8. Change in surface water flow and discharge	• Construct drainage ways and holding ponds on site
9. Vegetation removal and habitat loss	• Select alternative site or site layout to avoid loss of ecological resources • Restore or create similar vegetation or habitats
10. Dredging and filling of wetlands	• Select alternative site or site layout to avoid loss of wetlands • restore or create similar wetlands
11. Avian hazards from stacks, towers, and	• Site stacks and tower away from flyways

transmission lines	• Install deflectors, lights, and other visible features
12. Human population displacement	• Select alternative site or site layout to avoid displacement • Involve affected parties in the resettlement planning and program • Construct socially and culturally acceptable settlements/infrastructure development
13. Disruption of traffic	• Develop traffic plan that includes phasing road use by workers • Upgrade roads and intersections
14. Modification of historically or archaeologically significant structure or lands (e.g., churches, temples, mosques, cemeteries)	• Select alternative site or site layout • Develop and implement "chance find" procedures to recover, relocate or restore structures • Fence or construct other barriers to protect structures or lands
15. visual impact on historical, archeological, and cultural resources and on landscapes	• Select alternative site or site layout • Construct visual buffers (e.g., plant trees)
16. Worker exposure to dust from ash and coal	• Provide dust collector equipment • Maintain dust levels < 10 mg/m^3 • Monitor for free silica content • Provide dust masks when levels exceed
17. Worker exposure to toxic gases leaking from boilers	• Maintain boilers properly • Monitor concentrations with levels not to exceed: • SO_2 5ppm • CO 50ppm • NO_2 5ppm
18. Worker exposure to excessive noise	• Maintain noise levels below 85 dBA, or provide ear protection
19. Induced secondary development including increased demands on infrastructure	• Provide infrastructure plan and financial support for increased demands • Construct facilities to reduce demands
20. Changes in demographic patterns and disruption of social and cultural values and patterns	• Develop plan to educate workers on sensitive values and patterns