

Ex-Post Monitoring for Completed ODA Loan Projects

Evaluator: Hiromi Osada (IC Net, Ltd.)

Project Name: United Mexican States: "The Mexico City Sulfur Dioxide Emission Reduction Project" (L/A No. ME-P2)

Loan Outline

Loan Amount/Disbursement Amount: 69,338 million yen/59,889 million yen
Loan Agreement: November 1990
Loan Completion: April 1998
Ex-Post Evaluation: FY 2001
Executing Agency: Petroleos Mexicanos (PEMEX)

Project Objective

By reducing the sulfur content of heavy oil and diesel oil (heavy oil desulfurization, diesel desulfurization) in the Mexico City Metropolitan Area, this project aims to reduce the volume of SO₂ emissions, a substance which causes air pollution, and thereby contribute to improvement in the health of metropolitan area residents.

Consultant: Japan Consulting Institute (Japan)

Contractor: SNAMPROGETTI S.P.A. (Italy) and others

Overview of Results

Item	At time of Ex-post Evaluation	At time of Ex-post Monitoring
Effectiveness/ Impact		A new policy prohibited the use of any form of heavy oil in the metropolitan area (a drastic change of environmental policy by the government, etc.). Also, growth in demand for desulfurized diesel oil was slower than initially forecasted. Thus, the reductions in volume of SO ₂ emissions in the metropolitan area are less than at the time of ex-post evaluation. However, current SO ₂ concentration in the metropolitan area is still at a level below the environmental standard (0.13ppm). Although there

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Effectiveness	<p>(1) Air pollution reduction results (reduction in volume of SO₂ emissions) Two subprojects were implemented (heavy oil desulfurization installation, diesel oil desulfurization installation) which were designed to achieve reductions.</p> <p>1. Subproject A (heavy oil desulfurization installation) [Miguel Hidalgo Refinery] Although the plant itself was installed for the most part according to plan, actual reduction in the volume of SO₂ emissions in the metropolitan area was only about 20% of the planned amount.</p> <ul style="list-style-type: none"> • Plan: 111,000 tons/year reduction → Result: 21,700 tons/year reduced (in the year 2000). <p>(This is mostly because nearly 60% of low sulfur heavy oil produced is consumed outside the Mexico City Metropolitan Area)</p> <p>2. Subproject B (diesel oil desulfurization installation) [Miguel Hidalgo Refinery, Antonio M. Amor Refinery] Actual reductions in volume of SO₂ emissions in the Mexico City Metropolitan Area were above plan, and objectives were achieved.</p> <ul style="list-style-type: none"> • Plan: 17,000 tons/year reduction → Result: 18,430 tons/year reduced (in the year 2000) <p>3. Overall results from project implementation</p>	<p>are minor fluctuations depending on environmental policy requirements, the project has been achieving a certain amount of contribution up to the time of ex-post monitoring.</p> <p>(1) Air pollution reduction results (reduction in volume of SO₂ emissions)</p> <p>1. Subproject A (heavy oil desulfurization installation), Subproject B (diesel oil desulfurization installation)</p> <p>The following table shows actual reduction volumes and percentage of plan achieved. From 2004, the achievement rate was zero for subproject A¹, and was only 36-40% for subproject B. The largest reason for this was sluggish supply of desulfurized oil due to demand growth below initial forecasts.</p> <p style="text-align: center;"><Reductions in SO₂ Emission Volume, 1999-2005> (Unit: Tons/Year)</p> <table border="1" data-bbox="1211 815 2027 1313"> <thead> <tr> <th colspan="2" rowspan="3">Year</th> <th colspan="4">Actual</th> </tr> <tr> <th colspan="2">Total</th> <th colspan="2">In Mexico City Metropolitan Area</th> </tr> <tr> <th>Volume of Emission Reduction</th> <th>Achievement Rate</th> <th>Volume of Emissions Reduction</th> <th>Achievement Rate</th> </tr> </thead> <tbody> <tr> <td rowspan="3">1999</td> <td>Subproject A</td> <td>25,171</td> <td>22%</td> <td>N.A.</td> <td>N.A.</td> </tr> <tr> <td>Subproject B</td> <td>19,380</td> <td>85%</td> <td>10,066</td> <td>44%</td> </tr> <tr> <td>Total</td> <td>44,551</td> <td>32%</td> <td>N.A.</td> <td>N.A.</td> </tr> <tr> <td rowspan="3">2000</td> <td>Subproject A</td> <td>36,579</td> <td>32%</td> <td>N.A.</td> <td>N.A.</td> </tr> <tr> <td>Subproject B</td> <td>19,418</td> <td>85%</td> <td>7,975</td> <td>35%</td> </tr> <tr> <td>Total</td> <td>55,997</td> <td>41%</td> <td>N.A.</td> <td>N.A.</td> </tr> <tr> <td rowspan="2">2001</td> <td>Subproject A</td> <td>26,463</td> <td>23%</td> <td>N.A.</td> <td>N.A.</td> </tr> <tr> <td>Subproject B</td> <td>20,531</td> <td>90%</td> <td>9,425</td> <td>41%</td> </tr> </tbody> </table>	Year		Actual				Total		In Mexico City Metropolitan Area		Volume of Emission Reduction	Achievement Rate	Volume of Emissions Reduction	Achievement Rate	1999	Subproject A	25,171	22%	N.A.	N.A.	Subproject B	19,380	85%	10,066	44%	Total	44,551	32%	N.A.	N.A.	2000	Subproject A	36,579	32%	N.A.	N.A.	Subproject B	19,418	85%	7,975	35%	Total	55,997	41%	N.A.	N.A.	2001	Subproject A	26,463	23%	N.A.	N.A.	Subproject B	20,531	90%	9,425	41%
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¹ Since 1999, law prohibits the sale and use of any form of heavy oil in the Mexico City Metropolitan Area. This policy makes it impossible to supply desulfurized heavy oil produced with the Miguel Hidalgo Refinery HDR (hydrodesulfurization of residuals).

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	<p>Compared to the planned 133,800 tons/year reduction in SO₂ emissions, the actual reduction is estimated to have been 85,750 tons/year; about 2/3 of plan.</p> <p><Comparison of Planned and Actual Reductions in Volume of SO₂ Emissions (Year 2000 Data)></p> <table border="1" data-bbox="407 395 1173 692"> <thead> <tr> <th rowspan="2">Project</th> <th rowspan="2">Planned</th> <th colspan="2">Actual</th> </tr> <tr> <th>Total</th> <th>In Mexico City Metropolitan Area</th> </tr> </thead> <tbody> <tr> <td>Subproject A</td> <td>111,000 tons/year</td> <td>50,820 tons/year</td> <td>21,700 tons/year</td> </tr> <tr> <td>Subproject B</td> <td>17,000 tons/year</td> <td>34,930 tons/year</td> <td>18,430 tons/year</td> </tr> <tr> <td>Subproject C*</td> <td>5,800 tons/year</td> <td colspan="2">Cancelled</td> </tr> <tr> <td>Total</td> <td>133,800 tons/year</td> <td>85,750 tons/year</td> <td>40,130 tons/year</td> </tr> </tbody> </table> <p>*Subproject C (rehabilitation of existing sulfur recovery plant and construction of one new sulfur recovery plant at the PEMEX 18 de Marzo Refinery) was initially part of the project, but due to government policy, PEMEX independently decided to close the large scale refinery (18 de Marzo Refinery). This resulted in cancellation of the subproject.</p>	Project	Planned	Actual		Total	In Mexico City Metropolitan Area	Subproject A	111,000 tons/year	50,820 tons/year	21,700 tons/year	Subproject B	17,000 tons/year	34,930 tons/year	18,430 tons/year	Subproject C*	5,800 tons/year	Cancelled		Total	133,800 tons/year	85,750 tons/year	40,130 tons/year	<table border="1" data-bbox="1211 169 2022 608"> <thead> <tr> <th></th> <th>Total</th> <th>40,994</th> <th>30%</th> <th>N.A.</th> <th>N.A.</th> </tr> </thead> <tbody> <tr> <td rowspan="3">2002</td> <td>Subproject A</td> <td>4,350</td> <td>4%</td> <td>0</td> <td>0%</td> </tr> <tr> <td>Subproject B</td> <td>17,872</td> <td>78%</td> <td>7,609</td> <td>33%</td> </tr> <tr> <td>Total</td> <td>22,222</td> <td>16%</td> <td>7,609</td> <td>6%</td> </tr> <tr> <td rowspan="3">2003</td> <td>Subproject A</td> <td>27,942</td> <td>24%</td> <td>0</td> <td>0%</td> </tr> <tr> <td>Subproject B</td> <td>19,833</td> <td>87%</td> <td>9,201</td> <td>40%</td> </tr> <tr> <td>Total</td> <td>47,775</td> <td>35%</td> <td>9,201</td> <td>7%</td> </tr> <tr> <td rowspan="3">2004</td> <td>Subproject A</td> <td>18,299</td> <td>16%</td> <td>0</td> <td>0%</td> </tr> <tr> <td>Subproject B</td> <td>19,454</td> <td>85%</td> <td>8,291</td> <td>36%</td> </tr> <tr> <td>Total</td> <td>37,753</td> <td>27%</td> <td>8,291</td> <td>6%</td> </tr> <tr> <td rowspan="3">2005</td> <td>Subproject A</td> <td>10,557</td> <td>9%</td> <td>0</td> <td>0%</td> </tr> <tr> <td>Subproject B</td> <td>21,483</td> <td>94%</td> <td>9,140</td> <td>40%</td> </tr> <tr> <td>Total</td> <td>32,040</td> <td>23%</td> <td>9,140</td> <td>7%</td> </tr> </tbody> </table> <p>Source: *Calculation based on data in responses to questionnaires given to the executing agency. *Calculated assuming a 0.9 relative density for heavy oil, and 0.876 relative density for diesel. *The volume supplied by subproject A to the Mexico City Metropolitan Area is unclear from 1999-2001.</p> <p>(2) Mexico's current and future policy and planning regarding use of desulfurized heavy oil and desulfurized diesel oil</p> <p>All heavy oil use is currently prohibited in the Mexico City Metropolitan Area. As regards diesel oil, only desulfurized diesel oil can be sold. While demand for desulfurized oil is still weak, according to the executing agency that demand is showing a slight increase with 23,000 barrels/day in 2000 growing to 27,000 barrels/day in 2005, with 30,000 barrels forecast for 2008^{2(above)}. Thus it is presumed that an increasing volume will be supplied by the project's two HDD (Hydrodesulfurization of Distilled Intermediates) plants.</p>		Total	40,994	30%	N.A.	N.A.	2002	Subproject A	4,350	4%	0	0%	Subproject B	17,872	78%	7,609	33%	Total	22,222	16%	7,609	6%	2003	Subproject A	27,942	24%	0	0%	Subproject B	19,833	87%	9,201	40%	Total	47,775	35%	9,201	7%	2004	Subproject A	18,299	16%	0	0%	Subproject B	19,454	85%	8,291	36%	Total	37,753	27%	8,291	6%	2005	Subproject A	10,557	9%	0	0%	Subproject B	21,483	94%	9,140	40%	Total	32,040	23%	9,140	7%
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² This is the opinion of the executing agency regarding future demand.

³ No heavy oil has been supplied to the Mexico City Metropolitan Area since 2002, according to data from the executing agency. (We were unable to obtain data from 2001 or earlier)

⁴ All desulfurized diesel from the Miguel Hidalgo Refinery has been supplied to the Mexico City Metropolitan Area since 2002, according to data from the same executing agency. (We were unable to obtain data from 2001 or earlier)

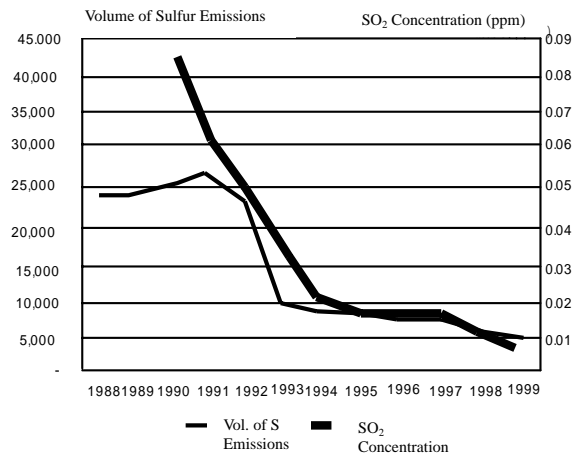
Item	At time of Ex-post Evaluation	At time of Ex-post Monitoring
		<p>(3) Market supplied with desulfurized fuel from the project</p> <ol style="list-style-type: none"> 1. Subproject A (heavy oil desulfurization installation; HDR) [Miguel Hidalgo Refinery] Heavy oil use has been prohibited in the Mexico City Metropolitan Area since 1999, so there is no supply to the metropolitan area through this subproject³. Desulfurized heavy oil from the project is mainly used outside the metropolitan area. 2. Subproject B (diesel desulfurization installation; HDD) [Miguel Hidalgo Refinery, Antonio M. Amor Refinery] All desulfurized diesel oil produced at the Miguel Hidalgo Refinery is supplied to the Mexico City Metropolitan Area⁴, but that production volume is only 67-88% of the plant's processing capacity. In addition, as part of the project the HDD in the Antonio M. Amor Refinery was built to supply a forecasted increase in demand for diesel oil in the Mexico City Metropolitan Area, but shipments from the Miguel Hidalgo Refinery currently meet metropolitan area demand. Shipments from the Antonio M. Amor Refinery have been shifted to meet demand in domestic northern regions, but as described above in (2), it is presumed that the volume supplied to the metropolitan area will increase in the future. <p>In short, only diesel oil from the Miguel Hidalgo Refinery is being supplied to the initial project target area, the Mexico City Metropolitan Area. This is mainly because of a) elimination of demand due to policy regulations (subproject A), and b) slow demand growth in the metropolitan area (subproject B).</p>

Impact

(1) Environmental impact

1. Reductions in volume of sulfur emissions and SO₂ concentration

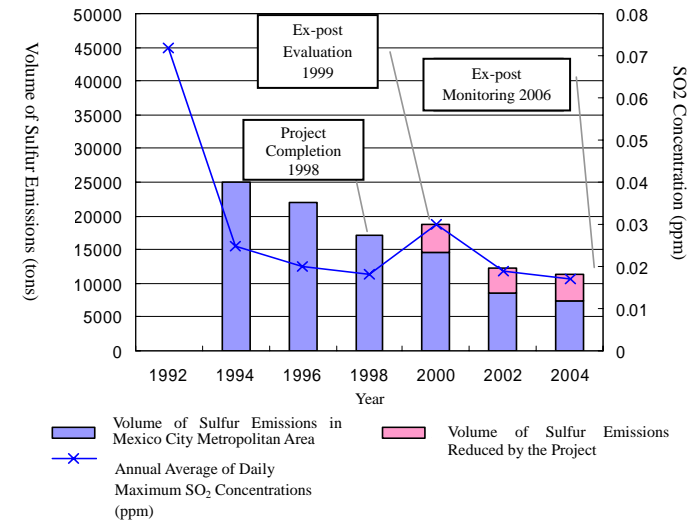
Through a series of air pollution countermeasures, including HDD and HDR, the volume of SO₂ emissions has rapidly decreased since 1990. SO₂ concentration has fallen dramatically, achieving levels below environmental standards since 1992.



(1) Environmental impact

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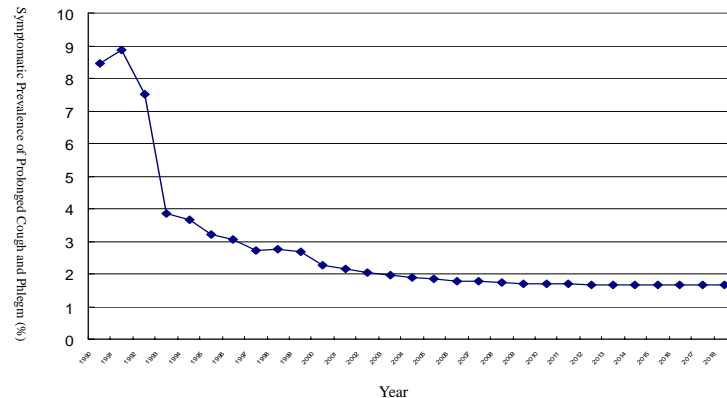
Although heavy oil with high sulfur content was used without permit in the metropolitan area surroundings from 2000 to 2001 and temporarily increased concentrations of SO₂, SO₂ levels fell thereafter to below the environmental standard (0.13 ppm). The project's HDD in the Miguel Hidalgo Refinery currently supplies about 70% of the low-sulfur diesel oil consumed in the Mexico City Metropolitan Area. Thus, the project is reducing sulfur emissions by about 3,800 to 4,000 tons per year in the metropolitan area. This contribution is equivalent to about 22-23% of sulfur emission volume before project completion (1998), and about 21-35% of total sulfur emissions during the period 2000 to 2004.



Source: Data from the Mexico Federal District Ministry of the Environment. Data on volume of sulfur emissions by the project is from the executing agency.

(2) Predicted health effects

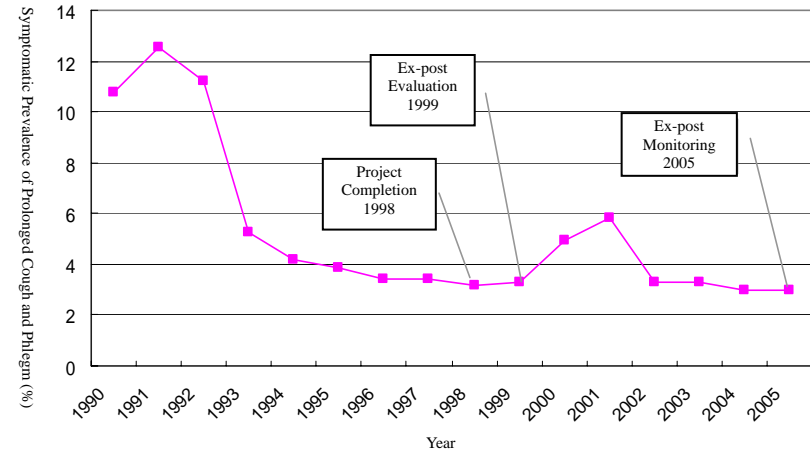
The causal relationship between sulfur oxide and lung disease has been verified in general, but the correlation between SO₂ concentration and lung disease in the Mexico City Metropolitan Area is unclear. Thus the ex-post evaluation applied an exposure–reaction function based on epidemiological research in other regions. The graph below shows the symptomatic prevalence of prolonged coughing and phlegm. (Up to 1999, calculation is based on the yearly average of actual daily maximum SO₂ concentrations. After 2000, the graph assumes that SO₂ concentrations continue their pre-1999 downward trend.)



Source: The above is the result of a regression function calculated until 1999, using SO₂ concentration data from the Secretariat of the Environment, Natural Resources and Fisheries (SEMARNAP). Data after 2000 uses values assumed based on data until 1999.

(2) Predicted health effects

There is no data on the percentage of people with lung disease in the Mexico City Metropolitan Area, thus a regression formula was used to calculate the percentage of sufferers of “prolonged coughing and phlegm” in the area, as was done at the time of ex-post evaluation. Illegal use of heavy oil in the year 2000 raised the daily maximum of SO₂ concentrations, as mentioned above in (1) Environmental impact. This resulted in a temporary rise in calculated disease rate. But overall, the effect of reduced sulfur emissions through the project is evident in the low level of disease rate, which is expected to further decline. In general, the rate of lung disease is said to correlate to airborne SO₂ concentration. Thus it is roughly estimated that the project’s reduction in sulfur (35% in 2004) contributes to an equivalent health improvement for metropolitan area residents.



Source: Calculated using SO₂ concentration data from the “Report on Air Quality and Trends 2004” and the “Air Monitoring System of the Local Government Environmental Ministry Under Federal Government Jurisdiction.”

(3) Impact on Mexican government policy

Following past success in SO₂ reduction, the Mexico City Metropolitan Area air pollution policy for 2002 to 2010 continues to focus on reduction of sulfur in vehicle and industrial fuel. It will also expand reduction targets to pollutant matter other than SO₂, such as nitrogen compounds and ozone. Introduction of gasoline desulfurization installations is also being considered, according to answers received in interviews with PEMEX for this survey. In this way, it can be said that the results of the sulfur emission reduction measures, including this project, have made a positive impact on promotion of measures to reduce pollutant matter emissions.

<p>Sustainability</p>	<p>(1) Technical capacity The desulfurization equipment installed by this project is operated and maintained by specialist staff at each PEMEX refinery. At the Miguel Hidalgo Refinery of subproject A, about 330 employees participate in operation and maintenance (there are about 3,000 to 4,000 employees in the entire refinery). At the Antonio M. Amor Refinery of subproject B, about 30 employees participate (out of a total 4,500 employees at that refinery).</p> <p>(2) Structural Organization PEMEX is the only institution in Mexico which performs oil refining. It has operated oil refineries over the past several decades, and there are no particular problems with the structural aspect.</p> <p>(3) Financial status PEMEX annual sales for 1999 were about 320 billion pesos (about 4.6 trillion yen). Pretax profit was about 207 billion pesos (about 2.9 trillion yen). Its profit margin was over 60%, but it is paying heavy taxes which exceed pretax profit, so its ordinary balance is negative. However, it has made between 300 million</p>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>Technical capacity, structural organization, and financial status continue to prove their sustainability. In the Miguel Hidalgo Refinery HDR of subproject A, mechanical troubles still arise which affect utilization rate. Thus, problem prevention and countermeasures are remaining minor issues, but in general, there is no major problem.</p> </div> <p>(1) Technical capacity PEMEX internal technical staff perform periodic operation and maintenance work. Training is also provided to maintain their technical level. Large scale or technically advanced maintenance work, such as replacement of catalytic equipment, is outsourced to external specialists. PEMEX staff numbers were reduced at each plant through an overall restructuring in 2004 but, according to local specialists, sufficient quality and numbers of technicians have been kept for maintenance operations.</p> <p>(2) Structural Organization Changes in government policy affecting the organizational structure of PEMEX have not been seen since the year 2000. Such changes are not expected in the future, either.</p> <p>(3) Financial status PEMEX 2005 annual sales amounted to about 928 billion pesos, and pretax profit was about 506 billion pesos. PEMEX maintains a profit margin greater than 50%, and when compared with the time of ex-post evaluation, no cause of financial deterioration seen.</p>
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and 2.2 billion dollars (40-300 billion yen) of ordinary profit annually for over 10 years, up to last year. Thus, its financial aspect is also not considered to be a future problem.

(4) Operation and maintenance

Several technical troubles arose at the startup stage of each installation, but those are currently resolved (at the time of ex-post evaluation), and each installation is operating well.

Year	Sales	Pretax Income	Profit Margin
2002	514,849	289,392	56.2%
2003	625,429	339,785	54.3%
2004	799,368	474,615	59.4%
2005	928,643	506,112	54.5%

Source: PEMEX web page, <http://www.pemex.com/>

(4) Operation and maintenance

1. Subproject A (heavy oil desulfurization installation; HDR)

The installation stopped operating three times for a total 2,520 hours in 2005, mainly due to mechanical problems. Each problem was resolved by technical work such as repair and part replacement. The following periodic maintenance work is performed: cleaning of the entire installation once per year, maintenance inspection of compressor three times per year, maintenance inspection of catalytic oil pumps five times per year. There were no breakdowns leading to large accidents, but mechanical problems which affect the utilization rate continue to arise, so problem prevention measures, including maintenance work, remains an issue.

2. Subproject B (diesel oil desulfurization installation; HDD)

The HDD at the Antonio M. Amor Refinery was shut down for 29 days for general maintenance inspection in 2005. As for periodic maintenance work on the Miguel Hidalgo Refinery HDD, maintenance inspection on the compressor is done once per year, with cleaning and inspection of the upper catalytic layer done every three months. At the Antonio M. Amor Refinery HDD, a periodic work cycle is scheduled for each section of the installation, and preventative maintenance work is done on electronic equipment. At subproject B, maintenance does not appear to have created large obstacles affecting operation.

		<p>Regarding operation and maintenance cost, sufficient funds have been continually secured for planned maintenance in all subprojects.</p>
<p>Lessons Learned, Recommendations, Information Resources and Monitoring Methods.</p> <p>(1) Follow up on lessons learned and recommendations made in the ex-post evaluation report, or in later evaluations.</p> <p>(2) Proposals for securing sustainability and instructions given at time of follow-up monitoring</p>	<p>(1) Lessons learned</p> <p>Large scale conversion of thermal power plants to natural gas led to decreased consumption volume in the Mexico City Metropolitan Area. This was different from initial assumptions. Part of production was supplied to other regions, so reduction of SO₂ reached a wide area, metropolitan area included. Therefore, for projects like this that are implemented as part of large scale environmental policy on a national level, repeated review is needed for consistency with policy changes. Also, it is necessary to devise optimal combinations of policies and aid projects in aid recipient countries to achieve large-scale results.</p>	<div data-bbox="1223 277 2036 456" style="border: 1px solid black; padding: 5px;"> <p>Chronic mechanical difficulties are continuing in the heavy oil desulfurization installation (HDR) at the Miguel Hidalgo Refinery. This threatens sustainability, so it is hoped that a policy to prevent problems will be investigated.</p> </div> <p>(1) Lessons learned None.</p> <p>(2) Recommendations Systematic maintenance work is done periodically on the HDR at the Miguel Hidalgo Refinery. Despite this, even after the ex-post evaluation it is still experiencing some mechanical troubles which are obstacles to achieving production targets. Therefore, it is hoped that the responsible PEMEX department will study and implement an even more comprehensive policy to manage the equipment, leading to prevention of these mechanical problems.</p>