Mexico

# The Mexico City Sulfur Dioxide Emission Reduction Project

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## 1 Project Profile and Japan's ODA Loan

### 1) Background

In 1988 the Mexican government adopted 100 Necessary Devices for the Environment as an action plan for countermeasures against atmospheric pollution in the Mexico City capital region, which had been worsening year by year. In 1989 the Integrated Plan Against Atmospheric Pollution in the Mexico City Capital Region, containing specific countermeasures, was adopted. The plan identified $SO_2$ as one of the main atmospheric pollutants, and named power stations, factories and diesel-engine vehicles as the main sources of $SO_2$ pollution. It called for a project to improve fuel oil (heavy oil, diesel) into low sulfur oil, and this loan project was implemented as a way of funding that $SO_2$ reduction initiative.

### 2) Objectives

To reduce the sulfur content of heavy oil and diesel supplied by the Mexican Petroleum Corporation (PEMEX) to the Mexico City Capital Region as a way of cutting emissions of $SO_2$, one of the major atmospheric pollutants in the area, and also to cut $SO_2$ emissions from the PEMEX refinery in Azcapotzalco .

### 3) Project Scope

The scope of this project is as follows:

1. Sub-project A (Heavy oil desulfurization facilities)

   One heavy oil desulfurization plant (with processing capacity of 50,000 barrels per day) was constructed at the Tula Oil Refinery, which is situated 8km east of Tula in Hidalgo State, 82km north of Mexico City. The sulfur content of heavy oil before desulfurization is 4.2%.

2. Sub-project B (Diesel oil desulfurization facilities)

   One diesel oil desulfurization plant (with processing capacity of 25,000 barrels per day) was installed at the Tula Oil Refinery, and another at the Salamanca Oil Refinery, located approximately 240km northwest of Mexico City. The sulfur content of diesel oil before desulfurization is 2%.

3. Sub-project C (sulfur recovery facilities)

   The existing sulfur recovery plant at the

Azcapotzalco Oil Refinery was refurbished, and one new sulfur recovery plant will be constructed.

4.Consulting Service

Overall supervision.

The ODA loan covered 75% of the total project cost.

### 4) Borrower/Executing Agency

The Government of the United Mexican States/ the Mexican Petroleum Corporation (PEMEX)

### 5) Outline of Loan Agreement

| | |
|---|---|
| Loan Amount / Loan Disbursed Amount | \69,338 million / \59,889 million |
| Exchange of Notes / Loan Agreement | October 1990 / November 1990 |
| Terms and Conditions | Interest rate: 2.9%, Repayment period: 25 years (7 years for grace period) |
| Final Disbursement Date | April 1998 |

## 2 Results and Evaluation

### 1) Relevance

By reducing the sulfur content of the heavy oil and diesel consumed in the Mexico City capital region, this project was positioned to reduce $SO_2$ emissions and thereby contribute to improving the atmosphere of the capital region. However, after the loan agreement was signed, the situation surrounding this project changed markedly, and the $SO_2$ countermeasure for the capital region shifted from emission reduction by switching to low-sulfur petroleum-based fuels to suppression of the use of petroleum-based fuels . Specific measures involved the use of natural gas, which is a cleaner solution, and the scrapping of refineries in Mexico City.

This policy shift led to the scrapping of theAzcapotzalco Oil Refinery in Mexico City, where the sulfur recovery plant was to be installed under sub-project C. Therefore sub-project C was cancelled.

Sub-projects A and B were constructed as planned. However, the plan envisaged consumption of all or most of the petroleum products (low-sulfur diesel and heavy oil) from those refineries within the capital region. Under the above policy shift, demand in the capital region declined, and a considerable volume of the low-sulfur products came to be consumed outside the region (see 3) 1. below).

Thus the installed plant is working correctly and removing sulfur from fuels, but it is contributing to $SO_2$ reduction over a wider area, including the capital region, rather than just meeting the original objective of reducing $SO_2$ emission in the capital region . That was possible because alternative energy sources such as natural gas in the capital region could now be used, and environmental standards for $SO_2$ there have already been met. The situation has caused some degree of change in the supply destination of the low-sulfur heavy oil and diesel produced by this project.

The project was one element of the 100 Necessary Devices for the Environment package set by the Mexican government in power in 1988 as a policy task for tackling atmospheric pollution. At the time it was unclear whether it would be possible to provide a stable supply of natural gas, and as such the judgement made then was relevant. In November 1989 the Mexican government discussed with a Japanese mission to Mexico the cancellation of their request for sub-project A on the grounds that heavy oil was to be replaced by natural gas as the fuel for power stations in the

capital region. That was followed by another policy shift, and the Mexican government later confirmed in writing that it would use desulfurized heavy oil in its power stations if a supply became available.

After the loan agreement was signed, progress was made in the switch to natural gas in the capital region, and the supply destination for products from this project changed somewhat to serve other regions, which required desulfurized heavy oil and diesel. This change spread the $SO_2$ reduction impact over a wider area. While the target of the project was altered in that way, the combination of this project with the switch to natural gas spread the $SO_2$ reduction over a wider area, and therefore this project remains highly significant today.

### 2) Efficiency

1. Project Cost

The total Yen-based cost of the project overran slightly, by 0.55%, but as payments were made in US Dollars or local currency, the cost varied wildly with exchange rates (the dollar moved between ·94 and ·144 within the duration of the project), making it impossible to judge whether or not the project remained within its budget.

Comparing the planned and actual Yen-based loan values, disbursement was approximately 87% of the planned amount. The change was mainly due to the appreciation of the Yen.

2. Implementation Schedule

Delays in budget procurement on the Mexican side and problems with initial operation caused some delays in construction, but the equipment was installed without major confusion.

3. Implementation Scheme

PEMEX, the executing agency for this project, was split into four organizations in 1992. All matters concerning this project were carried on by PEMEX Refinacion, the oil refining division. At the time of the appraisal there was concern that the executing agency might lack the technical ability to carry out the project, but in fact its performance was mainly good.

### 3) Effectiveness

1. Operational Status

After the completion of construction, the plants encountered various problems at the trial running stage, and it took time for them to move into full operation. Recently they have been operating well on the whole.

Approximately 1/6 of the desulfurized heavy oil produced by sub-project A is consumed in the capital region with the remainder being supplied to surrounding regions. Of the low-sulfur diesel oil produced by sub-project B, approximately 70% is supplied to the capital region and 30% to surrounding regions.

2. Quantitative impact (reduction of air pollution)

Comparing the $SO_2$ emission reduction calculated at the planning stage for 2000 (133,800 tons/ year), and the actual reduction (85,750 tons/year), the actual value is around 2/3 of the planned value. Around 30% of the planned reduction (40,130 tons/year) is in the capital region. The main reason for the substantial shortfall is the reduction in heavy oil consumption due to the government ŝ decision to switch to natural gas.

(Observation 1) The impact of replacing heavy oil with natural gas

One of the sulfur emission reduction policies to date, as mentioned above, is the conversion of power stations to burn natural gas instead of oil. For reference we have examined the cost-benefit side of the substitution, comparing project A, which provides fuel to heavy oil power stations, with natural gas to examine the economics of sulfur reduction.

The benefits of replacing this project with natural gas burning to achieve a unit reduction of sulfur are as follows:

(The equipment construction cost for this project and the reduction in maintenance cost-immediate opportunity benefits) — (The cost of converting equipment for thermal electricity generation from natural gas and the maintenance cost-immediate opportunity costs)

The value of EIRR calculated on the basis of annual cost-benefit by the above method is 2.60%. That means that for a unit sulfur reduction in capital region power stations, natural gas rather than desulfurized heavy oil yields better economic efficiency. This result confirms that switching to natural gas burning in place of heavy oil was the right choice. Most of the power stations in the capital region have already been converted and the process is continuing. Heavy oil is now used in fields where conversion to natural gas would be difficult due to the cost of fuel conversion, or other obstacles. Therefore the conversion process does not mean that desulfurized heavy oil will be entirely superseded by natural gas, or that sub-project A will soon become superfluous.

(Observation 2) The impact of desulfurized diesel oil

In 1989, automobile exhaust was seen as the source of approximately 70% of atmospheric pollution in the capital region. That prompted a series of administrative ordinances, such as making one day a week no-car day, strengthening inspections of vehicle emissions, switching to low-pollution bus engines, renovating dilapidated vehicles, and installing catalytic converters. The decision to implement sub-project B to reduce the sulfur content of diesel oil was taken as one of those measures. Desulfurized diesel oil from sub-project B (with the world's lowest sulfur content at 0.05%) is supplied to the capital region and surrounding areas, helping to curb atmospheric pollution.

**4) Impact**

1. Environmental Impact

An economic evaluation was conducted for the portions of the project which contribute to reducing atmospheric pollution in the capital region. The environmental impact (reduction of damage to human health by reducing $SO_2$ emissions) of installing the desulfurization equipment was evaluated by calculating the loss of income caused by chronic coughing and phlegm, and the cost of medical treatment.

①Calculation method

The with-without cases for this project were envisaged as described below.

The with case (where the project was implemented)

Atmospheric pollution countermeasures, including the building of plants for sub-projects A and B, were carried out from 1990 onwards, substantially reducing sulfur emissions in the capital region and thereby preventing health damage. Atmospheric pollution countermeasures using this project will continue to be implemented in future.

The without case (where the project was not implemented)

Atmospheric pollution countermeasures for the capital region, including the building of plants for sub-projects A and B, were not carried out. Therefore $SO_2$ concentrations continued to increase at the 1990 rate, and the resulting health damage, manifested as chronic coughing and phlegm, led to loss of income and incurred medical costs.

The with-without benefit comparison for this project in the cases envisaged above is as follows:

(Difference in income and medical costs between the with and without cases) — (plant construction and maintenance costs for the with case)

For this cost-benefit analysis, the total benefit for all clean air measures was multiplied by the contribution rate for

sub-projects A and B, and only the share of production volumes from the sub-projects at the Tula Oil Refinery that were supplied to the capital region were included in the calculation.

②EIRR calculation results

When EIRR was calculated on the basis of the annual costs and benefits derived as described above, the values were 1.31～9.25% for sub-project A and 9.89～24.05% for sub-project B installation at the Tula Oil Refinery. The total for sub-projects A and B was 4.37～13.85%. Thus both sub-projects deliver an adequate level of impact on the Mexico City capital region.

2. Other Impact

The following can be raised as indirect impacts of the project.

①Increased employment at the construction stage.

②High-sulfur crude oil (heavy maya oil), which was unusable in the previous equipment, became usable.

③Knowledge of difficult technologies was built up.

④Use of local resources (equipment and materials) in the construction stage.

**5) Sustainability**

1. Operation and Maintenance

The desulfurization equipment installed under this project is operated and maintained by expert staff at PEMEX oil refineries.

The equipment suffered some technical problems at the commissioning stage, but those have now been solved and the equipment is running smoothly. There is no problem with the operation and maintenance scheme.

The executing agency, PEMEX, is the only oil refiner in Mexico, and it has decades of experience in refinery operation. Its future financial position appears to be secure.

2. Locations of demand for the products

Consumption of the low-sulfur heavy oil and diesel oil produced by this project will increasingly be centered in areas surrounding the Mexico City capital region, and not in the region itself.

The power stations which are the largest consumers of the low-sulfur heavy oil from sub-project A are being considered for complete conversion to natural gas. If that is done, there might be no consumers left in the capital region and its surroundings. However, that would be a desirable outcome from an environmental point of view, as natural gas is cleaner energy.

## 3 Lessons Learned

The desulfurization equipment for sub-projects A and B was installed as planned and is now running smoothly, greatly reducing the sulfur content of the processed fuels. The project has clearly made a strong contribution to cutting the emission of sulfur oxides.

Contrary to initial expectations, the major shift to natural gas as the fuel for thermal power stations sharply cut demand in the Mexico City capital region. As a result, the products of the project were more widely distributed in other regions, and the $SO_2$ reduction effect spread to a wider area, including the capital region.

Projects such as this one, which are implemented as elements of national-level, large-scale environmental policies, need to be reviewed repeatedly to ensure their conformity with changes in those policies. Measures should be devised to deliver greater impact by optimizing the combination of aid projects with the policies of the recipient country.

# Comparison of Original and Actual Scope

## 1) Project Cost

| Project content | ① Plan (at the time of appraisal) | ②Actual | Difference |
|---|---|---|---|
| 1. Sub Project A<br>・Heavy oil desulfurization equipment | One system (processing capacity 50,000 barrels/day, sulfur content not exceeding 0.8%) | Same as left | None |
| 2. Sub Project B<br>①Diesel oil desulfurization equipment (Tula Oil Refinery)<br><br>②Diesel oil desulfurization equipment (Salamanca Oil Refinery) | One system (processing capacity 25,000 barrels/day, sulfur content not exceeding 0.1%)<br>Same as above | One system (processing capacity 25,000 barrels/day, sulfur content not exceeding 0.05%)<br>Same as left | Sulfur content not exceeding 0.1%→Sulfur content not exceeding 0.05%.<br>Same as above |
| 3. Sub Project C<br>・Sulfur recovery equipment | Construction of one sulfur recovery plant<br>Repair of one existing sulfur recovery plant | Suspended in accordance with the abolition of oil refineries | Equipment was not installed |
| 4. Consulting Service | 160.8M/M | 220.99M/M | 60.19M/M |

## 2) Implementation Schedule

| Item | ① Plan (at the time of appraisal) | ②Actual | Difference |
|---|---|---|---|
| 1. Sub Project A<br>・Process selection, basic design<br><br>・Selection of contractor, detailed design, procurement of equipment, construction works | (59 months)<br>Apr. 1991～ Apr. 1992<br>(13 months)<br>May 1992 ～ Feb. 1996<br>(46 months) | (71 months)<br>Mar. 1991～ Sep. 1991<br>(7 months)<br>Oct. 1991～ Jan. 1997<br>(64 months) | Approx. 1 year delay |
| 2. Sub Project B<br>・Process selection, basic design<br><br>・Selection of contractor, detailed design, procurement of equipment, construction works | (44 months)<br>Apr. 1991～Feb. 1992<br>(11 months)<br>Mar. 1992 ～ Nov. 1994<br>(33 months) | (67 months)<br>Mar. 1991～ Jan. 1992<br>(11 months)<br>Feb. 1992 ～ Sep. 1996<br>(56 months) | 23-month delay |
| 3. Sub Project C<br>・Process selection, basic design<br><br>・Selection of contractor, detailed design, procurement of equipment, construction works | (42 months)<br>Apr. 1991～ Feb. 1992<br>(11 months)<br>Mar. 1992 ～ Aug. 1994<br>(31 months) | — | Not installed |
| 4. Consulting Service<br>・Selection<br><br>・Consulting service | (72 months)<br>Nov. 1990 ～ Mar. 1991<br>(5 months)<br>Apr. 1991～ Feb. 1996<br>(67 months) | (87 months)<br>Nov. 1990 ～ Feb. 1991<br>(4 months)<br>Mar. 1991～ Jan. 1998<br>(83 months) | 15-month delay |

3) Project Cost

| Item | ① Plan (at the time of appraisal) | | | ② Actual | | | Difference |
|---|---|---|---|---|---|---|---|
| | Foreign currency (¥ million) | Local currency (US$1,000) | Total (¥ million) | Foreign currency (¥ million) | Local currency (US$1,000) | Total (¥ million) | (¥ million) |
| 1. Sub project A | 18,798 | 246,864 | 56,569 | - | 635,254 | 73,689 | △17,120 |
| 2. Sub project B | 2,816 | 63,805 | 12,579 | - | 87,917 | 18,597 | △6,018 |
| 3. Sub project C | 398 | 8,766 | 1,739 | - | - | - | 1,739 |
| 4. Consulting service | 489 | 461 | 559 | 680 | - | 680 | △121 |
| 5. Contingency | 1,099 | 15,972 | 3,542 | - | - | - | 3,542 |
| 6. Interest rate of construction | 3,102 | | 3,102 | - | - | - | 3,102 |
| 7. Tax etc. | | 93,858 | 14,361 | - | - | - | 14,361 |
| Total project cost | 26,702 | 429,726 | 92,451 | 680 | 723,171 | 92,966 | △515 |

※Exchange Rate: At the time of appraisal: $1=¥153
Actual: $1=¥116

Introduction Facilities ①:
HDR Equipment in Tula Oil Refinery

Introduction Facilities ②:
HDD Equipment in Tula Oil Refinery


Introduction Facilities ③:
HDD Equipment in Salamanca Oil Refinery