

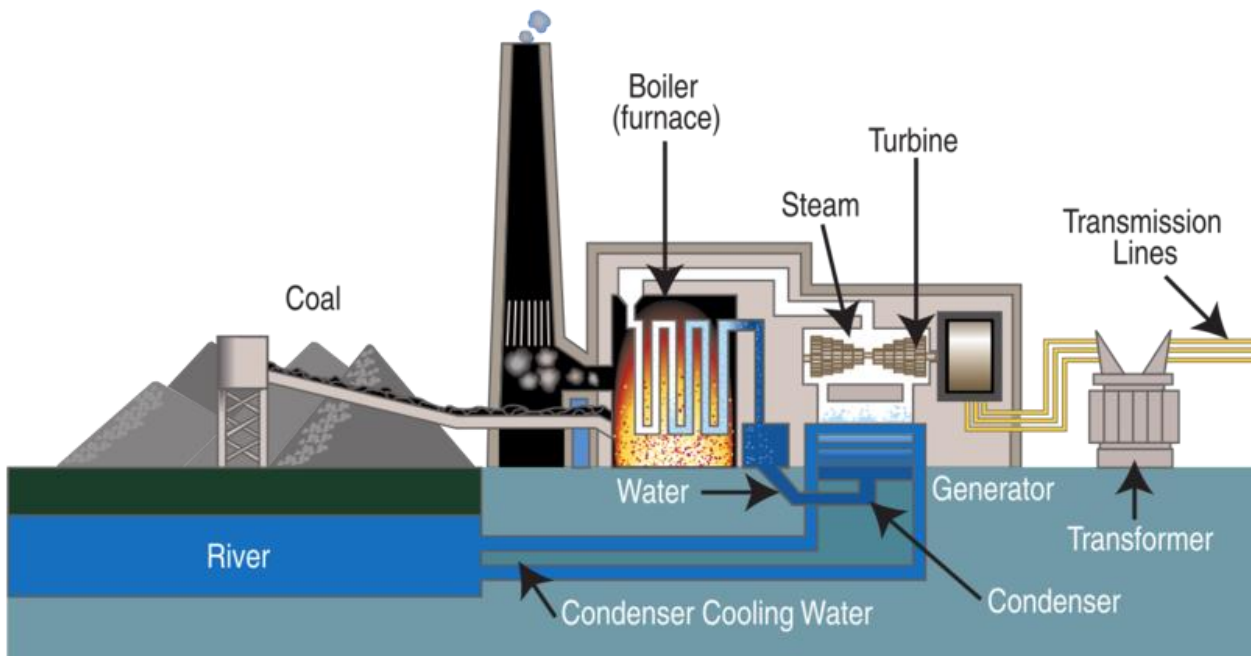
**KINGDOM OF CAMBODIA
NATION RELIGION KING**



**POLLUTANT RELEASE ESTIMATION TECHNIQUE
MANUAL**

FOR

COAL POWER PRODUCTION PLANT



Supported by:
United Nation Institute for Training and Research
(UNITAR)

Prepared by:
PRTR Project Management Unit
Department of Hazardous Substance Management
General Directorate of Environmental Protection
Ministry of Environment



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List of Abbreviation

- BOD	Biochemical Oxygen Demand
- CAS	Chemical Abstracts Service
- CASRN	Chemical Abstracts Service Registry Numbers
- CEMS	Continuous Emissions Monitoring System
- CMC	Carboxymethyl cellulose
- CO	Carbon Monoxide
- COD	Chemical Oxygen Demand
- DO	Dissolve Oxygen
- EET	Emission Estimation Technique
- EFR	Emission Factor Rating
- g	Grams
- Kg	Kilograms
- m ³	Cubic meters
- MoE	Ministry of Environment
- NO ₂	Nitrogen Oxide
- °C	Celsius
- PEM	Predictive Emission Monitoring
- PM	Particulate Matter
- PM ₁₀	Particulate Matters < 10 micrometer
- PRTR	Pollutants Release and Transfer Register
- PVA	Polyvinyl alcohol
- SO ₂	Sulfur Dioxide
- t	Tons
- TN	Total Nitrogen
- TP	Total Phosphorous
- TSP	Total Suspended Particulate
- TSS	Total Suspended Solids
- VOCs	Volatile Organic Coumpounds

1. Introduction

A Pollutant Release and Transfer Register (PRTR) is a catalogue or register of potentially harmful pollutant releases or transfers to the environment from a variety of sources. A PRTR includes information about releases or transfers to air, water and soil as well as about wastes transported to treatment and disposal sites. This register also consists of reports about specific species such as benzene, methane or mercury as contrasted with broad categories of pollutants such as volatile organic compounds, greenhouse gases or heavy metals. The development and implementation of a PRTR system adapted to national needs represents a means for governments to track generation, release and the fate of various pollutants over time.

A PRTR can be an important tool in the total environment policy of a government providing information about the pollution burden that would be otherwise difficult to obtain, encouraging reporters to reduce pollution, and engendering broad public support for government environmental policies. Indeed, governments may wish to set forth long-term national environmental goals to promote sustainable development and then use PRTR as an important tool to examine objectively how well these goals are being met.

The purpose of the Emission Estimation Technique (EET) Manuals is to assist Cambodia manufacturing, industrial and service facilities to report emissions of listed substances to Ministry of Environment (MoE). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in Coal power plant production.

2. Benefits of Using PRTR System

The following are some of the possible used and benefits of implementing PRTR system from the perspective of three main stakeholders such as: Government, Industry, and the public:

2.1. Benefit to Government

PRTR will provide comprehensive information to assist the government in addressing some data after it is designed and approval by royal government of Cambodia such as:

- Identifying industries or facilities which are generating potentially harmful chemical release in to the environment;
- Providing information on pollutants being release and how much is being release and over what time period;
- Identifying geographic area of pollutants being release and how much of each substance is going to air, water and land
- Pointing out the geographic distribution of pollutant emission
- Monitoring enforcement of current regulation
- Providing inventory data that related to chemical substance and environmental Pollution issues for measuring national progress toward risk reduction and pollution prevention goal and
- Reducing monitoring work and government expending while large waste is decrease

PRTR system will produce enough information regarding to chemical substances, and pollutants for the government to basically identify to the future workplan or determine priority action plans to prevent and reduce pollution as well as any possible serve impact to human health and environment. In additional to this, PRTR system will also help reduce government national budget's expenditure on monitoring and inspecting work as well.

2.2. Benefit to Industry

The private sector, such as factories and industries, may wrongly believe that PRTR reporting of chemicals substance use, waste generation and emission will be a burden. The experiences from PRTR implementing from private sector of other countries show that PRTR is the very vital tool in providing key information for their trade implementing as below:

- Providing information regarding to efficiency level of raw material and other resources consumption in the production such as: chemical substance consumption, water consumption, electricity, fuel, and so on.

- Identifying the loss of raw materials and resources during the production process from leaking or any utility's error.
- Identifying types and quantity of waste from the production
- Identifying the types of pollutant release and emission to the environment
- Monitoring production flow from raw material until the semi-final product or final product in order to understand whether there is any technical problem or not
- Providing the data regarding to the loss of raw materials or the other resource during the production process.

In short, all participants in PRTR system from private sector including companies, and factories will receive information regarding to management process of production, raw materials, and waste, which will help them improve their waste management status and reduce any risk in their facility that could be able to decrease company's expenditure and increase their production efficiency.

2.3. Benefit to the Public

Regarding to the principle of agenda 21 stating that "communities and workers have right to access information on chemical risks and have its origin in a straightforward notion" means that those who are potentially exposed to risks from chemical are entitle to known about these risks so they can make informed choices and take appropriate actions. Thus, PRTR is the significant tool for ensuring community and workers can access information.

Moreover, PRTR data is very useful in helping public access all kinds of information which relevant to harmful environmental impacts like chemical or hazard waste disposal so that the public will able to participate in making decision with government in order to reach to pollution prevention, as well as, to reduce the harmful health effect to the human as well.

3. Target of the Manual

This manual is aimed:

- To provide procedures to enable users to compile emission database that meet quality criteria for transparency, consistency, completeness
- To provide estimation methods and emission factors for database compiler

3.1. Reporting Threshold and Emission

The list of type of pollutants and chemicals released and transferred into the environment that the production establishment oblige to report could be founded in the **Table 3** and **Table 4** in **Section 5.3 of Basic Release Estimation Technique Manual** or in the **Annex 2 and Annex 3 of the Sub-Decree on Management of Pollutant Release and Transfer Register**.

Table 1: List of the potential chemicals and pollutants from coal power plant.

No	Parameters	Source of Emission	How it happens
1	CO	Source of Emission	How it happens
2	SO _x	Boiler	Combustion
3	NO _x	Boiler	Combustion
4	PM	Boiler	Combustion
5	BOD ₅	Coal handling	Raw material preparation, Crushing
6	Chlorine Free	Coal washing and exhausting stream	Washing and condensing
7	COD	Coal washing and exhausting stream	Washing and condensing
8	Total Dissolved Solids	Coal washing and exhausting stream	Washing and condensing
9	Total Suspended Solid	Coal washing and exhausting stream	Washing and condensing
10	Sulfur(S)	Storage ash, crushing, bottom ash	Processing, combustion
11	Arsenic(As)	Storage ash, crushing, bottom ash	Processing, combustion
12	Mercury(Hg)	Storage ash, crushing, bottom ash	Processing, combustion
13	Selenium(Se)	Storage ash, crushing, bottom ash	Processing, combustion

4. General Process of Coal Power plant Production

4.1. Production Process of Coal Power Plant

In general, the coal power plant which is a power plant used coal for generating electricity, normally consists of a three main steps as following as in *Figure 1*.

(1). *First Step*

This primary procedure is a step which is a raw material processing and treatment chemical waste and other materials of generation for electricity. Coal is a main raw material for electricity production and should be washed before using as burning. On the other hand water is also treated and neutralized. Water is pumped from water resource and filtrated by mechanic method to remove waste and treat the hard water. The treated water is continuously pumped by the Deming Water Treatment system to reduce or remove some inorganic chemicals for power plant processing. This wasted processing may result in fugitive particulate emission into water and land from the raw materials.

(2). *Second step*

This second step is a starting procedure for firing coal as an energy which was changed steam to electricity generation by turbine. Energy change was applied in an oven system of factories. Before the raw material (as coal) was burned in oven system it was transferred into the coal handling system of the factories which is a system where coal was washed and grinded to be a powder. After grinding, it was transferred and stored in a coal Bunker for identify the coal composition and then it was transferred into another bunker for burning with exist oxygen. There is huge amount of carbon dioxide and heat emitted to the air and surrounding.

(3). *Third Step*

The heat energy was produced from coal bunker burning, made boiling water then the steam was occurred within high pressure . The steam was flowed into a tube to increase higher pressure toward a turbine for fan motion. The motion turbine made the rotor for electricity generation.

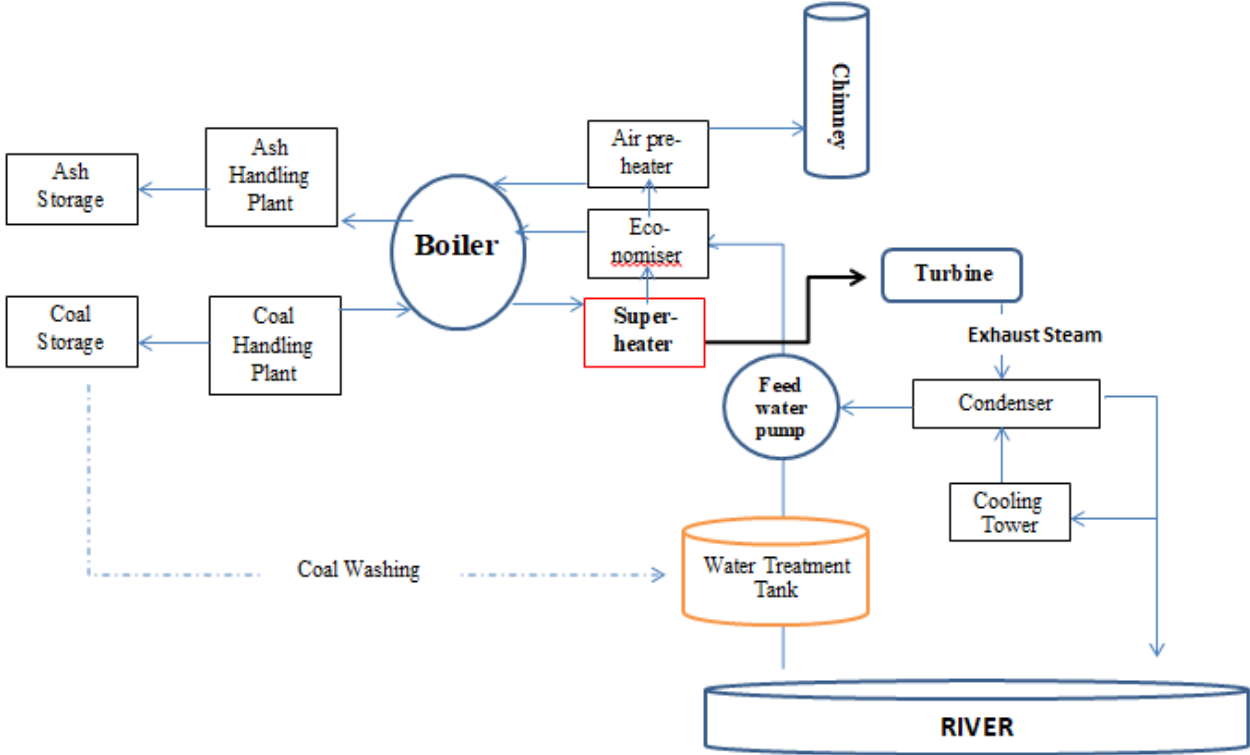


Figure 1: Schematic coal power plant to generate the electricity

4.2. Emission source and pollutant control

There are various type of fossil fuel electric power, thus his section examines the emissions to the destination of air, land and water from coal electric power generation facilities. When reporting to the destination of pollutant emissions needs to be determined.

4.2.1. Emission to the Air

Emissions to air can be categorized as either point sources, such as stacks, or fugitive sources, such as stockpiles. The major emission to air include carbon monoxide (CO), nitrogen oxide (NO_x), sulfur dioxide (SO₂), carbon dioxide (CO₂) and water vapor.

Sources of emission to air for fossil fuel electric power generation include:

- Coal combustion products (from stacks);
- Fugitive emissions from coal stockpiles and handling equipment;
- Fugitive emission from ash storage;
- Additives used for water treatment;
- Solvents used for degreasing metal components

Table 2: Type of pollutants released into air

No	Parameter	Source of Emission	How it happens
1	CO	Boiler	Combustion
2	SO _x	Boiler	Combustion
3	NO _x	Boiler	Combustion
4	PM	Coal handling	Raw material Preparation, Crushing

4.2.2. Emissions to Water

There is currently no emission factors included for emissions to water. Sources of emissions to water are primarily from steam cycle facilities and can include:

- Ash transport wastewater and discharge from wet ash dams;
- Boiler and cooling tower blow down;
- Coal stockpile run off;
- Floor drains;
- Metal and boiler cleaning waste (gas and water sides); and
- Water treatment facility discharges.

Table 3: Type of pollutants released into water

No	Test Parameters	Source emission	How it happen
1	BOD 5	Coal washing and exhausting stream	Washing and condensing
2	Chlorine Free	Coal washing and exhausting stream	Washing and condensing
3	COD	Coal washing and exhausting stream	Washing and condensing
4	Total Dissolved Solids	Coal washing and exhausting stream	Washing and condensing
5	Total Suspended Solids	Coal washing and exhausting stream	Washing and condensing

4.2.3. Emissions to Land

Emissions to land are to the land on which the facility is located. Emissions to land include solid wastes (follow to the Sub-degree on Solid Waste Management), slurries, sediments, liquid spills and leaks, and chemicals used to control various environmental issues where these chemicals should be qualified by Ministry of Environment. These emission sources can be broadly categorized as: groundwater; Surface impoundments of liquids and slurries; and unintentional leaks and spills.

Table 4: Type of pollutants released into land

No	Parameters	Source emission	How it happen
1	Sulfur(S)	Storage ash, crushing, bottom ash	Processing, combustion
2	Arsenic(As)	Storage ash, crushing, bottom ash	Processing, combustion
3	Mercury(Hg)	Storage ash, crushing, bottom ash	Processing, combustion
4	Selenium(Se)	Storage ash, crushing, bottom ash	Processing, combustion

5. Release estimation techniques

There are various types of emission estimation techniques (EETs) that may be used to estimate emissions from each facility. They are Direct Measurement, Mass Balance, Emission Factors, Engineering Calculation, so on.

5.1. Direct Measurement

In a place of emission can be calculated from this data using Equations (1) or (2) below. Stack tests for Ministry of Environment reporting should be performed under representative operating conditions, and in accordance with the methods, or standards, approved by the relevant environmental authority. However, the acceptability of using existing monitoring program data and test methods should be checked with your local environmental regulatory authority. This Section shows how to calculate emissions in kg/hr based on stack sampling data.

Equation 1: Calculation of PM concentration

$$C_{PM} = C_f / V_{m,STP}$$

Where:

$$\begin{aligned} C_{PM} &= \text{concentration of PM}_{10} \text{ or gram loading (g/m}^3\text{)} \\ C_f &= \text{filter catch (g)} \\ V_{m,STP} &= \text{metered volume of sample at STP (m}^3\text{), dry.} \\ STP &= \text{standard temperature and pressure. 1 atmosphere (101.325) kPa} \\ &\quad \text{and 273 degrees Kelvin.} \end{aligned}$$

(The mass concentration of a gas (C gas) is obtained directly by measurement results in units g/m³, or converted from units such as g/m³, or parts per million by volume (ppmv), which may be on a wet or dry basis.)

Equation 2: Calculation of PM₁₀ concentration

$$E_{PM10} = C_{PM} \times Q_d \times 3.6$$

Where:

$$\begin{aligned} C_{PM10} &= \text{hourly emissions of PM}_{10} \text{ in kg/hr} \\ Q_d &= \text{stack gas volumetric flow rate (m}^3\text{, STP,dry/s)} \\ 3.6 &= \text{3,600 seconds per hour multiplied by 0.001 kilograms per gram} \end{aligned}$$

Example 1: Estimating PM₁₀ and PM_{2.5} emission factors from monitoring information

PM₁₀ emissions calculated using **Equation 1** and **Equation 2**, and the stack sampling data based on USEPA Method 201A, for the following monitoring information:

$$\begin{aligned} \text{Total sampling time} &= 7,200 \text{ sec} \\ \text{Moisture collected} &= 395.6 \text{ g} \\ \text{PM}_{2.5} \text{ cyclone (} C_{pm2.5}\text{)} &= 0.01 \\ \text{PM}_{10} \text{ cyclone (} C_{pm10}\text{)} &= 0.05 \\ \text{Filter catch (} C_f\text{)} &= 0.0851 \text{ g} \\ \text{Average sampling rate} &= 1.67 \times 10^{-04} \text{ m}^3 \text{ STP, dry/s} \\ \text{Standard metered volume (} V_{m,STP}\text{)} &= 1.185 \text{ m}^3 \text{ STP, dry} \\ \text{Volumetric flow rate (} Q_d\text{)} &= 8.48 \text{ m}^3 \text{ STP, dry/s} \\ \text{Exhaust gas temperature} &= 25^\circ\text{C \{298K\}} \end{aligned}$$

$$\begin{aligned} C_{Total PM} &= (C_f + C_{pm10} + C_{pm2.5}) / V_{m,STP} \\ &= (0.085 + 0.05 + 0.01) / 1.185 \\ &= 0.122 \text{ g/m}^3 \text{ STP, dry} \end{aligned}$$

$$\begin{aligned} E_{Total PM} &= C_{Total PM} \times Q_d \times 3.6 \\ &= 0.122 \times 8.48 \times 3.6 \\ &= 3.74 \text{ kg/hr} \end{aligned}$$

$$C_{PM10} = (C_{pm10}) / V_{m,STP}$$

$$\begin{aligned}
&= (0.05) / 1.185 \\
&= 0.042 \text{ g/m}^3 \text{ STP, dry} \\
E_{pm10} &= C_{PM10} \times Qd \times 3.6 \\
&= 0.042 \times 8.48 \times 3.6 \\
&= 1.29 \text{ kg/hr} \\
C_{PM2.5} &= (C_{pm2.5}) / Vm, \text{ STP} \\
&= (0.01) / 1.185 \\
&= 0.008 \text{ g/m}^3 \text{ STP, dry} \\
E_{pm2.5} &= C_{PM2.5} \times Qd \times 3.6 \\
&= 0.008 \times 8.48 \times 3.6 \text{ 0.26 kg/hr}
\end{aligned}$$

To convert actual exhaust flows into STP, use the below **Equation 3**.

Equation 3: Calculation of gas flow rate

$$Q_d = Q_a \times (1 - MC/100) \times (273 / (T + 273)) \times (P_s / 101.325)$$

Where:

$$\begin{aligned}
Q_d &= \text{stack gas volumetric flow rate (m}^3 \text{ STP, dry/s)} \\
Q_a &= \text{actual gas volumetric flow rate (m}^3 \text{/s)} \\
MC &= \text{moisture content of stack gas (\% by volume)} \\
T &= \text{actual stack gas temperature (}^\circ\text{C)} \\
P_s &= \text{Absolute stack gas pressure (kPa)}
\end{aligned}$$

The most appropriate method for determining emissions to the environment via wastewater is to use direct measurement. However, you may use other EETs, particularly mass balances, for the purposes of reporting to the Ministry of Environment. While discharges waste to groundwater or pollute the area of industrial or factory, are generally not allowed by environmental legislation, the owner has to reset the emission infrastructure and then reports to the Ministry

5.1.1. Using CEMS Data

This method is used to monitor SO₂, NO_x, Total VOCs, and CO emissions using a CEMS, you use a pollutant concentration monitor that measures concentration in parts per million by volume dry air (ppmvd). Flow rates should be measured using a volumetric flow rate monitor. Emission rates (kg/hr) are then calculated by multiplying the stack gas concentrations by the stack gas flow rates. While it is possible to determine from this data the total emissions of an individual pollutant over a given time period (assuming the CEM operates properly all year long), an accurate emission estimate can be derived by adding the hourly emission estimates if the CEMS data is representative of typical operating conditions.

It is important to note that prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies the facility's territory environment authority.

Equation 4: Calculating the hourly emission of pollutants

$$E_i = (C_i \times MW \times Q \times 3,600) / (V \times 1,000,000)$$

Where:

$$\begin{aligned}
E_i &= \text{emissions of pollutant } i, \text{ kg/hr} \\
C_i &= \text{pollutant concentration in ppmvd} \\
MW &= \text{molecular weight of the pollutant (kg/kg-mole)} \\
Q &= \text{stack gas volumetric flow rate in m}^3 \text{ (STP, dry)/s} \\
3,600 &= \text{3,600 seconds per hour} \\
V &= \text{volume occupied by one mole of gas at standard temperature and pressure} \\
&\quad (22.4 \text{ m}^3 \text{/kg-mole at } 0^\circ\text{C and 1 atm)}
\end{aligned}$$

This may be applied to each hour that CEMS data is available for a year, and modified to account for time CEMS data is unavailable (weighted by load).

Alternatively, a estimation of emissions in kilograms per year can be calculated by multiplying the emission rate in kg/hr, by the number of actual operating hours (OpHrs) as shown in Equation (5) and Example 2.

Equation 5: Calculating the annual emission of pollutants

$$E_{kpy,i} = (E_i \times OpHrs)$$

Where:

$$E_{kpy,i} = \text{annual emissions in kg/year of pollutant } i$$

$$E_i = \text{hourly emissions in kg/hr of pollutant } i$$

$$OpHrs = \text{annual operating hours in hr/yr}$$

Emissions in kilograms of pollutant per tonne of fuel consumed can be calculated by dividing the emission rate in kg/hr, by the fuel consumption rate (tonnes/hr) during the same period (Equation (6)) as shown below. It should be noted that the emission factor calculated below assumes that the selected time period (that is, hourly) is representative of annual operating conditions. Use of the calculation is shown in Example 2

Equation 6: Calculating the emission of pollutants per fuel consumption

$$(E_{kpt,i})_1 = E_i / AR_{hr}$$

Where:

$$(E_{kpt,i})_1 = \text{emissions of pollutant } i \text{ per ton of fuel oil consumed, kg/tonne}$$

$$E_i = \text{hourly emissions of pollutant } i, \text{ kg/hr}$$

$$AR_{hr} = \text{fuel oil consumption, tons/hr}$$

Table 5: Example CEM Output Averaged for a Power Facility Firing Fuel Oil

Measurement	O ₂ (%V)	Concentration (C) (ppmv)				Gas Flow Rate (Q) (m ³ _{stp,dry} /s)	Oil Use Rate (ARhr) (tonnes/ hour)
		SO ₂	NO _x	CO	TVOCs		
1	10.3	150.9	14.9	42.9	554.2	8.52	290
2	10.1	144.0	145.7	41.8	582.9	8.48	293
3	11.8	123.0	112.7	128.4	515.1	8.85	270

Example 2: Estimating sulfur dioxide emissions using CEMS data

This example shows how SO₂ emissions can be calculated using Equation (4) based on the average CEMS data for Time Period 1 shown in the Table 3.

$$E_{SO_2} = (C \times MW \times Q \times 3\,600) / (V \times 1.0 \times 10^6)$$

$$C = 150.9 \text{ ppmv}$$

$$MW = 64$$

$$Q = 8.52 \text{ m}^3_{\text{stp, dry}}/\text{s}$$

$$V = 22.4 \text{ m}^3/\text{kg-mole}$$

$$E_{SO_2} = (150.9 \times 64 \times 8.52 \times 3\,600) / (22.4 \times 10^6)$$

$$= 296\,217\,907 / 22\,400\,000$$

$$= 13.22 \text{ kg/hr}$$

For time Period 2

$$E_{SO_2} = 12.56 \text{ kg/hr}$$

For time Period 3

$$E_{SO_2} = 11.2 \text{ kg/hr}$$

Say representative operating conditions for the year are:

$$\text{Period 1} = 1,500 \text{ hr}$$

Period 2 = 2,000 hr

Period 3 = 1,800 hr

Total emissions for the year = $(13.22 \times 1500) + (12.56 \times 2000) + (11.2 \times 1800)$ kg

E_{kpy,SO_2} = 65 110 kg/yr

Emissions, in terms of kg/tonne of oil consumed for time period 1, are calculated using equation 6.

E_{kpt,SO_2} = $E_{SO_2} / ARhr$
= $13.22 / 290$
= 4.56×10^{-2} kg SO_2 emitted per tonne of fuel oil consumed

5.1.2. Using Fuel Analysis Data

This analyzed method can be used to predict SO_2 , metals and metal compounds, and other emissions based on application of mass conservation laws.

It is important if using fuel analysis data to ensure that data are collected and reported in an approved and consistent manner from representative fuel samples. All data analysis should be relevant to legislative law about the pollution sectors of Ministry of Environment.

The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process. The basic equation used in fuel analysis emission calculations is the following equation:

Equation 7: Calculating the annual emission of pollutants

$E_{kpy,i}$ = $Q_f \times C_i \times (MW_p / EW_f) \times 10^{-6} \times OpHrs$

Where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr
 Q_f = fuel use (kg/hr)
 C_i = pollutant concentration in fuel – ppm or mg/kg
 MW_p = molecular weight of pollutant emitted (kg/kg-mole)
 EW_f = elemental weight of pollutant in fuel (kg/kg-mole)
 $OpHrs$ = annual operating hours in hr/yr

For instance, sulfur dioxide emissions from oil or coal combustion can be calculated based on the concentration of sulfur in the oil or coal. This approach assumes complete conversion of sulfur to sulfur dioxide. Therefore, for every kilogram of sulfur ($EW = 32$) burned, two kilograms of SO_2 ($MW = 64$) are emitted. The application of this EET is shown in Example 3.

Example 3: Estimating sulfur dioxide emissions using fuel analysis data

This example shows how SO_2 emissions can be calculated from oil combustion, based on fuel analysis results, and the fuel use information. The power station is assumed to operate 150 hours per year on oil and the sulfur content of the oil is 1.17% (11,700 ppm). E_{kpy, SO_2} can be calculated.

Assume:

Q_f = 2,000 kg/hr
 C_i = 11,700 ppm
 $OpHrs$ = 150 hr/yr
 E_{kpy,SO_2} = $Q_f \times C_i \times (MW_p / EW_f) \times 1.0E-06 \times OpHrs$
= $(2,000) \times 11,700 \times (64 / 32) \times 10^{-6} \text{ kg/hr} \times OpHrs$
= $46.8 \text{ kg/hr} \times 150 \text{ hr/yr}$
= $7.0 \times 10^3 \text{ kg/year or } 7,000 \text{ kg}$

5.2. Mass Balance

To assist in estimating emissions of some elements, the following information on behavior during combustion is relevant. The following summarizes the characteristics of the three classes.

- **Class I:** Elements which are concentrated in the coarse residues (bottom ash) or are partitioned equally between coarse residues and fly ash which is generally trapped by the particulate control systems.
- **Class II:** Elements concentrated more in the fly ash compared with coarse residues. Also enriched in fine-grained particles that may escape the particle control systems.
- **Class III:** Elements which volatilize most readily. They may be concentrated in the vapor phase and depleted in the solid phases.

Some substances as boron & compounds, mercury & compounds, fluorine compounds, chlorine and selenium & compounds may be emitted substantially in the gas phase: that is these five substances generally fall into Class III or are intermediate between Classes II and III. For these substances, it may be worth analyzing ash as well as coal samples to enable emissions to be determined via mass balance approach.

Equation 8: Calculating the emission of pollutant to air

$$E_{\text{kg/ton}} = \{C_i - [(A \times F \times CF) + (A \times B \times CB)]\} \times 1,000$$

Where:

E	=	emission of substance to air (kg/ton)
C_i	=	concentration of element (substance) in coal (ppm or mg/kg)
A	=	weight fraction of ash in coal (as received)
F	=	fly ash fraction of total ash
B	=	bottom ash fraction of total ash
CF	=	fly ash concentration of element (substance) (ppm or mg/kg)
CB	=	bottom ash concentration of element (substance) (ppm or mg/kg)

Where possible, attempts should be made to ensure that the ash and coal samples analyzing are derived from the source coal.

Example 4: Estimating fluoride compounds emissions based on fluoride levels in coal and ash

This example shows how fluoride compounds emissions can be calculated using a mass balance approach.

$$E_{\text{kg/ton HF}} = \{C - [(A \times F \times CF) + (A \times B \times CB)]\} \times 10^{-3}$$

Where:

C	=	250 mg fluoride / kg of coal
A	=	0.20
F	=	0.9
CF	=	500 mg fluoride /kg of coal
B	=	0.1
CB	=	50 mg/kg of bottom ash
$E_{\text{kg/tons}}$	=	$\{250 - [(0.20 \times 0.9 \times 500) + (0.2 \times 0.1 \times 50)]\} \times 10^{-3}$
$E_{\text{kg/tons}}$	=	$\{250 - (90 + 1)\} \times 10^{-3}$
$E_{\text{kg/ton HF}}$	=	0.159 kg/ton

5.3. Emission Factors

Emission factors usually relate the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors should be relevant to Ministry of Environment (Cambodia) which are usually expressed as the weight of a substance emitted for a unit mass, volume, distance, or duration of the activity emitting the substance (e.g. kilograms of sulfur dioxide emitted per ton of coal fired).

When available, it is preferable to use facility-specific information (e.g. monitoring data) for emission estimation. Emission factors are used to estimate a facility's emissions by the general equation:

Equation 9: Calculating the emission rate of pollutants

$$E_{\text{kgpy},i} = AR \times EFi \times [1 - (CEi/100)]$$

Where:

- $E_{kpy,i}$ = emission rate of pollutant i , kg/yr
- AR = activity rate (fuel use), t/yr ($AR = t/hr \times Ophrs$)
- $Ophrs$ = operating hours, hr/yr
- E_{Fi} = uncontrolled emission factor of pollutant i , kg/t
- CE_i = overall control efficiency for pollutant i , %.

Emission factors developed from measurements for a specific power station or process can sometimes be used to estimate emissions at other sites. If a company has several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources. The emission factor must be approved by the provincial Department of Environment or Ministry of Environment.

Emission factors are commonly available for emissions to air, but currently are rarely available for emissions to water or land. There are currently no emission factors for emissions to land. It is recommended that other EETs, particularly direct measurement and mass balance, be applied to these emissions.

5.4. Engineering Calculation

There are engineering equations available to enable emissions of a number of trace metals and metal compounds, from black and brown coal combustion, to be estimated with a high degree of confidence. The advantage of these emission equations over simple generic emission factors is that they require the input of facility-specific information relating to fuel type and operating conditions. The form of the emission equations is shown in **Equation 10**.

Equation 10: Calculating the emission factor for substances

$$E_{kg/PJ} = K \times [(C/A) \times PM]^e \text{ kg/PJ}$$

Where:

- $E_{kg/PJ}$ = emission factor for substance
- K = a constant
- C = concentration of metal in the coal, part per million by mass (as received basis)
- A = weight fraction of ash in the coal. (10% ash is 0.1 ash Fraction)
- e = an exponent
- PM = facility-specific emission factor for total particulate matter (kg/GJ) i.e. particulate matter emitted per GJ heat input.

Equation 11: Calculating the weight of PM per GJ energy

$$PM_{kg/GJ} = A \times F \times ER \times 1,000/SE$$

Where:

- $PM_{kg/GJ}$ = weight of particulate mater per GJ
- A = weight fraction of ash in coal
- F = fly ash fraction of total ash
- ER = fraction of fly ash emitted
- SE = specific energy GJ/ton as received

Example 5: Engineering calculations to estimate cadmium & compounds emissions from coal combustion.

This example shows how cadmium & compounds emissions can be calculated using the relevant emission equation.

$$E_{kg/PJ Cd} = 2.17 \times [(C/A) \times PM]^{0.5}$$

Where:

- C = 0.5 mg/kg
- A = 0.2 (20% ash)

$$\begin{aligned}
F &= 0.9 \text{ (90\% fly ash)} \\
CE &= 99.8\% \text{ (default for fabric filters)} \\
ER &= 1 - 99.8/100 \\
&= 0.002 \\
SE &= 24 \text{ GJ/ton} \\
PM &= 0.2 \times 0.9 \times 0.002 \times 1000 / 24 \\
&= 0.015 \text{ kg/GJ} \\
E_{\text{kg/PJ Cd}} &= 2.17 \times [(0.5/0.2) \times 0.015]^{0.5} \\
&= 0.42 \text{ kg cadmium \& compounds/PJ}
\end{aligned}$$

6. Control Technologies

Emission control technologies commonly used in the Cambodia coal power plant generation industry are considered below: these technologies are combined with environmental management systems on many sites to reduce the overall adverse environmental impact of coal power plant electric power generation.

New combustion technologies such as coal gasification and fluidised bed combustion, are still in the developmental stage for electricity generator in Cambodia. Also, since Cambodia coal are relatively low in sulfur, flue gas desulfurization has not been required.

Cogeneration, describing, improves the efficiency of fuel utilization. Cogeneration plants, generally using natural gas, and has been developed in Cambodia where suitable use for the heat is available.

6.1. Control Technologies for Air Emission

Control of air emissions from coal power plants electric power generation may be considered as:

- Pre-combustion (fuel treatment)
- Combustion control; and
- Post-combustion

Pre-combustion processes relate to the “cleaning” of undesirable substances from the fuel prior to combustion. This could also include the selection of fuels that can result in reduced emission of particular substance, such as low sulfur coal. Pre-combustion processes have limited application for Cambodia coal power plant electric power generation.

Combustion control process generally related to the control of oxides of nitrogen (NO_x) and carbon monoxide (CO) by control flame temperature and fuel /air ratio to ensure completed combustion. Common techniques include low NO_x burners, and the use of over fire air.

Post-combustion processes used in Cambodia primarily related to the control of particulate matter. Generally, this is achieved by the use of electrostatic precipitators and fabric filters (baghouses). Collection efficiencies commonly exceed 90% of input particulate load.

6.2. Control Technologies for Water Emission

Water emission include discharged from boiler water demineralizing plant, cooling water blowdown, ash transport water, and floor and site drainage.

A range of techniques is used to reduce the adverse environmental impact of water discharge example of such techniques include.

- Neutralizing of acid discharge
- Dense-phase ash transport (no ash transport water to discharge of);
- Impoundment of site drainage, i.e. Settling ponds ;
- “zero discharge “operation by evaporating excess water;
- Use of marine disposal for saline water;
- Control of floor drains discharges via oil and silt interceptor ;
- Mechanical condenser cleaning system; and
- Chemical substitution, i.e. non solvent cleaning techniques.

6.3. Control Technologies for Land Emissions

Land discharges are limited to waste material and ash (for coal fired plant). Control techniques include:

- Utilization of fly ash for cement products;
- Controlled waste landfill or disposal off-site;
- Wet ash dams (not impacted by wind erosion);Nara
- Twin ash dams (ash disposed landfill or mine overburden areas); and
- Bunding of oil and chemical storage (reduce the risk of spillage to soil).

Reference