ASSESSMENT OF AIR QUALITY IMPACTS OF FOSSIL FUELS AT STEAM POWER PLANTS

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WHAT IS AQIA?

(AQIA), in general, is defined as the identification of future consequences of a current or proposed action on air quality.
Scientific and Technical Credibility of AQIA

- Address environmental impacts
- Systematically analyze air impacts and consequences
- Determine monitoring requirements
- Recommend preventive and corrective mitigating measures
AQIA METHODS

- Qualitative Approaches
  Depend Heavily on Expert Judgment

- Quantitative Approaches
  Air Quality Monitoring:
  - Ambient air
  - Source emissions

  Air Quality Modeling
AIR POLLUTION

- Contamination of air by harmful substances such as oxides of
  - Sulfur
  - Nitrogen

Or suspended particulate matter
Current PME Ambient Air Quality Standards (µg/m³)

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>SO₂</th>
<th>PM&lt;sub&gt;10&lt;/sub&gt;</th>
<th>NO₂</th>
<th>CO</th>
<th>H₂S</th>
<th>F-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>730  (a)</td>
<td>660  (a)</td>
<td></td>
<td>40,000 (a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-Hour</td>
<td></td>
<td></td>
<td></td>
<td>10,000 (a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Hour</td>
<td>365  (b)</td>
<td>340  (b)</td>
<td></td>
<td></td>
<td>40  (b)</td>
<td></td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Annual</td>
<td>80</td>
<td>80</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PME Air Pollution Source Standards

Source standards for combustion facilities that are equal to or greater than 30 MW (100 MMBtu/h) are as follows:

<table>
<thead>
<tr>
<th>Emission component</th>
<th>Allowable Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gas</td>
</tr>
<tr>
<td>Sulfur Dioxide µg/j</td>
<td>1.0</td>
</tr>
<tr>
<td>Nitrogen Oxides ng/J</td>
<td>86</td>
</tr>
<tr>
<td>Particulates ng/J</td>
<td>43</td>
</tr>
</tbody>
</table>
Purpose of Air Quality Standards

To prevent adverse effects on human health, vegetation, animal health, and environment as a whole.
NOx cycle

nitrogen oxide sources such as combustion, lightning, transport from the stratosphere, NH$_3$ oxidation

- HOO$^-$ + NO $\rightarrow$ NO$_2$ + HO$^-$
- ROO$^-$ + NO $\rightarrow$ NO$_2$ + RO$^-$
- HO$^-$ + NO$_2$ $\rightarrow$ HNO$_3$
- HO + NO$_2$ $\rightarrow$ $\cdot$ + HNO$_3$
- NO + O$_3$ $\rightarrow$ NO$_2$ + O$_2$
- O + NO $\rightarrow$ $\cdot$ + NO$_2$

washout with precipitation
The study area is located in the Power Plant North on the Arabian Gulf coast in a remote area. The study area is about 20km wide and 20km long.
## EPA Preventive Significant Deterioration (PSD) Increments ($\mu g/m^3$)

<table>
<thead>
<tr>
<th>Type</th>
<th>Time</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM</td>
<td>Annual</td>
<td>5</td>
<td>19</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>24-hr</td>
<td>10</td>
<td>37</td>
<td>75</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Annual</td>
<td>2</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>24-hr</td>
<td>5</td>
<td>91</td>
<td>182</td>
</tr>
<tr>
<td></td>
<td>3hr</td>
<td>25</td>
<td>512</td>
<td>700</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>Annual</td>
<td>2.5</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>
OBJECTIVES

The main objective of this study is to make an air quality impact assessment due to typical thermal power plant stack emissions by estimating the ground-level concentrations of air pollutants using a non-steady state air dispersion model.
Specific Procedures

1. To establish baseline data concerning the meteorology and present air quality in the area of study based on the US EPA AP-42 emission factors.

2. To conduct air quality dispersion model using the collected meteorological data in order to portray the plume dispersion patterns of air pollution.

3. To evaluate the predicted emissions of air contaminants from firing different types of fossil fuels and compare the results with the PME Standards.

4. To recommend practicable mitigation measures.
Research Methodology

1. **Establish Baseline Assessment**
   - Collect Ambient Air Quality data
   - Prepare Meteorological Input data

2. **Define Source Emissions Parameters**

3. **Perform Air Quality Modeling**

4. **Determine compliance with PME Standards**
BASELINE AIR QUALITY

On site one-year Air Quality Data were collected for

\( \text{SO}_2, \text{NO}_2, \text{and PM}_{10} \)
## Summary of Monthly SO₂ Data

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Concentration</th>
<th>Hourly Max Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ppb)</td>
<td>(µg/m³)</td>
</tr>
<tr>
<td>Oct 06</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Nov 06</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Dec 06</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Jan 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Feb 07</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Mar 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Apr 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>May 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Jun 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Jul 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Aug 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Sep 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Oct 07</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>
## Summary of Monthly $\text{NO}_2$ Data

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Concentration</th>
<th>Hourly Max Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ppb)</td>
<td>(µg/m³)</td>
</tr>
<tr>
<td>Oct 06</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Nov 06</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Dec 06</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Jan 07</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Feb 07</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Mar 07</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Apr 07</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>May 07</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Jun 07</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Jul 07</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>Aug 07</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Sep 07</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Oct 07</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Mean</td>
<td>7</td>
<td>14</td>
</tr>
</tbody>
</table>
## Summary of 24-Hour PM$_{10}$ Data

<table>
<thead>
<tr>
<th>Date</th>
<th>Concentration (µg/m$^3$)</th>
<th>Date</th>
<th>Concentration (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>05 Oct,06</td>
<td>587</td>
<td>04 March,07</td>
<td>471</td>
</tr>
<tr>
<td>11 Oct,06</td>
<td>52</td>
<td>10 March,07</td>
<td>867</td>
</tr>
<tr>
<td>17 Oct,06</td>
<td>53</td>
<td>16 March,07</td>
<td>140</td>
</tr>
<tr>
<td>23 Oct, 06</td>
<td>52</td>
<td>22 March,07</td>
<td>122</td>
</tr>
<tr>
<td>29 Oct, 06</td>
<td>42</td>
<td>28 March,07</td>
<td>120</td>
</tr>
<tr>
<td>04 Nov,06</td>
<td>21</td>
<td>07 Apr., 07</td>
<td>90</td>
</tr>
<tr>
<td>10 Nov,06</td>
<td>26</td>
<td>16 Apr., 07</td>
<td>119</td>
</tr>
<tr>
<td>16 Nov,06</td>
<td>647</td>
<td>17 Apr., 07</td>
<td>160</td>
</tr>
<tr>
<td>22 Nov,06</td>
<td>216</td>
<td>22 Apr., 07</td>
<td>156</td>
</tr>
<tr>
<td>29 Nov,06</td>
<td>41</td>
<td>29 Apr., 07</td>
<td>173</td>
</tr>
<tr>
<td>06 Dec,06</td>
<td>41</td>
<td>04 May,07</td>
<td>332</td>
</tr>
<tr>
<td>10 Dec,06</td>
<td>1226</td>
<td>10 May,07</td>
<td>158</td>
</tr>
<tr>
<td>15 Dec,06</td>
<td>159</td>
<td>16 May,07</td>
<td>112</td>
</tr>
<tr>
<td>21 Dec,06</td>
<td>31</td>
<td>22 May,07</td>
<td>204</td>
</tr>
<tr>
<td>27 Dec,06</td>
<td>16</td>
<td>28 May,07</td>
<td>70</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>160</strong></td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSIONS of Baseline Air Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SO$_2$ (µg/m$^3$)</th>
<th>NO$_2$ (µg/m$^3$)</th>
<th>PM$_{10}$ (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Mean</td>
<td>6</td>
<td>14</td>
<td>160</td>
</tr>
<tr>
<td>STANDARD</td>
<td>80</td>
<td>100</td>
<td>80</td>
</tr>
</tbody>
</table>

- Particulate Concentrations were found to be high on occasion due to naturally dusty environment.
- Particulate Concentrations were generally < 100 (µg/m$^3$) for 24-hour average.
Maximum 1-Hour SO₂ Concentration

Natural Gas

SO₂ Emission 0.82 MTPD
RESULTS AND DISCUSSIONS

All observed hourly and daily pollutant concentrations are less than current PME standards. With some exception for Particulate matter.
Baseline Meteorology

Meteorological parameters
Include
Wind speed, Wind direction
Temperature
Dew point temperature
Stability and Mixing height
Annual Wind Rose for the Study Area

- Hourly wind speed ranged between 1 to 5 m/s
- Wind speed > 11 m/s occurred less than 1% of the time
- Annual wind speed 4.5 m/s from northwest
Monthly Temperature Profile

- **Temperature (deg. C)**
  - Max
  - Mean
  - Min

- **Month**
  - Oct
  - Nov
  - Dec
  - Jan
  - Feb
  - Mar
  - Apr
  - May
  - Jun
  - Jul
  - Aug
  - Sep
  - Oct
# Pasquill Chart – Atmospheric Stability

<table>
<thead>
<tr>
<th>Atmospheric Stability Class</th>
<th>Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Extremely unstable</td>
</tr>
<tr>
<td>B</td>
<td>Unstable</td>
</tr>
<tr>
<td>C</td>
<td>Slightly unstable</td>
</tr>
<tr>
<td>D</td>
<td>Neutral</td>
</tr>
<tr>
<td>E</td>
<td>Slightly stable</td>
</tr>
<tr>
<td>F</td>
<td>Stable to extremely stable</td>
</tr>
</tbody>
</table>

## Day Incoming Solar Radiation

<table>
<thead>
<tr>
<th>Surface Wind Speed (m/s)</th>
<th>Strong</th>
<th>Moderate</th>
<th>Slight</th>
<th>&gt; 4/8 Low</th>
<th>&lt;3/8 Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2</td>
<td>A</td>
<td>A-B</td>
<td>B</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>2-3</td>
<td>A-B</td>
<td>B</td>
<td>C</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>3-5</td>
<td>B</td>
<td>B-C</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>5-6</td>
<td>C</td>
<td>C-D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>
Baseline Meteorology Results

Meteorological parameters will be used for the air quality dispersion model.
Methodology

All emission rates were calculated using US EPA AP-42 emission factors for Boilers with a heat input capacity greater than 100 MBtu/h
SOURCE CHARACTERIZATION

Assumptions

The specifications of LAC corresponds to ASTM Residual fuel oil of grades 4 or 5,

HAC corresponds to grades 5 or 6.

AP-42 emission factors for grade 4 were used to represent LAC and grade 6 for HAC.
### AP- 42 Emission Factors

<table>
<thead>
<tr>
<th></th>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{2}</th>
<th>PM\textsubscript{tot}</th>
<th>PM\textsubscript{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LAC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emission Factor (lb/10\textsuperscript{3} gal fuel)</td>
<td>Emission Factor (g/m\textsuperscript{3} fuel)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>283.5</td>
<td>8.5</td>
<td>7.735</td>
</tr>
<tr>
<td></td>
<td>3,834.8</td>
<td>33,974.3</td>
<td>1,018.6</td>
<td>927.0</td>
</tr>
<tr>
<td><strong>HAC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emission Factor (lb/10\textsuperscript{3} gal fuel)</td>
<td>Emission Factor (g/m\textsuperscript{3} fuel)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32.00</td>
<td>473.36</td>
<td>32.43</td>
<td>29.51</td>
</tr>
<tr>
<td></td>
<td>3,834.8</td>
<td>56,726.3</td>
<td>3,886.1</td>
<td>3,536.4</td>
</tr>
</tbody>
</table>
## Fuel Consumption and Fuel Content

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Fuel Flow</th>
<th>Sulphur Content</th>
<th>H₂S Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m³/h)</td>
<td>(lb/h)</td>
<td>(MMBtu/h)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>155,629</td>
<td>257,724</td>
<td>5,936</td>
</tr>
<tr>
<td>LAC</td>
<td>155</td>
<td>294,211</td>
<td>5,639</td>
</tr>
<tr>
<td>HAC</td>
<td>150</td>
<td>294,211</td>
<td>5,509</td>
</tr>
</tbody>
</table>
### Pollutant Mass Emission Rates

<table>
<thead>
<tr>
<th>Fuel</th>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{2}</th>
<th>PM\textsubscript{tot}</th>
<th>PM\textsubscript{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>125</td>
<td>0.4</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>LAC</td>
<td>165</td>
<td>1,466</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>HAC</td>
<td>160</td>
<td>2,370</td>
<td>162</td>
<td>148</td>
</tr>
</tbody>
</table>
The CALPUFF modelling system was used to predict ambient concentrations of the \( \text{SO}_2, \text{NO}_x, \text{PM}_{10} \) at ground-level.

As there are no air quality standards for PM\(_{\text{tot}}\); predicted PM\(_{\text{tot}}\) concentrations are compared to the air quality standards for \( \text{PM}_{10} \).
## Max. Predicted Concentrations - LAC

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>Maximum Predicted Concentration (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>1-Hour</td>
<td>200</td>
</tr>
<tr>
<td>8-Hour</td>
<td>-</td>
</tr>
<tr>
<td>24-Hour</td>
<td>-</td>
</tr>
<tr>
<td>Annual</td>
<td>5.7</td>
</tr>
</tbody>
</table>
One-Hour $\text{NO}_2$ Concentrations ($\mu g/m^3$)
First One-Hour $\text{SO}_2$ Concentration ($\mu g/m^3$)
24-Hour $\text{PM}_{10}$ Concentrations (µg/m$^3$)

LAC
# Max. Predicted Concentrations - HAC

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>Maximum Predicted Concentration (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>1-Hour</td>
<td>206</td>
</tr>
<tr>
<td>8-Hour</td>
<td>-</td>
</tr>
<tr>
<td>24-Hour</td>
<td>-</td>
</tr>
<tr>
<td>Annual</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Max. Predicted Concentrations for NG and HAC

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>Maximum Predicted Concentration (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>1-Hour</td>
<td>209</td>
</tr>
<tr>
<td>8-Hour</td>
<td>-</td>
</tr>
<tr>
<td>24-Hour</td>
<td>-</td>
</tr>
<tr>
<td>Annual</td>
<td>7.1</td>
</tr>
</tbody>
</table>
CONCLUSIONS OF AIR DISPERSION MODELING

- Emission estimates indicate that current PME ambient air pollution standards will be exceeded for $SO_2$ and $PM_{tot}$ when firing HAC.

- Model results also indicate that ambient $SO_2$ concentrations will not comply with current PME air quality standards for all three scenarios.
3 types of mitigation were assessed to achieve compliance with current Saudi Arabian air quality standards:

- Increasing Stack Height
- Reducing Load
- Implementing Control Technologies.
### CONTROL TECHNOLOGIES (SO₂)

<table>
<thead>
<tr>
<th>Control Technology</th>
<th>Typical Control Efficiencies</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Scrubber</td>
<td>80-95+%</td>
<td>Lime/lime stone; Sodium carbonate; Magnesium hydroxide; Dual alkali</td>
</tr>
<tr>
<td>Spray drying</td>
<td>70-90+%</td>
<td>Calcium hydroxide slurry, vaporizes in spray vessel</td>
</tr>
<tr>
<td>Furnace injection</td>
<td>25-50+%</td>
<td>Dry calcium carbonate/hydrate injection in upper furnace cavity</td>
</tr>
<tr>
<td>Duct injection</td>
<td>25-50+%</td>
<td>Dry sorbent injection into duct,</td>
</tr>
</tbody>
</table>

CEPA: The Canadian Env. Protection Act. March 2005
### Control Technologies (PM$_{tot}$)

<table>
<thead>
<tr>
<th>Control Technology</th>
<th>Typical Control Efficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Scrubber</td>
<td>20-95+%</td>
</tr>
<tr>
<td>Electrostatic Precipitator</td>
<td>20-95+%</td>
</tr>
<tr>
<td>Fabric Filters</td>
<td>99+%</td>
</tr>
</tbody>
</table>

Source: MHI design analysis, 1997
CONCLUSION

✓ Emissions of NOx, SO₂, and PM₁₀ were calculated based on US EPA AP-42 emission factors for three scenarios (LAC, HAC, and NG/HAC).

✓ SO₂ and PM₁₀ emissions for firing HAC will exceed PME ambient air pollution standards.
CONCLUSION

✓ Model results indicate that $SO_2$ will exceed the PME standards for all three scenarios.

✓ The required $SO_2$ emission reduction to meet the PME standards is 46%.

✓ The required $PM_{10}$ emission reduction to meet the PME standards is 65%.

✓ Implementation of Control Technologies is recommended.
THANK YOU!