No. 5

JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY, ISLAMIC REPUBLIC OF IRAN

THE STUDY ON EVALUATION OF ENVIRONMENTAL IMPACT OF THERMAL POWER PLANTS IN ISLAMIC REPUBLIC OF IRAN

FINAL REPORT (SUMMARY)

DECEMBER 1999

SUURI-KEIKAKU CO., LTD.

TOKYO ELECTRIC POWER ENVIRONMENTAL ENGINEERING CO., INC.

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PREFACE

In response to the request from the Government of the Islamic Republic of Iran, the Government of Japan decided to conduct the Study on Evaluation of Environmental Impact of Thermal Power Plants in the Islamic Republic of Iran and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent a study team, led by Mr. Masaaki Noguchi of Suuri Keikaku Co., Ltd. (SUR) and organized by SUR and Tokyo Electric Power Environmental Engineering Co., Inc. to the Islamic Republic of Iran, six times from December 1996 to September 1999.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Iran, and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the results of the Study and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Iran for their close cooperation throughout the study.

December 1999

Kimio Fujita
President
Japan International Cooperation Agency

December 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir:

We have pleasure of submitting to you the Final Report of the Study on Evaluation of Environmental Impact of Thermal Power Plants in the Islamic Republic of Iran. This report presents the monitored and evaluated influences on ambient air of the regions within 20 km of the two thermal power plants located individually in Tabriz and Esfahan, and also proposes required actions drawn from the evaluation.

This report consists of separated volumes of the summary, the main, and the supporting appendices. The summary volume gives essences of the study results, and the main volume contains explanations all the methods employed, results obtained and recommendations drawn. The supporting appendices compiled from details of employed equipment and methods, individual data, description of transferred technologies, background information, and the like.

On this occasion, we would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study, in particular to the officials concerned of your agency, Ministry of Foreign Affairs, Ministry of International Trades and Industries, and Embassy of Japan, and also Iranian officials concerned of Ministry of Energy, our counterparts under the Deputy Minister for Energy Affairs and people in the two thermal power plants.

We hope this report will contribute to the solution of environmental issues in Iranian thermal power plants and to the development of the Islamic Republic of Iran.

Sincerely yours,

Masaaki Noguchi

Masaaki Noguchi
Supervisor, the JICA Study Team

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List of Abbreviation

Az	Code of Iranian Residual Fuel Oil
BOD	Biological oxygen demands
BS	Particulates having aerodynamic diameter less than 4.5 μm
Bz	Code of Iranian Residual Fuel Oil
COD	Chemical oxygen demands
deg C	Centigrade temperature difference
DF/R	Draft Final Report
DST	Iranian Daylight Saving Time
DO	Dissolved oxygen
DOE	Department of Environment in the Iranian President's Office
ED-MOE	Environmental Department in the organization of the Deputy of Energy Affairs, MOE
EHC	Iranian Environmental High Council
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
Fig.	Figure or Figures
F/R	Final Report
GDP	Gross Domestic Product
GNP	Gross National Product
ICES	Iranian Center for Energy Studies
IC/R	Inception Report
I. R. Iran	Islamic Republic of Iran
IT/R	Interim Report
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
MOE	Iranian Ministry of Energy
MW	Mega Watt
NG	Natural Gas: NGL - Natural Gas Liquid, LNG - Liquefied NG
NIOC	National Iranian Oil Company
NOx	Mixture of mainly Nitrogen oxide (NO) and Nitrogen dioxide (NO_2)
OJT	On the Job Training
PG/R	Progress Report
PM	Particulates emitted from sources (include soot from stacks)
ppb	Parts per billion
ppm	Parts per million
PTIO	2-phenyl-4,4,5,5-tetramethylimidazoline-3-oxide-1-oxyl (used for passive samplers)
Rls.	Iranian Currency Unit (Rials); in this Report U.S. $ 1.00 = Rls. 8,000
SOx	Mixture of sulfur dioxide (SO_2) and sulfur trioxide (SO_3)
SPM	Suspended Particulate Matter in air
SS	Suspended solid in water
TEA	Tri-ethanol-amine (used for passive samplers)
TSP	Total Suspended Particulate in air
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
U.S. EPA	Environmental Protection Agency of the United States
WHO	World Health Organization
¥	Japanese Currency Unit; in this Report U.S.$ 1.00 = ¥120

CHAPTER 1 INTRODUCTION

1.1 Background

The Ministry of Energy of I. R. Iran solicited technical cooperation from the Government of Japan in evaluation of environmental effects of power plants in north and northwestern areas of the country in October 1995. The Japan International Cooperation Agency (JICA), appointed by the Japanese Government as an executing agency, surveyed the Iranian situation as the preparatory step and concluded the Study should target Tabriz and Esfahan Power Plants. The executing agency in Iran was the Environment Department in the Energy Planning Office under Deputy Minister for Energy Affairs in the Ministry of Energy. JICA appointed for the full scale team which started the Study from December, 1996.

1.2 Study Overviews

The objectives of the Study were:

a) to contribute MOE to increase its own capability for preparation of EIA on existing and planned thermal power plants, for implementation of mitigation plans, for preparation of efficiency improvement plans of the studied power plants, and for other related tasks,

b) to measure current environmental characteristics of existing thermal power plants and their surrounding areas, to evaluate their ambient qualities and to propose mitigation plans and to formulate frames of EIA procedures in consideration of current Iranian conditions, and

c) to transfer relevant technologies to Iranian people through site work, seminars etc. in the course of the Study.

The JICA Study focused two power plants and their surrounding areas of 20 km in radius (**Figs. 1.1 and 1.2**). The characteristics of the two plants are given in **Table 1.1**.

Table 1.1 Power Plants in the Study

Plant	Unit	Rated	Fuel Burnt		Stack (m)		Start-	Remarks
		MW	Name	S %	Height	Diameter	up	
Tabriz	1	368	Fuel Oil	3.0	120	5.0	1986	two stacks in one 12m shield,
	2	368		3.0	120	5.0	1988	recycled 15% of flue gas
Esfa-han	1	37.5	Gas Oil &		25	1.5	1969	two stacks in one shield,
	2	37.5	Natural Gas		25	1.5	1969	
	3	120	Fuel Oil &	3.5	55	2.5	1974	
	4	320	Natural Gas	3.5	80	5.0	1980	Fuel oil only in winter
	5	320		3.5	80	5.0	1988	

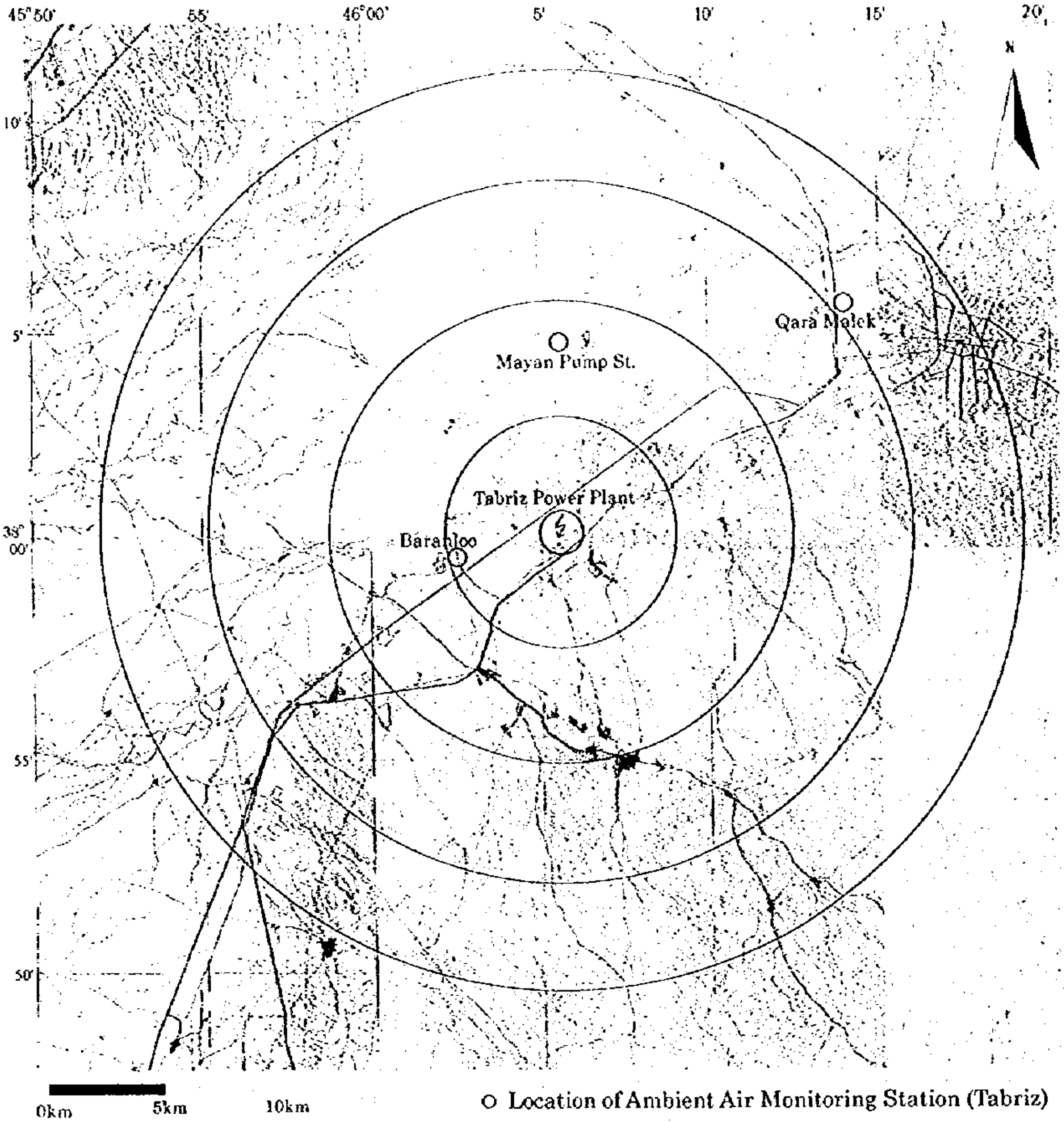


Fig. 1 Tabriz Power Plant and its Surrounding Area

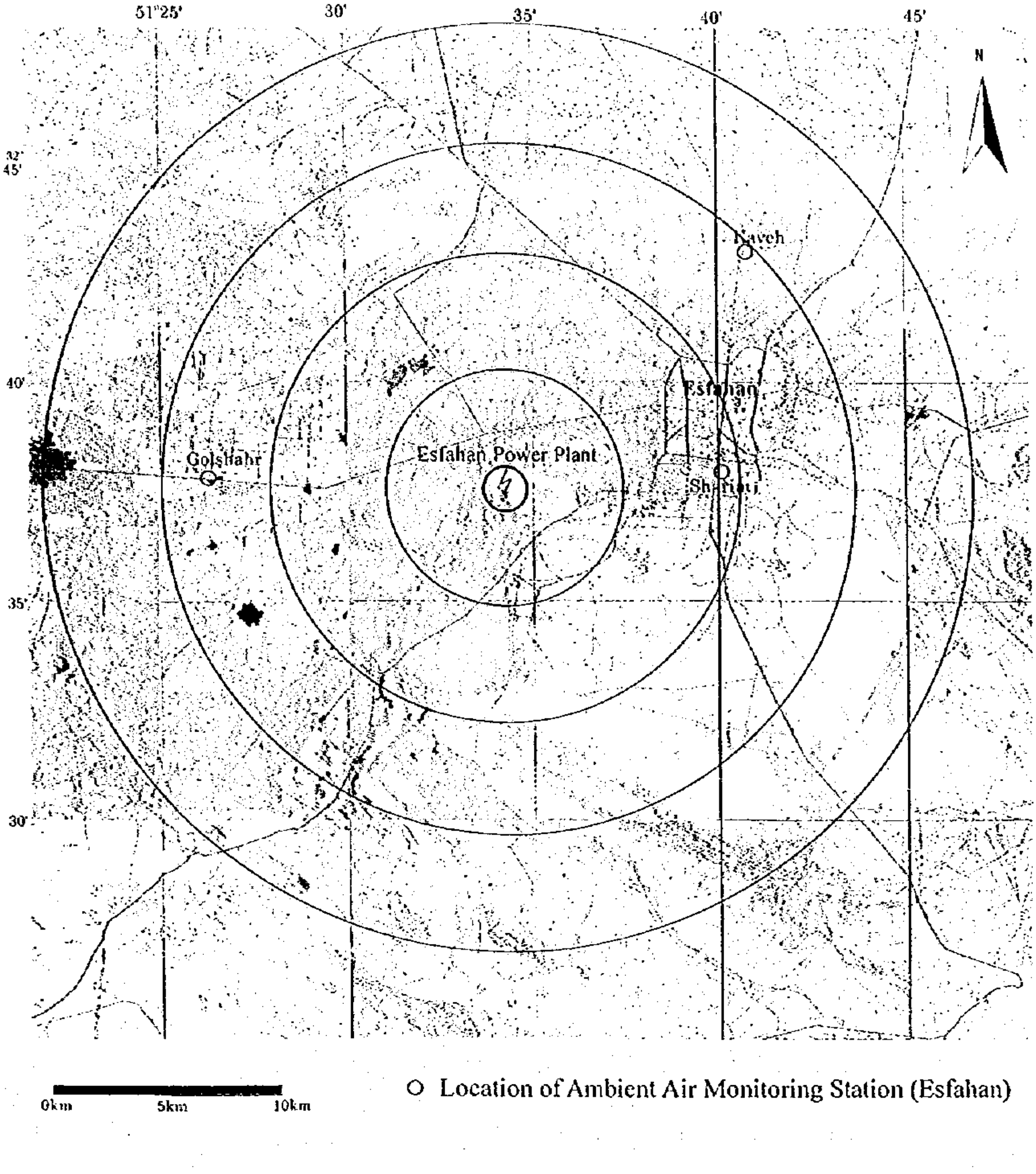


Fig. 2 Esfahan Power Plant and its Surrounding Area

Pollutants to be studied were sulfur oxides (SOx), nitrogen oxides (NOx), and particulates. Also analyzed were vanadium, nickel, lead, and zinc as heavy metals in particulates.

The Tabriz area contains a part of Tabriz City (population 1,088,000 - the capital of Eastern Azarbayjan Province), Tabriz Refinery (Crude oil 100,000 barrels/day), and Petrochemical Complex of total 250,000 tons annual production. Other major industrial products are carpets, tractors, etc. The power plant locates in 15 km southwest from the city and in a plain of 1350 m altitude. South-east of the target area is mountainous sloped to 2200 m altitude and all other area is almost flat with agricultural and fruit production. In winter the area is cold and often thick with snow, while in summer it is hot. Spring and autumn are pleasant.

The Esfahan area has Esfahan City (population 1,127,000), which is the capital of Esfahan Province and has many historical monuments. The history of Esfahan itself can be said to be the one of Iran. The power plant locates 9 km to southwest from the city. A saddle-backed hill of 1720 to 1895 m altitude and 3500 m length is on the immediate north of the power plant (altitude 1600m). The area has mild weather of four seasons and it snows in winter. Outside of the area in the north, there is Shahid M. Montazeri Power Plant having total capacity of 800 MW in operation and additional 800 MW under construction. Near the Montazeri Power Plant, located is Esfahan Refinery having a crude capacity of 400,000 barrels/day which supplies fuel oil and natural gas to both Esfahan and Montazeri power plants.

Table 1.2 Work Stages and Tasks

Divided Work Stages (Schedule)	Major Tasks during the Stage
1) First Field Work (12/96 to 1/97)	Discussion of IC/R and collection of data & others
2) First Analytical Work (1 to 2/97)	Preparation of the JICA Equipment specification
3) Second Field Work (1 to 3/98)	Custom clearance and installation of JICA Equipment, commencement of monitoring, observation & analysis (except SOx and NOx monitoring in air and stack gases by automated instrument)
4) Second Analytical Work (2 to 3/98)	Data analyses and EIA formulation study
5) Third Field Work (5 to 7/98)	Commencement of SOx and NOx monitoring in ambient air and stack gases by automated analyzers, and assurance of monitoring, etc.
6) Third Analytical Work (7 to 9/98 and 2/99)	Preparation of IT/R, and preliminary simulation modeling in 2/1999
7) Fourth Field Work (9/98)	Discussion on IT/R
8) Fifth Field Work (2 to 3/99)	Checking of the JICA Equipment conditions and installation of the preliminary simulation model
9) Fourth Analytical Work (5 to 7/99)	Final. of simulation model & DF/R Preparation
10) Sixth Field Work (9/99)	Discussion on DF/R, installation of the final simulation model, and holding a seminar

The Study work was divided by periodical stages into four analytical and six field ones. Table 1.2 lists the major tasks accomplished in each stage. Analytical work devoted mostly to analyses, compilation, and evaluation of data and information collected in the field work. Table 1.3 shows the overall time schedule actually consumed for the Study with names of the JICA Team member. Also Table 1.4 lists names of Iranian counterparts.

Table 1.3 Overall Schedule

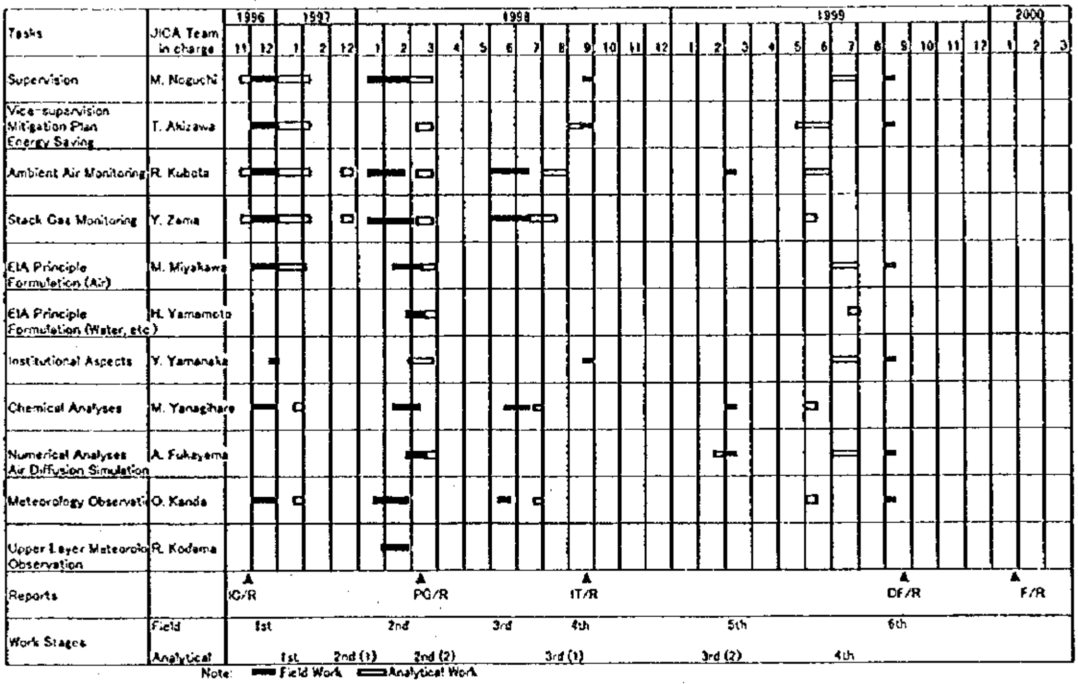


Table 1.4 Iranian Counterpart Team

	NAME	MAJOR ROLES
1	Abdul Reza Karbassi, Dr.	General Supervision, Mitigation Plan, Energy Saving, EIA, and Institutional & Legal Aspect
2	Bahman Jabbarian Amiri	Project Coordination, and EIA
3	Forood Azari Dehkorodi	Stack Gas Monitoring and Its Planning Data Management & Simulation, and EIA
4	Reza Samadi	Ambient Air Monitoring and Its Planning, including Meteorology (upper layer) and Simple Air Samplers, Data management & Simulation, and EIA
5	Nastaran Rahimi	Upper Layer Observation and Chemical Analysis
6	Teeka Sohrab	Chemical Analysis

CHAPTER 2 SOCIO-ECONOMICS IN IRAN

2.1 General

The Islamic Republic of Iran was founded in 1979. It was at war with Iraq for eight years from September 1980 to August, 1988. The First Five-Year Development Plan was launched in 1989 to reconstruct the damaged country. It had made significant progress in a number of economic domains until 1993. The Second Five-Year Socio-economic and Cultural Development Plan has consecutively been implemented from March 1995 to March 2000. The Third Five Year Plan is ready for ratification by the Parliament and will go into effect from March 2000.

The land area is 1,648,416 square kilometers and most of the country is above 460 meters height. One sixth of the land is barren desert with almost no rain fall. The 1996 census revealed 59,500,000 of population, of which 57% live in urban areas.

The official language in Iran is Farsi. However, it is not used by 14.9% of the population. Iran uses three calendar systems: Persian solar, Islam lunar and Gregorian calendar.

Iran's GNP per capita was US$ 1780 in 1997 with its growth rate of 1.7% annual in 1997. However, it is assumed to be minus 0.8% during the 1998 - 2002 period. Inflation rate was 23.2% in 1997.

Reserves of energy resources is given in Table 2.1 in comparison with the World.

Table 2.1 Proved Recoverable Energy Reserves in Iran

Resources	Recoverable Reserves (1990)		
	World	Iran	% in Iran
Bituminous coal/anthracite, 10^6 tons	460,600	193	0.04
Sub-bituminous coal/lignite, 10^6 tons	516,319	--	--
Crude oil and NGL, 10^6 tons	136,754	12,700	9.29
Natural gas, 10^9 m^3	128,584	17,000	13.22

2.2 Second Five-Year Development Plan

The Second 5 Year Development Plan (1995 - 2000) promulgated after the First Plan (1989 - 1994) aims a) to improve international competitiveness, b) to direct savings to manufacturing activities, c) to increase efficiency in the use of public resources, d) to facilitate the implementation of ongoing projects, e) to reduce dependency on oil revenue by expansion of non-oil export, f) to transfer services to the private sector, g) to eliminate gradually subsidies in the oil, water, electricity, and post and communications, h) to reduce in the size of government, and i) to expand support for small and medium scale industry, in addition to the environmental protection and optimal utilization of the natural resources.

It seems that the Plan intends to establish the order in principal economic activities, to make society efficient in its usage of resources for socio-economic and cultural development, to exercise a strict supervision over the execution of projects, and to reduce on inductive growth resulted from oil revenues.

The Plan has set up targets of industrial production. Reportedly, actual productions of steel, vehicles, cement, and petrochemicals have been satisfying the targets. Crude oil daily production rate was 4.1 million barrels in 1993 and it seems easy to achieve the 1999 target of 4.75 million barrels. As for natural gas, one of the primary energy sources in Iran, its production was around 45,500 and 71,905 million m^3 respectively in 1990 and 1994. The annual average growth rate was 12.1 % in the four year period.

The balance of the trade was unfavorable to Iran until 1992. However, it turned around from 1993, and actually it was US$ 6 billion in favor to Iran in 1994 and US$ 7.5 billion in 1996. Oil has produced the highest revenue. Actually it was US$ 18 billion in 1996 and US$ 15.5 billion in 1997. Dependency on the oil revenue is apparently lessened towards to end of the Plan period. The income revenue of US$ 5 billion was generated by exporting non-oil products such as carpets, fresh or dried fruits, manufactured goods, etc.

Iran has vast amount of archaeological, historical and cultural monuments to offer international visitors. Reportedly the number of Japanese to Iran increased 39, 86 and 66 % respectively annually in 1995, 1996 and 1997. The number was expected to be in the range of 15,000 to 20,000 in 1998.

CHAPTER 3 ELECTRIC POWER IN IRAN

3.1 General

The power industry was initially brought to Iran in 1903. The current organization for the power industry under the Deputy of Power Affairs, MOE is as in **Fig. 3.1**.

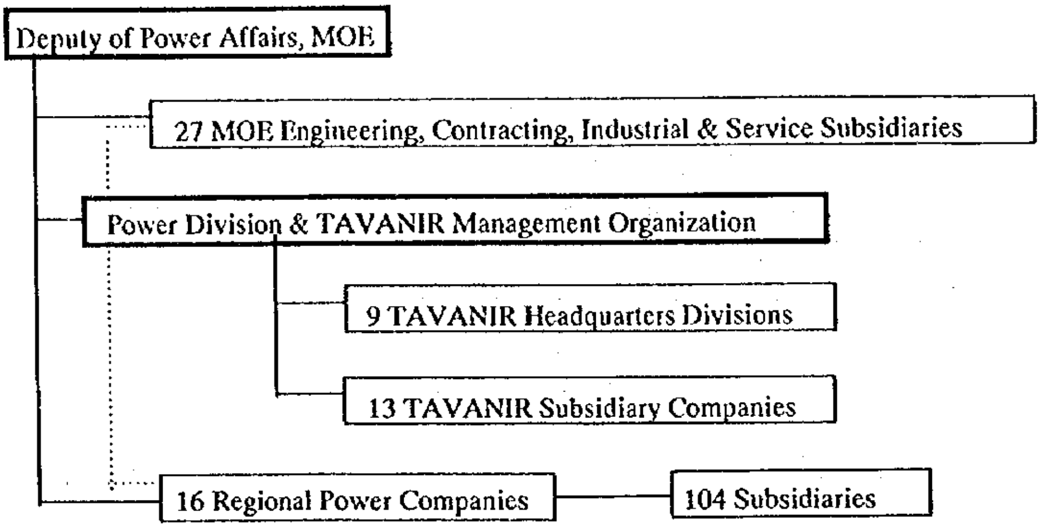


Fig. 3.1 Organization Chart of Power Industry under MOE

The industry has succeeded in 1993, for the first time after victory of the Revolution and after a period of 20 years, in bringing the blackouts to the level of zero. Once the long and arduous years of power shortage were left behind and extensive power cuts were over. During the First and the Second 5 year Development Plans, privatization has been continued in management of generating and distribution companies. The following are some of the basic objectives and guidelines of the Second 5 year Plan with regard to the Sector:

- Continuation of attempts for suitable organization and compilation of an optimum structure for the Sector.
- Improvement of consumption management, savings and rational use of electricity.
- Research development and increasing the use of local productions for the erection of industrial electricity installations.
- Raising standards of soft-wares and project management in order to maximize the use of hard-wares existing in development and reconstruction.
- Improved operation and optimum use of industrial electricity installations.
- Attempting to develop and raise information technology in the Sector.

The consumption of electricity produced by MOE was 73,358GWh in 1997. The installed capacity is 23,257MW, within which steam power plants have a share of 50.2%, followed by gas turbines 38.3%, and hydroelectric power plants 8.6%. The annual load factor was 57.2% in 1997.

Annual average growth rate of generation was 7.4% during 1989 to 1997. Annually one 1600 MW plant has to be constructed to satisfy the 7.5% of growth.

3.2 Thermal Power Plants in the Study

Table 1.1 gives the general specifications of existing units at the Tabriz and Esfahan power plants. The Tabriz plant is burning residual fuel oil (Az) only. The Esfahan plant is burning residual fuel oil (Bz) and natural gas together in summer and the fuel oil only in winter. Both plants were decided to convert completely to natural gas in the future. No stack gas emission control unit is installed in the plants. No expansion plan is neither at Tabriz nor at Esfahan.

The annual load factors of the Tabriz and Esfahan power plants were respectively 86% and 71.6%. The factors are comparatively higher than those of common knowledge. The factors are higher in summer: high electricity demands for air conditioning.

Power generation efficiency was 33.7% and 33.6% individually at No. 1 and 2 of Tabriz Plant in 1996. It is quite low in consideration of the plant size. Internal consumption of power was 7.5% and 7.7% at No. 1 and 2 units of Tabriz in 1996, and 8.0 to 8.63% at Esfahan in 1993 and 1994. The consumption is high in comparison with recent power plants of the similar size.

The electricity demand in Iran is low from midnight and to early morning, higher in daytime, and highest at night from 18:00 to 22:00. Major operational changes are instructed to each power plant by the central dispatcher in Tehran three times during 7 - 9, 16:00 - 18:00, and 22:00 - 24:00.

Tabriz power plant is normally in operation with 200 - 350 MW depending on demand. These are designed to burn fuel oil and natural gas simultaneously. However, at present, fuel oil only is used as fuel, because there is no facilities to supply the gas. The palnt equipments look well-worn because of war damage and local repairs, although these were started in operation in 1986 and 1988. Underground water is used for cooling at a steam condenser after cooled at the cooling tower. In winter when the ambient temperature is low, visibility is decreased by steam condensate from the cooling tower and the sky is clouded over the surrounding. The Unit No. 2 stopped its operation when the JICA Study started, and it entered in a long maintenance.

Esfahan power plant is normally in operation with capacities: 50% of Units No.1 and 2, 60% of Unit No.3, and 50 - 100% of Units No.4 and 5. Presently mixed combustion of gas oil and natural gas is used for Unit No. 1 and 2, and Bz only or mixed combustion of Bz and natural gas is for Units No.3, 4, and 5. As the allocation of natural gas is decreased for electricity generation in winter because of its priority use for heating in the housing domestic sector, Units No.3, 4, and 5 have been fueled with Bz only. Underground water is used for cooling of condensers after re-circulated through a cooling tower. The steam condensate from the cooling tower does not have so much influence as that of Tabriz though white smoke from the tower is visible.

Tabriz Power Plant once tried to install electrostatic precipitators when it received complaints concerning air pollution from farmers living in the surrounding area. No facility implementing environmental measures has been installed since the complaints were received. Smoke from the stack has brown to gray color from soot and steam condensate. Wastewater from the power plant is discharged into the river without treatment.

Esfahan Power Plant does not have any facility to control pollution. The township of Qa-e-Mich is located to the north of the plant beyond a hill of 300 m height and people there has complained air pollution affected by smoke. The plant is trying to burn natural gas to alleviate the pollution. However, availability of the gas prohibits its use in winter at all units. Therefore, the plant is using the gas in winter at No. 1 and 2 units having stacks of lowest height. Wastewater from the power plant is discharged into the river flowing along the plant site after neutralizing, precipitating and filtrating.

According to the measurement in the JICA Study, the residual O_2 concentration was 12.2 - 13.5% of Unit 1 at Tabriz and was 3.5% after maintenance of an air heater. The concentration was also high in the range of 8.8 - 16.9% at Esfahan. The high concentrations are from excess combustion air, excess air leakage from air heaters, and a combined effect of the above two. High O_2 in the stack gas decreases boiler thermal efficiencies and increases thermal losses.

Following are results after examination of operation at the control panel and one month logged operational data, both of Tabriz and Esfahan.

a) Stack gas temperature is 40 to 65 deg C higher than the designed one at Tabriz. At Esfahan, the differences are negligible. However, the temperature measured by the JICA Study indicated it was in 38 deg C higher at Tabriz (Aug. 8, 1998) and 21 deg C at Esfahan (June 6, 1998). Wide fluctuation of the stack gas temperature and unstable operation in some parts of the systems such as combustion control, heat exchangers, thermometers were noticed.

b) Steam temperatures incoming to turbines are well within the range of the designed ones.

c) Oxygen contents in flue gas measured at the outlet of the economizer are recorded in the log sheets to be 0.005 to 0.9% in Tabriz. However, it is almost impossible to operate the boiler of fuel oil combustion with the oxygen below 1% in flue gas. The oxygen meter was found not calibrated.

d) Both plants were in operation of the absolute pressure at each condenser to be about 20 mmHg higher than the designed values. Higher operational pressure at the condenser means less efficiency at the turbine, because of less expansion of steam in the turbine.

e) Differences of cooling water inlet and outlet temperatures at the steam condensers were higher than the designed one at Tabriz and lower at Esfahan. Tabriz was in trouble of a water supply system. Esfahan plant seems in good conditions of its condenser system from the standpoint of water temperatures, because of help of higher condensing temperature of steam. There always remains uncertainty of temperature indications at both plants.

Tabriz plant receives its Az fuel oil by piping from the Tabriz Refinery of the National Iranian Oil Company, 8 km apart from the power plant. Construction of the planned natural gas piping has been suspended for the time being. Esfahan receives Bz fuel oil from the nearby refinery by road at the rate of around 200 lorries per a day. Natural gas is conveniently piped from the refinery.

3.3 Energy Saving at Power Plant

The thermal power plant can convert only 40% of heat input to electricity from its nature. The 44% go to the condenser as steam cooling energy and the 13% go to energy escaped to atmosphere with stack gas. Therefore, reduction of these two big losses are effective in saving energy at the thermal power plant.

In Iran, gasoline price is far less than prices in the world, and electricity price is allegedly less than half of the production cost. Under these situations, it is unavoidable and regrettable that operators and managers of both plants seem not to concern about keeping high or improving thermal efficiency of power generation.

Measures generally employed for energy saving of existing power plants are control of stack gas temperature and oxygen contents in the gas, improvement of air leakage into the flue gas stream, control of vacuum at the condenser, reduction of internal energy consumption, and so on. Required for these measures are maintenance and calibration of instrument, strict management of operation and maintenance, education to cultivate energy saving minds, etc.

3.4 Air Pollution Control Measures

Generally, control measures taken at thermal power plants for air pollutants of SO_2, NOx, and soot can roughly be classified into three categories; i.e. fuel, facility and operation measures. Energy saving is another measure, since it can reduce fuel consumption and resultantly reduce emissions proportioning with the fuel rate. These measures are integrated to work together in the best way.

One of the objectives of the JICA Study is to contribute MOE to increase its own capability for preparation of EIA and to implement mitigation plan on existing and planned thermal power plants. For this objective, various mitigation measures are described in the **Supporting Appendices.**

3.5 Waste Water Treatment in Power Plants

There are five kinds of waste water streams from thermal power plants: a) Oily water, b) Chemical waste water, c) High SS (suspended solid) water, d) Blow down water, and e) Toilet and kitchen waste.

Both power plants seem not to well prepared to meet the National Waste Water Disposal Standards published by DOE. Although there are neutralization and coagulation facilities in Esfahan, there are not enough facility to treat oily waste water such as floor drains. Tabriz does not have any waste water treatment facility.

This JICA Study did not measure or collect data of water qualities. A schematic flow sheet is given in the Appendix as an example of a typical waste water treatment unit in a thermal power plant from quality protection of river water.

CHAPTER 4 LAWS AND INSTITUTIONS FOR ENVIRONMENT PROTECTION

4.1 Environmental Control in National Government

The constitution of the Islamic Republic of Iran has expressed a strong commitment towards protecting the environment. Its Article 50 states that *'Protection of the environment, in which the present and future generations must lead an ever-improving community life, is a general obligation. Therefore, all activities, economic or otherwise, which may cause irreversible damage to the environment, are forbidden'*.

The highest authority in the Islamic Republic is the Leader. Next to the Leader, the second highest authority in Iran is the President who nominates twenty two ministers controlling respective sectoral ministries and also vice-presidents.

For the environmental issues, the President heads the Environmental High Council (EHC) which is composed of two vice-presidents, all (ten) economic cabinet ministers, the attorney general, and experts as members. EHC is quite broad and strong in deciding on environmental policies, strategies, and standards. It is assisted by four coordinating councils on different aspects of environment, such as 1) environmental programs, 2) environmental research and information, 3) environmental education and awareness, and 4) environmental and sustainable development.

Department of Environment (DOE) is responsible to EHC partly for acting as a kind of a secretarial office. DOE is one of organizations included in the President's Office. It was originally founded in 1971 with general jurisdiction for environmental protection and broad powers based on the Game and Fish Law of 1967. It is now responsible for controlling any activity considered damaging to the environment assigned by the Environmental Protection and Enhancement Act of 1975 enacted after the United Nations' Stockholm Conference 1972. It prepares necessary regulations, standards or criteria by coordinating and consulting other relevant ministries and offices, and presents the regulations, etc. to EHC for approval. DOE's roles for air pollution are a) source identification, b) determination of ambient air quality, c) inspection and monitoring, d) technical assistance, and e) others, according to the Air Pollution Control Act.

Total environmental protection expenditure is planned to grow annually at average 8.8% by the Second 5 Year Development Plan. However, its growth rate is smaller than the average annual growth rate of the whole budget (15.4%) and the distribution of the environmental protection expenditure is planned to become smaller than 0.1% of the whole budget in 1998.

Air Pollution Control Act is composed of 6 sections and 38 articles. Section 3 is for Factories, Workshops and Power Plants. It contains 10 articles. The articles related to power plants are as follows:

1) Construction of power plants requires compliance with the regulations and standards in regards to their location.
2) Operations of power plants which produce air pollution above the permitted levels are forbidden.
3) Owners of power plants emitting pollution higher than the permitted levels will be given a specified time to take action in relation to the elimination of the pollution, whether the action may or may not require temporary closure of their activities.
4) If the owners of the power plants do not modify their activities so as to reduce pollution, their activities will be curbed, and the owners will be penalized according to this law.
5) Power plants must allocate at least 10 % of their area to greenery and tree.
6) Power plants are required to use fuels and combustion systems that reduce air pollution.

The Iranian Second Five Year Development Plan indicates the strong direction of environmental protection and optimal utilization of natural resources in its Objective No. 10th (within 16 objectives) with nine basic policies.

1) conserve, renew, and properly exploit natural resources,
2) enhance operations related to detailed exploration, equipment and preparation of the mines needed by industries,
3) exploit mines to supply required raw material and to replace imported materials,
4) make easy for participation of non-governmental mine developers,
5) increase water supply through completion of irrigation and drainage networks, etc.,
6) establish necessary environmental regulations, standards, criteria and indexes, and reform existed legal frameworks on the basis of the latest scientific findings and in accordance with Iran's conditions and possibilities,
7) utilize energy resources optimally by modification of existing consumption pattern, increasing efficiency and use of clean substitutes,
8) conserve and rehabilitate renewable natural resources; preserve rare flora; control desertification; reclaim desert lands; prevent soil erosion and pollution, various pollution of air, water, and marine; prevent destruction of wildlife habitats; exploit properly mineral resources in compliance with environmental regulations, and finally
9) apply optimally pesticides and fertilizers in farming; use biological techniques for controlling pests with a view to reduce reliance on poisons.

To implement the Second Five Year Plan, a law concerning the Plan was promulgated on December 29 1994. Notes 82 and 83 of the law are for the environmental issues.

Note 82 states mainly as follow, by aiming sustainable development and energy saving:

1. The large projects shall, in the stage of feasibility and location studies, be assessed from the viewpoints of environment preservation approved by EHC.
2. Any industrial and mineral operation shall be within the criteria of environment standards.
3. The utilization of energy in the country shall be made by the revision in the consumption pattern and decrease of fuel pollution.
4. The government shall take necessary steps for reducing the air pollution of 7 large cities including Tehran, Tabriz, and Esfahan to the standard of WHO.

Note 83 is for prevention of water pollution by industries. The industrial units and factories located in the towns and industrial complexes shall take measures for the establishment and commissioning of collection and transfer networks, as well as the installations of filtration of industrial sewage.

4.2 Ministry of Energy (MOE)

MOE is composed of seven Deputies: 1)Energy Affairs, 2)Power Affairs, 3)Water Affairs, 3)Municipal Waste Water Affairs, 4)Planning and Monitoring Affairs, 5)Recruit, 6)Education and Personnel Affairs, and 7)Support and Parliament Affairs.

The counterpart of this Study, the Environment Department in the Energy Planning Office, is under the Deputy of Energy Affairs. It has staffed with 7 specialists in the middle of 1999. Projects accomplished in the Department are a) Development of mathematical model for environment of watershed basin of dams, b) Evaluation of present status of power plants and preparation of suitable strategy for site selection, c) Preparation of a book on environmental effects of power plants, d) Marine pollution due to oil export and response to oil pollution, etc. Also the Department is ready to take part in management of power plants solid and liquid waste effluents, power plant's site selection, its social costs, EIA of hydropower dams, health of artificial lakes, etc. With regard to air pollution, this Study is substantially the first experience of the Department.

MOE has many affiliate organizations, among which Tavanir is the operator of all power plants including Tabriz and Esfahan, the two target power plants of the Study. Also affiliated to the Ministry, there are non-profit 'cum-companies' which are responsible for execution of projects interested by the Ministery. They are required to increase capacities of the Ministry to meet ever-progressing and diversifying technologies related with energy.

Iran Center for Energy Studies (ICES) is one of such companies. ICES has 75 experts and some of them carry out projects, such as this JICA Study, assigned by the Environment Department of MOE. In addition to the environmental issues, ICES handles projects related to the fields of economics, gas, oil, electrical and mechanical, renewable energy, energy conservation and management, etc.

4.3 Local Municipalities

There is a branch of DOE (the President's Office) in all 28 provinces. Budget of each DOE branch is allocated by DOE Headquarters. With the limited manpower, budget and equipment, each DOE branch is concentrating for its local interests in monitoring, negotiating with pollution sources for reduction, establishing local standards of ambient air quality, and trying to do else.

Within the two targeted regions, the Eastern Azarbayjan DOE branch has kept operation of 3 air monitoring stations for more than 15 years in Tabriz and recommending the power plant for switching its fuel to natural gas, and the Esfahan DOE branch is now concentrating on monitoring CO concentration once in a week at the busiest intersection in Esfahan. Ministry of Health and Medical Education is going to operate one intermittent monitoring (SO_2 and TSP) station at Esfahan and report its data to GEMS (Global Environmental Monitoring System of United Nations), in addition the Ministry's three such stations in Tehran.

4.4 Ambient Quality and Emission Standards

(1) Air Quality

Table 4.1 shows Iranian air quality standards based reportedly on WHO Guidelines and authorized by EHC.

(2) Stack Emission

There is no ratified national or local emission standards for any pollutant from any industrial stack gas. DOE drafted the emission standards and published them for discussion and for basis of local standard preparation. **Table 4.2** is the drafted emission standards of power plant.

Table 4.1 Iranian Air Quality Standards

Pollutants	Averaging Periods	Primary Standards[2]		Secondary Standards[3]	
		$\mu g/m^3$	ppm	$\mu g/m^3$	ppm
CO	Maximum in 8 hours	10,000	9	10,000	9
	Maximum in 1 hour[1]	40,000	35	40,000	35
SO_2	Annual average	80	0.03	60	0.02
	Max. in 24 hours[1]	365	0.14	260	0.1
	Max. in 3 hours[1]	--	--	1,300	0.5
Non-methane hydrocarbons	Max. in 3 hours of 6 to 9 am[1]	160	0.24	160	0.24
NO_2	Annual average	100	0.05	100	0.05
SPM	Annual average	75	--	60	--
	Max. in 24 hours[1]	260	--	150	--
Photo-chem. Oxidants	Max. in 1 hour[1]	160	0.08	160	0.08

Note 1) not to be exceeded for more than once per year
2) for public health 3) for public welfare

Table 4.2 Drafted Emission Standards of Air Pollutants from Power Plants (#90)

Pollutants	units	Primary Standard	Secondary Standard	Remark
Sulfur dioxide	ppm	800	800	
Carbon monoxide	mg/m^3	150	150	
Nitrogen oxides	ppm	350	350	
Soot	mg/m^3	150	350	fuel oil
Smoke Index	%	20	20	burning

Note: No description given on O_2 contents, temperature and pressure of exhaust gases

(3) Waste Water Quality

Waste water quality standards were regulated by DOE Headquarters. Table 4.3 is an extract of 52 pollutants regulated.

As the quantitative target of river water quality, 14 rivers, including Zayandehrud of Esfahan, should have BOD of 10 mg/liter by the end of the Second Development Plan, gradual reduction from 40 - 50 mg/liter values in 1993. BOD of a power plant waste stream should be less than 10 mg/l instead of 30 as given in Table 4.3, if the stream flows in Zayandehrud.

Table 4.3 Maximum Permissible Concentration of Pollutants in Waste Stream

Pollutants	Units	Waste Water discharged to		
		Surface Water	Absorption wells	Irrigation Use
BOD	mg/l	30	30	100
COD	mg/l	60	60	200
Color	Unit	75	75	75
DO	mg/l	2	--	2
Ammonia	mg/l as NH_4	2.5	1	0
pH	Unit	6.5 - 8.5	5 - 9	6 - 8.5
TSS	mg/l	40	--	100
Vanadium	mg/l	0.1	0.1	0.1
Nickel	mg/l	2	2	2
Lead	mg/l	1	1	1
Zinc	mg/l	2	2	2

CHAPTER 5 METEOROLOGICAL OBSERVATION

5.1 Introduction

Meteorological observation in this JICA Study consists of Upper Layer Observation from the ground level to a height of 1500 m and Surface Observation on the ground level.

5.2 Methods

The Upper Layer Observation at Tabriz and Esfahan Power Plants had been carried out in each three days (72 hours) in each four season. Items observed are wind directions and speeds (Pilot Balloon) and air temperatures (Low-Level Radio Sonde) from the ground level to 1500m height.

Surface Observation at Tabriz and Esfahan Power Plants had been carried out continuously in one year at each plant. Items observed were wind direction and velocity, temperature, solar radiation and net radiation. Furthermore, atmospheric stability was obtained from wind speed and solar radiation or net radiation for the dispersion simulation.

5.3 Results and Evaluations of Upper Layer Observation

Upper layer wind was mainly in the west by influence of "the prevailing westerlies of the earth" at both sites in winter. In spring, the wind was mainly in the east by influence of an anticyclone covering the Caspian Sea. In summer at Tabriz, wind was also mainly in the east by the same effect of the Caspian Sea. However, at Esfahan in summer, it was variable by a high pressure system covering the central part of Iran. In autumn, wind was mainly in the south-west at Tabriz though somewhat variable, and in the south-east at Esfahan by a high pressure system covering the eastern to the southern parts of Iran. Wind speed generally increased from the ground by heights at both of Tabriz and Esfahan.

Upper air temperature was unstable in daytime except in winter. Especially, in spring and summer seasons, it was unstable even in the upper layer. It is favorable for diffusion of air pollutants. At night, the ground inversion layer was formed by radiation cooling. This inversion layer is not favorable for diffusion of air pollutants.

The inversion layers near the ground level were stronger at Esfahan than at Tabriz, with its maximum temperature difference of about 12 degree C. The Esfahan power plant located in a small basin where low-temperature air is accumulated. Especially, in a condition with easterly or southerly weak surface wind, the ground inversion layer appears predominantly. When upper layer easterly wind extends its strength to the ground level, low-temperature air mass accumulated in the small basin flows out to the western area and the upper layer air mass fills up the basin. Accordingly, the ground inversion layer disappears temporarily, and later it appears again.

5.4 Surface Observation

Eastery wind was dominated, and it was stronger in July and weaker from October to January in Tabriz. In Esfahan, there was no specific feature of wind direction and wind was generally weak.

Except Mayan of Tabriz, all other stations had the highest frequency of the wind velocity class of 1.0 to 1.9 m/sec. The predominated calm condition backed up the weak condition in those stations. However, Mayan had the highest frequency of the wind class of more than 6.0 m/sec.

Mayan had high percentage of Neutral of the atmospheric stability. On the contrary, all other stations had high percentage of the stable condition. These indicate unfavorable to pollutant dispersion in Tabriz and Esfahan except Mayan.

CHAPTER 6 AIR QUALITY MONITORING

6.1 Introduction

Three ambient air monitoring stations were placed each within about 15 km around the power plants at Tabriz and Esfahan. SO_2, NOx, wind direction and speed were monitored by automatic continuous analyzers. SPM and settled dust samples were collected at each station. As a supplemental method for automatic monitoring, passive samplers of SO_2 and NOx were set up at about 30 to 40 places within a 20 km radius of both power plants in each season.

6.2 Air Quality Standards

Table 6.1 lists Iraian air quality standards of particulates, SO_2 and NO_2 based on WHO guidelines. The ppm values are converted from μ g/m^3.

Table 6.1 Air Quality Standards in Iran

Pollutants	Averaging Time	Primary Criteria 2)		Secondary Criteria 3)	
		μ g/m^3	ppm	μ g/m^3	ppm
SO_2	Annual	8	0.03	60	0.02
	24 hours 1)	365	0.14	260	0.1
	3 hours 1)	-	-	1,300	0.5
NO_2	Annual	100	0.05	100	0.05
SPM	Annual	75	-	60	-
	24 hours 1)	260	-	150	-

Note: *1) not to be exceeded for more than one day per year

*2)Criteria required for protecting the health

*3)Criteria requiredfor protecting social welfare

6.3 Automatic Air Monitoring

Monitoring results summarized here in **Tables 6.2** and **6.3**. Because NOx analyzer at Kaveh in Esfahan was malfunctioned in September, 1998 and AC/DC converter was found to be changed as a result of a local agent's investigation. The converter was not delivered in time for the latter half of data logging because it took too much time to clear through the customs.

Table 6.2 Results of Air Monitoring from June, 1998 to May, 1999 (Tabriz)

	SO_2(ppm)			NO_2 (ppm)	
	Annual Mean	Daily Mean (Max.)	Hourly Mean (Max.)	Annual Mean	Hourly Mean (Max.)
Baranloo	0.005	0.023	0.140	0.008	0.062
Mayan Pump	0.003	0.037	0.230	0.007	0.068
Qara Malek	0.012	0.051	0.194	0.020	0.111

Table 6.3 Results of Air Monitoring from June, 1998 to May, 1999 (Esfahan)

	SO_2(ppm)			NO_2 (ppm)	
	Annual Mean	Daily Mean (Max.)	Hourly Mean (Max.)	Annual Mean	Hourly Mean (Max.)
Golshahr	0.011	0.032	0.129	0.024	0.198
Kaveh	0.014	0.058	0.121	0.019*	0.073*
Sharieati	0.012	0.047	0.221	0.038	0.266

Note : * Data logged from June to September for four months

SO_2 and NO_2 concentrations at all stations in both areas are low in comparison with the Air Quality Standards of annual and daily averages.

6.4 SPM, Settled Dust and Bag Samplings

SPM monitoring was carried out on the roofs of air monitoring stations or in the neighborhood of the stations. The SPM monitoring results are summarized in Table 6.4. Sampling days varied every month from 9 to 31 days.

Table 6.4 Results of SPM Monitoring

Location		SPM ($\mu g/m^3$)	Annual mean ($\mu g/m^3$)
Tabriz	Baranloo	29.4 ~ 97.7	58.8
	Mayan Pump	22.0 ~ 71.7	41.2
	Qara Malek	23.7 ~ 72.6	44.4
Esfahan	Golshahr	27.7 ~156.9	69.1
	Kaveh	22.0 ~150.0	65.8
	Shariati	17.3 ~128.8	69.6

The annual average SPM loadings at all six stations are lower than 75 $\mu g/m^3$, the Iranian Standard. The low volume samplers is unable to generate accurated daily average value. Hower, the highest monthly average of 156.9 $\mu g/m^3$ at Esfahan in summer is possible to have higher daily average values than 260 μg/m³ given in the Iranian Standard. It is recommended to check the daily average value using an automated continuous SPM analyzer.

Settled dust monitoring was carried out on the roofs of air monitoring stations or in the neighborhood of the stations. The settled dust monitoring results are summarized in **Table 6.5**.

Table 6.5 Results of Settled Dust Monitoring from February to December 1998

Location		Monthly Range	Annual Average
Tabriz	Baranloo	0.764 ~ 8.815	5.4
	Mayan Pump	0.877 ~ 9.987	5.9
	Qara Malek	2.860 ~ 8.831	5.3
Esfahan	Golshahr	0.670 ~ 7.245	3.6
	Kaveh	0.571 ~ 8.372	3.3
	Shariati	0.851 ~ 6.324	2.7

unit : $ton/km^2/month$

In general, Esfahan has less settled dust than that of Tabriz.

Bag sampling monitoring, air is inhaled with a pump and is introduced to a Teflon Bag, was carried out at Qa-e-Mieh, a small community, which was allegedly affected by air pollution from the power plant. Samples were taken on every hour for 24 hours and analyzed using an automated analyzers at the Shariati station. The results of monitoring are shown in **Table 6.6.**

Table 6.6 Results of Air Monitoring at Qa-e-Mie

Date measured	SO_2 (ppm)	NOx (ppm)
from June 30 to July 1, 1998	0.0001 ~ 0.0006	0.0018 ~ 0.0178
from Jan.25 to Jan.26, 1999	0.0011 ~ 0.0058	0.0154 ~ 0.0661

When the summer monitoring was carried out, apparently wind blew in the opposite direction. In winter, the concentrations were higher than those of summer. However, wind direction was again in the opposite. The JICA Team recommends to monitor the situation in Qa-e-Mieh for a long period, possibly for a year, using automated continuous analyzers and wind meters.

CHAPTER 7 STACK GAS MONITORING

7.1 Monitoring

No.1 and 2 boilers of Tabriz power plant and No. 3, 4 and 5 boilers of Esfahan power plant were selected for four times of stack gas monitoring in the JICA Study. No. 1 and 2 boilers of Esfahan power plant were excluded from the target because of their small capacity and no appropriate space for sampling. Tabriz No. 2 Unit was monitored only once in winter 1999, because of prolonged maintenance and repair work.

7.2 Monitoring Results and Evaluations

In order to evaluate consistently all monitored data of SO_2, NOx and soot, oxygen concentration remaining in the stack gas is converted by calculation to beat constant of 6 %. Following two tables are considered for the basis of evaluation: a) **Table 4.2** DOE Proposed Emission Primary Standards, and b) **Table 7.1** Emissions from Similar Boilers.

Table 7.1 Emission from Similar Boilers

Fuel Oil Combustion	
Pollutant	Emissions / Fuel Oil
NOx	5.64 kg/m^3
PM	$(9.19(S)+3.22)\times 0.12$ kg/m^3

Natural Gas Combustion	
Pollutant	Emissions / Natural Gas
NOx	4,480 $kg/10^6m^3$
PM	121.6 $kg/10^6m^3$

Note: S - sulfur in fuel oil % by weight

Generation Capacity and Fuel Requirment - Heat input rates of Tabriz Units 1 and 2 are designed to be 1,852 kcal/kwh at 100% generating capacity and 2,232 kcal/kwh at 25 % capacity. Actually the rates were 2,240 and 2,200 kcal/kwh respectively at Tabriz No 1 and Esfahan No.4, both running almost at 100% capacity with fuel oil burning. The heat input rates were quite high and close to the designed rate at 25% capacity. Suggestive from these values are low thermal efficiency of the power generation or inaccuracy of fuel flow rate measurements.

SO_2 - **Table 7.2** arranged to give all monitoring results of SO_2 emissions. All boilers except Tabriz No. 2 do not satisfy the standard value of 800 ppm proposed by DOE (**Table 4.2**), when burning fuel oil. Amounts of SO_2 emission should be proportional to sulfur contents in the fuel. If the fuel input rates per kwh are nearly equal and the same kind of fuel is used in each case, amounts of SO_2 emission per kwh should be equal in each case. Actually there are wide difference even in the same boiler unit and with burning fuel oil only. Also because there are about twice of difference in the results of Tabriz No. 1 and 2, there must be wide fluctuation of sulfur contents in fuel oils. There are apparent and inherent differences of SO_2 concentrations in Esfahan between fuel oil only and fuel oil and natural gas simultaneous burning.

Table 7.2 SO_2 Monitoring Results

Power Plant	Unit	Fuel	SO_2		
			Concentration (ppm)	Emission (kg/hr)	Emissions per Output (kg/MWh)
Tabriz	1	Fuel Oil	1180~1370	1930~4530	6.7~13.1
	2	Fuel Oil	618	2000	5.8
Esfahan	3	Fuel Oil	1300~1390	944~1280	12.3~17.3
		Oil & Gas	625~664	362~794	4.8~6.6
	4	Fuel Oil	1350~1420	2580~2820	8.1~17.6
		Oil & Gas	202~650	315~872	2.0~5.5
	5	Fuel Oil	1390	2540	14.9
		Oil & Gas	85~93	77	0.4

NOx - **Table 7.3** gives the results of NOx monitoring. Tabriz Unit No. 1 only has data above the DOE proposed standard of 350 ppm (**Table 4.2**). The monitoring seems acceptable since the emissions per generation output are within narrow ranges, except Esfahan Unit No. 4.

Table 7.3 Results of NOx Monitoring

Power Plant	Unit	Fuel	NOx		
			Concentration (ppm)	Emission (kg/hr)	Emission per Output (kg/MWh)
Tabriz	1	Fuel Oil	385~486	269~417	0.9~1.2
Esfahan	3	Fuel Oil	163~215	60~70	0.8~0.9
		Oil & Gas	132~298	67~167	0.9~1.4
	4	Fuel Oil	240~296	231~235	0.7~1.5
	5	Fuel Oil	180	154	0.9
		Oil & Gas	78~112	44	0.2

When burning simultaneously fuel oil and natural gas, NOx concentrations monitored are under the proposed standard. As the gas has no flamable nitrogen compound and is easy to mix with air before burning, natural gas burning will not generate NOx exceeding the drafted standard.

Soot - **Table 7.4** is a compilation of soot monitored results. Many data do not satisfy the primary standard value of 150 mg/m^3 proposed by DOE (**Table 4.2**) when burning oil only. However, after conversion of fuel oil to natural gas, this is not a problem anymore. Esfahan data of oil and gas burning evidences this. All the data except one in Esfahan are under the referred data.

Table 7.4 Results of Soot Monitoring

Power Plant	Unit	Fuel Oil (t/hr)	Natural Gas (m^3/hr)	Soot Load (mg/m^3N)	Soot Emission (kg/hr)	Referred Data Table 7.1 (kg/hr)
Tabriz	1	65~79	—	90~210	54~258	276~335
	2	73	—	..	—	310
Esfahan	3	19.2~20	—	130~260	33.9~84.5	81.4~84.8
		11~19.2	11000~17100	120~470	48.4~50.9	47.9~83.5
	4	36~71	—	90~740	66.2~467	153~301
		3.2~23	20000~32700	40~90	20.8~41.3	17.5~99.9
	5	39	—	140	87.0	165
		3~4	45000~47000	50~60	14.8	18.1~22.6

Residual Oxygen in Stack Gas - **Table 7.5** shows monitored results of residual oxygen concentration in stack gases. The concentration was in the range of 11 to 13 % in the data of Tabriz Unit No. 1. However, reportedly it was reduced drastically to 3.5% after maintenance of the air heater. In Esfahan, the concentration was rather consistently in the range of 7 to 11 % when burning oil. It was in the wide range of 9 to 17 % when oil and gas were burnt simultaneously. It is supposed to have difficulty to control combustion in those occassions. Both plants were aware of air leakage from the air heaters.

Table 7.5 Residual Oxygen in Stack Gases

Power Plant	Unit	Fuel	Residual O_2 Concentration (vol %)
Tabriz	1	Fuel Oil	11.6~13.5 (3.5 after maintenance)
	2	Fuel Oil	— (4.6 after maintenance)
Esfahan	3	Fuel Oil	8.5~11.0
		Oil & Gas	9.3~16.9
	4	Fuel Oil	6.8~12.7
		Oil & Gas	9.2~10.9
	5	Fuel Oil	8.1
		Oil & Gas	14.8~15.5

By assuming fuel oil composition to be carbon 85, hydrogen 11, sufur 3, and nitrogen 1 % by weight, combustion caluculation resulted residual oxygen to be in the range of 2 to 7.3 % by volume at the air ratio range of 1.1 to 1.5. Esfahan reported that the oxygen concentration was in the range of 2 to 3 % by Orsat analyses in flue gas before the air heater in the end of January 1999. It seems to be in operation in good control. However, the operation should be under the ratio of 1.15 to have residual oxygen below 3 % according to the assumed calculation. It is unusual to operate fuel oil burning under the air ratio below 1.15. The JICA Team suggests to check and maintain Orsat analyzers carefully.

Stack Gas Flow Rate - **Table 7.6** is a summary of wet stack gas flow rates. By assuming the design stack gas flow rate at the rated power generation output to be respectively 2,580 of units at Tabriz, 3,670 of Esfahan Unit No. 3, and 3,220 m^3/MWh of Esfahan Units No. 4 and 5. There are 1.22 to 1.67 times more monitored than the assumed design flow rates. It seems that there are difficulty of combustion control or leakage of air to the system.

Table 7.6 Monitored Wet Stack Gas Flow Rate

Power Plant	Unit No.	Fuel	Capacity (MW)	Wet Stack Gas (10^5 m^3 N/hr)	Wet Stack Gas per Output (m^3N/MW.hr)	Ratio (Left Column / Assumed Rate)
Tabriz	1	Fuel Oil	290~350	1.13~1.27	3230~4000	1.25~1.55
	2	Fuel Oil	345	1.15	3330	1.29
Esfahan	3	Fuel Oil	74~77	0.37~0.42	4930~5540	1.34~1.51
		Oil & Gas	75~120	0.40~0.60	5000~5330	--
	4	Fuel Oil	160~320	0.84~1.26	3940 ~5390	1.22~1.67
		Oil & Gas	160	0.77~0.80	4810~5000	--
	5	Fuel Oil	170	0.82	4820	1.50
		Oil & Gas	220	0.93	4230	--

Following are the conclusion obtained from the stack gas monitoring of both power plants:

①Oxygen contents in the stack gases are far higher than those of normal fuel oil burning boilers. Both power plants understood there were air leakage from air heaters.

②Wet stack gas rates are 22~67 % higher than the designed rates.

③There were less relevancy in the relations of output capacities vs. fuel consumptions, output capacities vs. stack gas rates, and fuel consumptions vs. SO_2 emissions.

④There must be a wide variation of sulfur contents in fuel, or inaccuracy of fuel oil flow meters.

⑤The stack gases have higher NOx concentrations and narrower the concentration ranges at oil burning than at oil and gas simultaneous burning method.

⑥Oxygen monitoring by a field Orsat Analyzer is questionable, and also indications of oxygen meters on the control panel seem not working correctlly.

The power plant operation was far from environmental consideration and energy saving at both power plants. It was just to generate power as required or specified.

CHAPTER 8 EFFECTS OF POWER PLANTS ON AIR QUALITIES

8.1 Outline of Impact Assessment from Stack Gas

Impacts of the stack gas emitted from the power plant stacks to the surroundings were estimated with a dispersion simulation model. The models used are based on Plume and Puff formulae, and simulate annual averages, daily averages, and hourly values of SO_2, NO_2, and SPM. The conversion from NO_x to NO_2 were conducted with a exponential model. The effects of buildings around the stacks and topography under special meteorological conditions were also estimated.

Input data on pollutant emissions and power generation of each plant were based on the results of **Chapters 3** and **7**. Gas turbines in Tabriz plant were included in the simulation based on fuel consumption. Esfahan burnt fuel oil or fuel oil and natural gas simultaneously. The fuel oil consumption under the exclusive burning was calculated by subtracting the oil amount consumed with natural gas which was given as the monthly consumption data.

Large emission sources with high stacks are treated as point sources, major road traffics as line sources, and non-pointed sources like small, medium industries, households, and minor road traffics as area sources in the simulation model.

Data of other emission sources in the target areas, such as large factories, small and medium factories and establishments, households and vehicles, were also obtained for fuel consumption, traffic volumes and so on. The large factories are Tabriz Refinery and Soofian Cement in Tabriz, and SH. M. Montazeri Power Plant, Esfahan Refinery, Poly-acrylonitrile Factory, Esfahan Steel, Esfahan Cement, and Sepahan Cement in Esfahan.

As for the line sources of mobile vehicle emissions, vehicle numbers ran through the major road in front of the Qara Malek monitoring station were counted and simulated. Similar and detailed data were presented by the Esfahan Municipality Office for the Study. As for the area sources, fuel consumption with their kinds and types of consumers in each province of East Azarbayjan and Esfahan were used to generate emissions.

The pollutant emissions are summarized in **Table 8.1** and **Table 8.2.** Tabriz power plant occupied 52.3 % of SO_x, 44.8 % of NO_x, 8.2 % of particulate matter (PM), and Esfahan power plant occupied 14.8 %, 36.8 % and 5.3 % of SO_x, NO_x, and PM. Accuracy is low in the data of the other emission sources, in this Study.

Table 8.1 Summary of Emission Sources in Tabriz Area

Emission Source	Type	Pollutant Emission Amounts		
		SO_x	NO_x	PM
Tabriz Power Plant	Point	30,019	7,855	1,279
Large Factories	Point	15,462	2,658	13,215
Small&Medium Factories	Area	5,302	830	201
Households	Area	4,097	1,334	218
Major Road Traffic	Line	45	117	20
Minor Road Traffic	Area	2,439	4,735	587
Total		57,364	17,529	15,520

Unit: tons/year

Table 8.2 Summary of Emission Sources in Esfahan Area

Emission Source	Type	Pollutant Emission Amoun		
		SO_x	NO_x	PM
Esfahan Power Plant	Point	28,550	11,774	1,660
Large Factories	Point	157,969	12,517	28,114
Small&Medium Factories	Area	1,995	748	189
Households	Area	1,325	346	46
Major Road Traffic	Line	1,747	4,789	820
Minor Road Traffic	Area	1,364	1,858	299
Total		192,950	32,032	31,128

Unit: tons/year

The necessary meteorological inputs to the simulation model are wind direction, wind speed, atmospheric stability, which were based on the winds, solar and net radiation described in **Chapter 5**. The upper layer observation results were analyzed, and correction factors for estimating wind speeds at the stack heights, lid heights, and potential temperature gradients were obtained and used by the simulation model. Diffusion parameters of atmospheric stability classes were calibrated based on the comparisons of the measured pollutant concentrations and the calculated values with all emission sources in the target areas.

8.2 Simulation Results

Annual average concentrations

All of the emission sources were used in the first series of the calculation to calibrate the model parameters to reproduce the measured concentrations. Although as much as possibly the input data were collected, the reproducibility of the model was not enough. As the major cause was the insufficient data on emission sources, it is necessary to improve the simulation model in filling up more data on various sources.

Comparisons of the maximum concentrations of pollutants in the target areas with the Iranian air quality standards (**Table 4.1**) are shown in **Table 8.3**. The contributions from the power plants for the pollutants in both areas were much less to the air quality standards. The SO_2 concentration in Esfahan shows the higher contribution and occupies one sixth of the standard.

Table 8.3 Maximum Concentration from Power Plant vs. Air Quality Standard

Pollutant	Tabriz	Esfahan	Standard
	Maximum	Maximum	Primary
SO_2(ppb)	1.0	4.9	30
NO_2(ppb)	0.3	1.3	50
SPM($\mu g/m^3$)	0.1	0.8	75

The maximum concentrations of all pollutants occurred at ENE with the distance of around 10 km from the stacks and the influences reached the city center area of Tabriz (**Fig. 8.1**).

Although pollutant emission of two plants were at similar levels, all of the maximum concentrations in Esfahan were higher than the ones in Tabriz. This is because of the meteorological factors, such as weaker wind and more frequent unstable conditions in Esfahan.

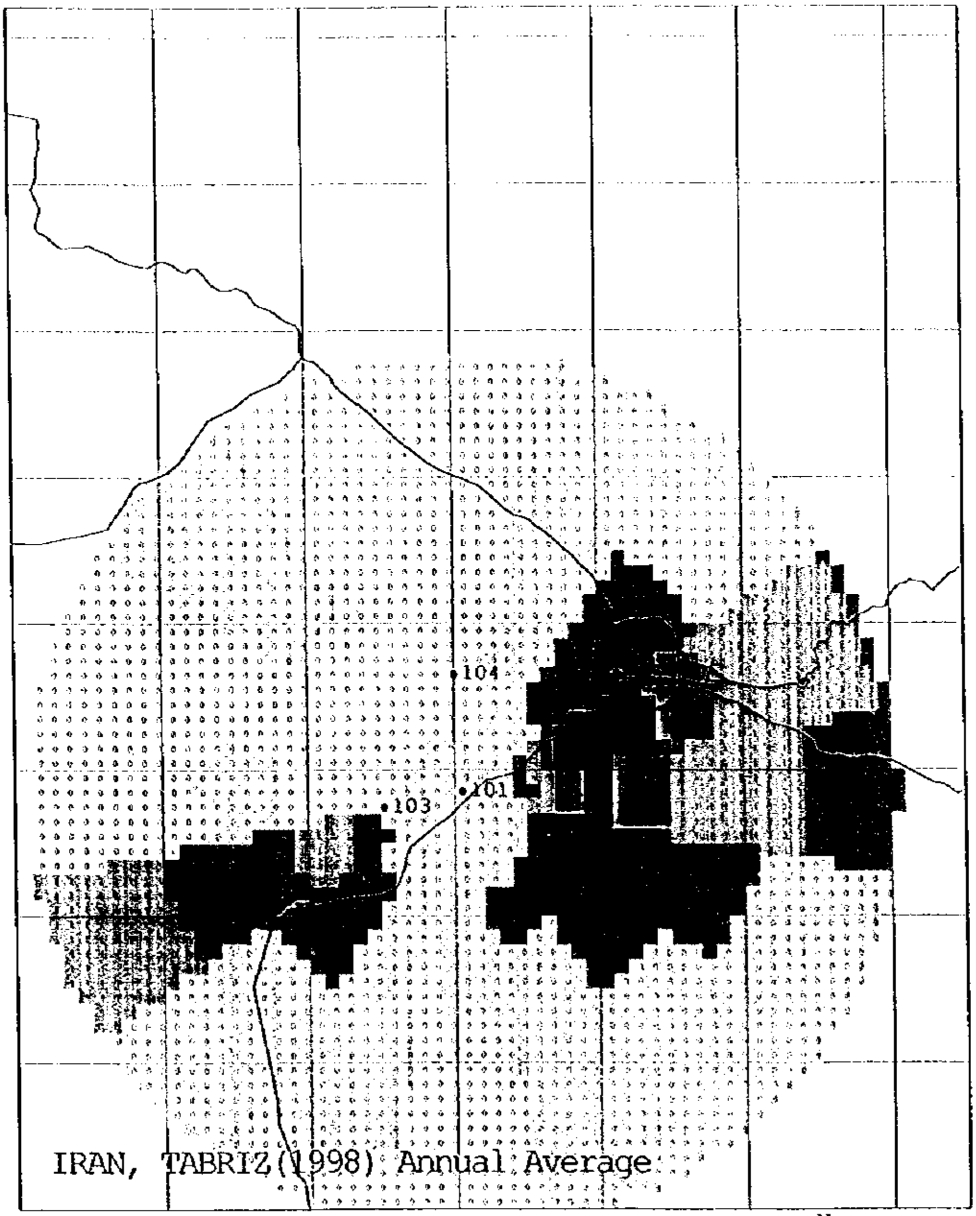
<u>Hourly Value and Daily Average</u>

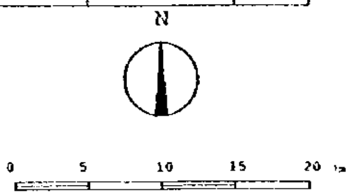
No air quality standard is defined for hourly values of pollutants concerned in Iran, and the standard for SO_2 is for 3 hours' average. One time exceeding is permitted during one year, and the comparisons were conducted with the second highest values, not with the highest values. There may exist a certain difference between hourly values and 3 hours' averages, and the former is usually higher than the latter. However, the comparison shown in **Table 8.4** is between the second highest hourly values of maximum pollutants concentrations emitted from the power plants in both areas and air quality standards of 3 hours' averages. Generally, the contributions from the Esfahan power plants were 6 or 10 times higher than the ones from the Tabriz power plants.

Table 8.4 Second Highest Hourly Concentrations from Power Plant vs. Standard

Pollutant	Tabriz	Esfahan	Standards
	Second Highest		Secondary
SO_2 (ppb)	87.0	621.1	500*
NO_2 (ppb)	20.0	129.0	-
SPM (μg/m3)	10.6	106.3	-

*: 3 Hours' Average (Secondary Standard)





LEGEND

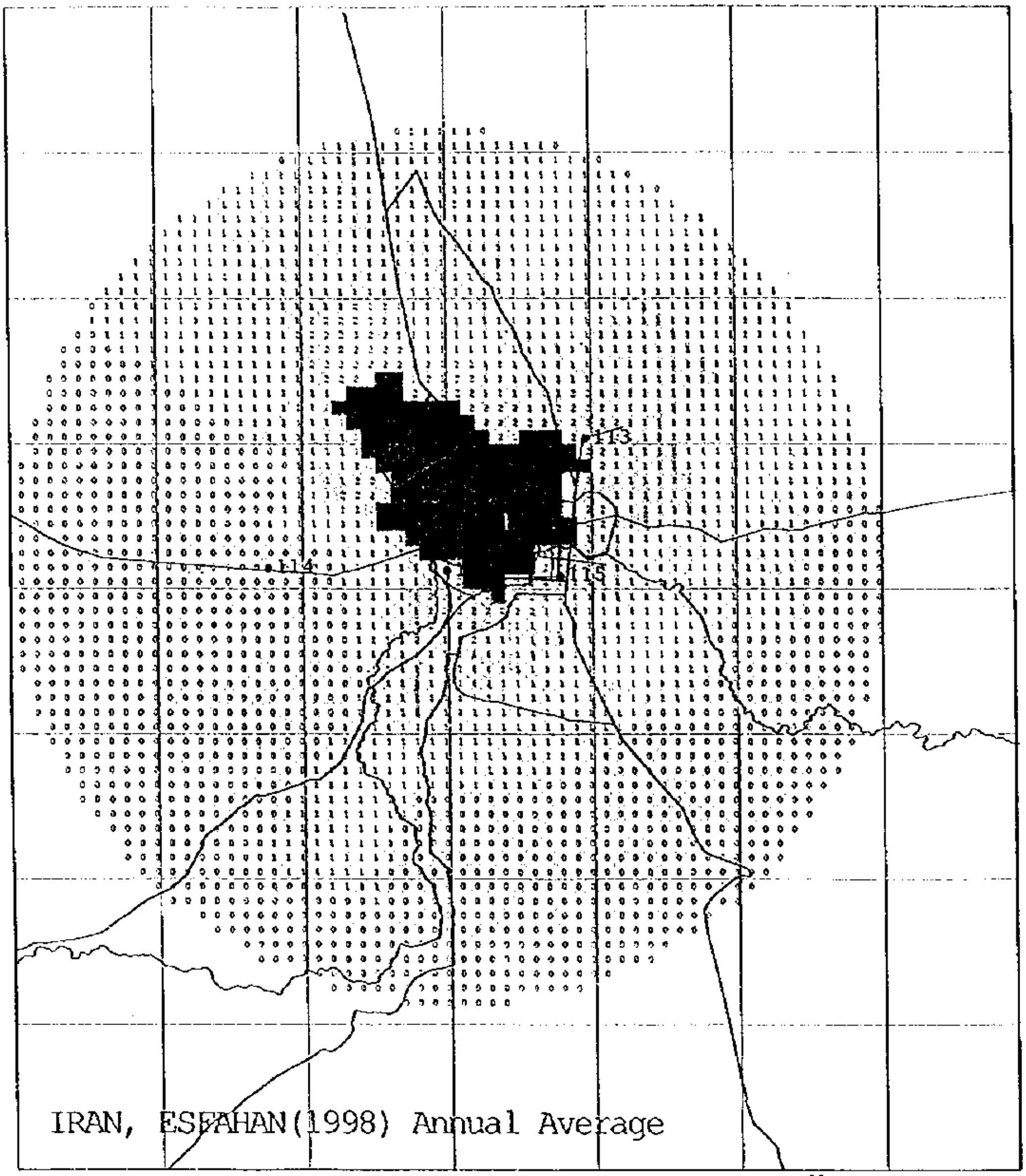
■	.90 < x <= 1.00 (ppb)	38 grids
■	.80 < x <= .90 (ppb)	112 grids
▒	.60 < x <= .80 (ppb)	281 grids
■	.40 < x <= .60 (ppb)	336 grids
⁞	.20 < x <= .40 (ppb)	1167 grids
⁞	.00 < x <= .20 (ppb)	868 grids

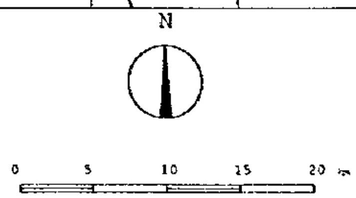
Monitoring Stations
- 103 Baranloo
- 104 Mayan
- 105 Qaramalek

Power Plant
- 101 Tabriz Power Plant

SO2 ppb □C MAX= 1.0ppb

Fig. 8.1 Distribution of Annual Average Concentration (SO_2 from Tabriz P/P)





LEGEND

■	4.5 < x <= 5.0 (ppb)	4 grids
■	4.0 < x <= 4.5 (ppb)	10 grids
▒	3.0 < x <= 4.0 (ppb)	41 grids
■	2.0 < x <= 3.0 (ppb)	91 grids
□	1.0 < x <= 2.0 (ppb)	519 grids
□	.0 < x <= 1.0 (ppb)	2201 grids

Monitoring Stations
113 Kaveh
114 Golshahr
115 Shariati

Power Plant
111 Esfahan Power Plant

SO2 ppb □C MAX= 4.9ppb

Fig. 8.2 Distribution of Annual Average Concentration (SO_2 from Esfahan P/P)

The comparison of the second highest daily averages of maximum pollutant concentrations emitted from the power plants in both areas and air quality standards are shown in **Table 8.5**. The SO_2 concentration from Esfahan power plant occupied around 40 % of the standard, and the contribution is much for one power plant. The contributions from the Esfahan power plant were also 6 or 8 times higher than the ones from the Tabriz power plant.

Table 8.5 Second Highest Daily Average Concentrations from Power Plants vs. Standard

Pollutant	Tabriz	Esfahan	Standard
	Second Highest		Primary
SO_2(ppb)	10.0	52.8	140
NO_2(ppb)	1.5	11.7	-
SPM($\mu g/m^3$)	1.2	8.7	260

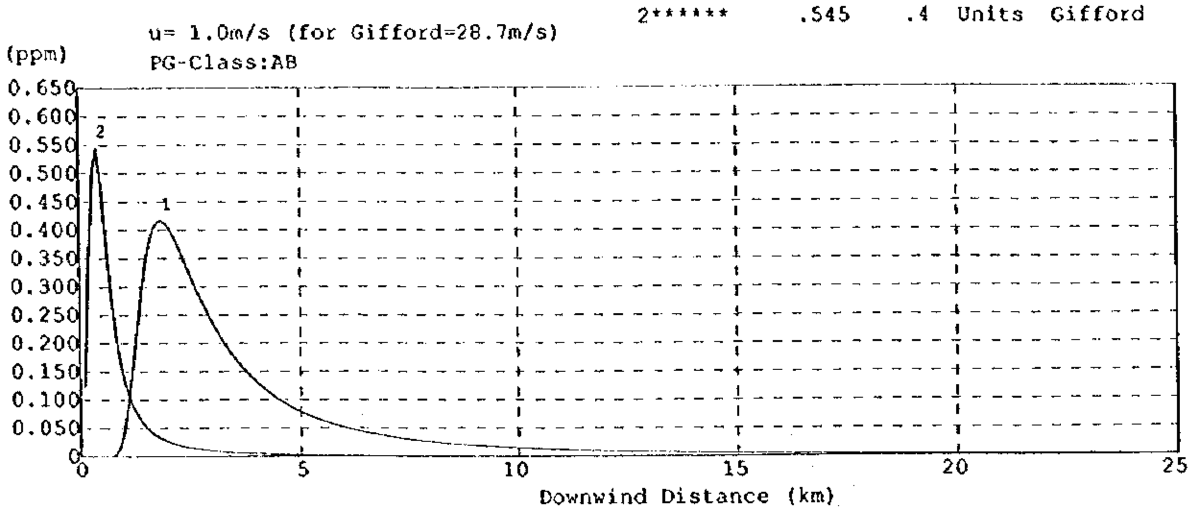
Simulations Under Special Meteorological Conditions

Four types of models were used for calculating hourly concentrations with the emission conditions of maximum pollutant by each unit and each pollutant, under the influences of buildings and topography. The terrain from the Tabriz power plant to Kohsrow Shah was considered to be the calculation basis. It has the hill with the relative maximum altitude of 130 meters between around 4 to 8 km from the plant. The hill between the Esfahan power plant and Qa-e-Mich was also considered, and the maximum relative altitude was around 110 meters.

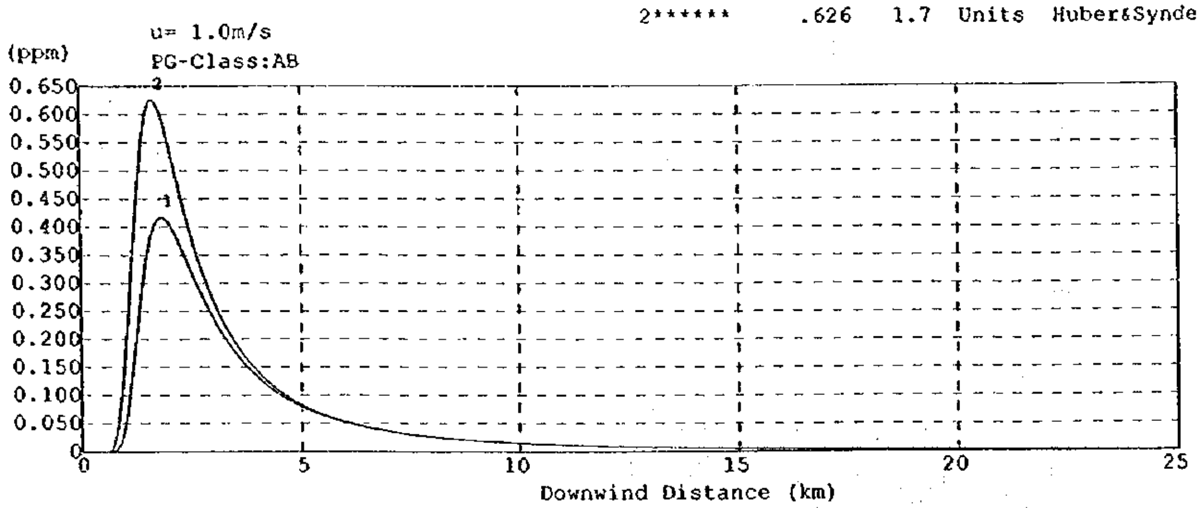
In Tabriz, the highest predicted SO_2 concentration (212.2 ppb) by Gifford model was less than the 3 hours' average standard (500 ppb). In Esfahan, total amount of SO_2 contribution is around 545 to 634 ppb which is over the 3 hours standard. The highest concentration point was located before the peak of the hill (500 meters downwind distance). See **Fig. 8.3**.

When the conversions to natural gas are completed, SO_2 concentrations contributed from both of Tabriz and Esfahan power plants will be reduced. Although the measured NO_2 concentrations were rather high in Esfahan, they were not from the power plant and were supposed to come from vehicles. The detailed regional simulation is necessary for the confirmation.

NO.	He (m)	Cmax (ppm)	Xmax (Km)		
1******		.417	1.9	Units	CONCAWE&Plume
2******		.545	.4	Units	Gifford



NO.	He (m)	Cmax (ppm)	Xmax (Km)		
1******		.417	1.9	Units	CONCAWE&Plu
2******		.626	1.7	Units	Huber&Synde.



NO.	He (m)	Cmax (ppm)	Xmax (Km)		
1******		.332	.8	Units	CONCAWE&Plu
2******		.634	.5	Units	Terrain

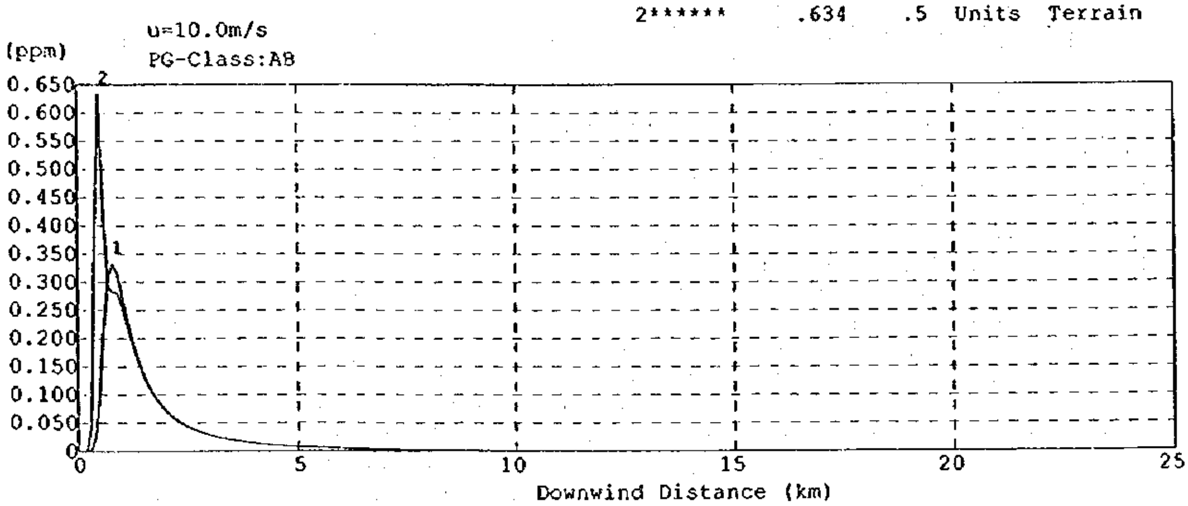


Fig. 8.3 Maximum SO_2 Profiles by Each Model (Esfahan)

CHAPTER 9 CHEMICAL ANALYSES

9.1 Introduction

Particulates and gaseous pollutants collected at Tabriz and Esfahan Power Plants and in the target areas were chemically analyzed: particulates for vanadium, nickel, zinc and lead by the Institute for Environmental Studies, University Tehran, and gaseous pollutants sampled by passive samplers for NO_2, NOx and SO_2 were analyzed by Chemical Engineering Department, Research Institute of Jihad, Ministry of Construction Crusade.

9.2 Results and Discussion

Average metal existence in the earth is given as Clarke Number by Clarke et. al.: V 135, Ni 75, Pb 13 and Zn 70, all in ppm. The contents of V and Ni in SPM are quite low in comparison with the Clarke Number. Each metal has more than 100 times of range when SPM metal contents are converted to ambient air contents. Ambient air in Esfahan has higher lead contents (0.27 micro gram/m^3) than Tabriz, and is lower than the US-EPA air quality standard of 1.5 micro gram/m^3.

Settled dusts at Mayan and Qaramalek stations had respectively three and two incidents of abnormally high zinc contents, supposedly affected by entering tips of artificial material such as paint-peels into the deposit gages by strong wind. The minimum lead contents obtained in February when there was less traffic of cars because of snow and in summer when atmosphere was favorable to dispersion because of the unstable condition. As vanadium and nickel contents are in the similar range respectively in Tabriz and Esfahan, it can be said that majority of the metals come from the same source. And the source will be soil.

Soot contained less vanadium than nickel. The ratio was 2 to 5 in the oil burnt soot at Tabriz and Esfahan.

Using the maximum soot load in stack gases and the maximum contents of each metal, metal emissions are lower than the values proposed by U.S.EPA as DMEG (Discharge Multimedia Environmental Goal), a kind of emission level goals.

Analyses of only 4 metals was not able to estimate contribution of soot to air borne particulate which are composed from artificial and natural sources. It is evident that the power plant is not the only source of the particulate emissions from the difference of nickel and lead contents.

By the passive sampler monitoring, the Tabriz plant site has higher SO_2 concentration generally among others. This may be resulted by down wash effects of stacks or leakage of gases from the plant equipment. The place near the refinery in Tabriz showed the highest SO_2 concentration in winter. The Esfahan plant site has the highest SO_2 concentration in Esfahan, although the data is far lower than the ones in Tabriz. There are several high NOx concentration detected along highways in both areas.

The data taken by the passive sampling showed good correlations with those by automatic continuous analyzers in Tabriz. However, the correlations were rather obscure in Esfahan, although passive data regression is better there than in Tabriz.

CHAPTER 10 EIA FORMULATION

10.1 Preface

In Iran, the Environmental Impact Assessment Preparation Act (EIA law) and the Environmental Impact Assessment Guidelines were approved by the Environmental High Council. Electric power plants having over than 100 MW generating capacity have to carry out EIA and DOE will decide whether the plants having less than 100MW generating capacity have to carry out EIA or not. MOE has to prepare technical EIA guidelines at first. MOE and the JICA Study Team discussed a framework of the EIA for power plants, and accordingly the JICA Study Team formulated and proposed the framework of technical guidelines of EIA on air pollution and water pollution due to operation of thermal power plants.

10.2 Outlines of Iranian EIA Process

Project site is determined before EIA. EIA process consists of Preliminary EIA and Detailed EIA. Usually, most projects start from the Preliminary EIA, and then to the Detailed EIA. The EIA report (EIS) shall be presented to DOE. Environmental impacts will be exerted in 3 stages of the projects (project execution stage): (1) Construction stage, (2) Operation stage, and (3) After finishing life-time stage. This report concentrates on the operation stage.

In the Preliminary EIA, the Project Initiator must predict potential environmental impacts by the proposed project based on a preliminary EIA matrix (a list showing relations between project activities and environmental factors), existing environmental data and basic project design. The Project Initiator submits a Preliminary EIA report (EIS) to DOE for review by Review Panel.

If a certain environmental factor is predicted to be impacted from the project significantly or uncertainly, potential impacts should be assessed in more detail in the Detailed EIA stage. Additional environmental data should be collected necessarily in order to assess potential impacts in more detail by scientific methods on the environmental factors chosen in the Preliminary EIA. The Review Panel may advise on environmental data collection and methodology. The data is used to formulate more detailed EIA matrixes and more concrete activity conditions, than in the Preliminary stage. The newly formulated matrix and activity conditions are to predict contribution of the project to the environmental changes.

An overall effect on each environmental factor by both the background and the project can be predicted by superimposing the effect of the latter on that of the former. Methods for predicting future environmental effects and impacts should be scientific and desirably quantitative as much as possible.

If there are environmental factors on which their overall impacts are judged to be significant, suitable mitigation measures should be planned to satisfy the criteria. The measures include alternatives of the project design on facilities, fuel and facility layout, etc. In case mitigation is required, its cost must be estimated, and a cost/benefit analysis will select the best feasible measure or judge profitability of the project.

The draft detailed EIA report shall be submitted to DOE and reviewed by the Review Panel. The Review Panel will give comments on the draft EIS. The Project Initiator must modify EIA or EIS accordingly to the comments and finalize the detailed EIS. It should state impacts of all the environmental factors regardless of their significance. An executive summary must brief environmental impacts on all environmental factors whether they are significant or not.

If the EIA reports reveal that the project has no potential significant impacts on environment, DOE will approve and permit implementation of the project. The Project Initiator must implement the monitoring plan formulated by the Environmental Impact Assessor.

10.3 Framework of EIA Technical Guidelines on Air Pollution

The target air pollutants shall be a) Sulfur dioxide, b) Nitrogen dioxide, and c) Particulate matter. The target area is, in principle, the surrounding area within 15 ~ 25km from the power station.

In order to know the actual current ambient air quality and to predict the future air quality in the area, data related to air qualities, meteorology, topography and sizes of buildings, land uses, stationary air pollutant sources, traffic volume, and laws and regulations have to be collected. In principle, one year data are required on air qualities and meteorology.

Next, emission rates and their impacts on air quality due to the Operation have to be predicted. The predicted time is when the Operation is expected to be in normal. The emissions can be estimated from fuel analyses, design figures, or published data and the quality impacts can be predicted in principle using air dispersion equations. By adding pollutant concentrations due to the Operation, the environmental concentrations shall be predicted.

Emission rates have to be evaluated in comparison with the emission standards, and changes of impacts in air quality have to be done with the air quality standards, or the like.

The Operation has to be monitored in order to confirm that the impacts of the Operation have been properly predicted and evaluated and that the power plant is operating as planned. In case that the monitored results differ significantly from the predicted ones and that the Operation gives significant impacts on the environment, stricter mitigation measures must be applied.

10.4 Framework of EIA Technical Guidelines on Water Pollution

The target area is public waters in the surrounding area of the power plant, within which the Operation may give environmental impacts. The target water pollutants shall be from the Waste Water Disposal Standards as briefly given below:

a. Items for living environmental protection: pH, BOD, COD, DO, etc.
b. Items for people's health protection: Cd, As, Hg, Cyanides, etc.
c. Other items: Water temperature, SS, N, P, etc.

In order to know the current environmental qualities of waters and to predict their future qualities in the area, necessary data are water qualities, bottom sediment qualities, hydrology, meteorology, water uses, water pollutant sources, and laws and regulations. If field surveys are carried out, they must be for a suitable period to be able to estimate the water qualities, etc. in a whole one year.

Current states of water pollutant sources, water qualities, hydrology, etc. in the area have to be realized from the data collected. Also pollutant emission rates and their impacts on water qualities, etc. due to the Operation have to be predicted. Emission rates can be estimated from design data, experiences and published data. Water dispersion equations are used in principle for prediction of impacts as needed.

Emission rates have to be evaluated with the emission standards. Impacts of water qualities, etc. have to be evaluated in consideration of the water quality standards, etc. If the Operation is evaluated to give significant impacts on the environment, necessary measures against them have to be planned with evaluation of their effects. Changes of emission rates and their impacts on water qualities, etc. due to feasible alternatives for the Operation or the plant itself have to be predicted.

The Operation has to be monitored in order to confirm that the influences of the Operation have been properly predicted and evaluated and that the power plant is operating as planned. In case that the monitored results differ significantly from the predicted ones and that the Operation gives significant impacts on the environment, stricter environmental mitigation measures must be considered.

10.5 Remarks on Environmental Impact Assessment

In order to survey, predict and evaluate, objectivity of methods, data reliability, and quantitative approach are quite important. Also EIS should have consistent description, simple and easy expression, little use of technical jargons, and clarification of grounds and reasons for selected or predetermined items.

CHAPTER 11 RECOMMENDATIONS

11.1 Preface

Key elements of the findings of the JICA Study are as follows:

a. Tabriz and Esfahan Plants will convert its fuel from residual fuel oil to natural gas in future. There is no expansion plan of the fuel oil firing plants at both plants.

b. Current air quality within 20 km around both plants is below the Iranian Standards of the maximum SO_2 and NO_2 concentrations, although meteorology is unfavorable for dispersion of the pollutants in both regions.

c. Ambient SPM in Esfahan is possibly above the Iranian Standards of the maximum daily average concentration. However, it contains particulates from various sources, not only from the power plants.

d. Both plants are operating with less efficiency of power generation than the ordinary ones.

It was also found that stack gases of both plants contained SO_2 and soot above the maximum permissible concentration of DOE's drafted emission standards. However, emissions of SO_2 and soot will be reduced to the levels far below the standards after natural gas is burnt for the power generation as having decided. Therefore, planning of SO_2 and soot removal units was eliminated from recommendations of the JICA Team.

The recommendations proposed here can be divided into two types. The first type involves required actions having direct relations with people, equipment, plant units of the power plants, such as training, modification, addition or the like in the plants. The second one has indirect relations with the plants and involves other agencies together with MOE for materialization.

11.2 Maintenance and Management of Power Plants

Recommendation

Strict management of operation and maintenance of power generating units should be implemented for the power plants in Iran. The purpose of this recommendation is to maintain and improve the power generating efficiency and to prevent the air pollution by means of the management of operation and maintenance.

Stack gas monitoring data and information obtained in this Study have suggested that there are lack of strict application of management on operation and maintenance of the plants. Especially, it has not been established for energy saving (Heat management).

The following are key items to be applied for the current purpose: a) Keeping the degree of vacuum at condensers, b) Controlling the stack gas temperature, c) Controlling O_2 concentration of stack gas at an economizer exit, d) Grasping the performance of air heater, and e) Keeping accuracy of operational instruments. Operational measures which conduct precise operation and proper maintenance of facilities, can be taken immediately because there is no call for any new equipment investment and great effect can be expected.

All staff engaged in power generation should understand their responsibility that they are obligated to endeavor to maintain and improve the power generating efficiency by implementing precise operation control and proper maintenance.

11.3 Improvement of Steam Turbine Efficiency

Recommendation

In order to improve the overall power generating efficiency of the power plants in Iran, appropriate measures to keep and improve the turbine efficiency should be implemented. The purpose is to raise up the efficiency about a few percent by means of the measures of improving the turbine efficiency.

The current power generating efficiency of Tabriz Plant is low as 33 – 34%. As abnormal vibration was found on the turbine at Unit No. 2 after the scheduled inspection, operation of the Unit was shut down and inspection and adjustment were carried out. Hearing from a supervisor at the time revealed the deterioration of turbine efficiency. In addition to taking the precise operational measures, it is necessary to improve the turbine efficiency which is the most influential factor on the power generating efficiency.

The steam turbine of Tabriz power plant is a shaft of tandem compound, which is composed of a high pressure (HP) turbine, a intermediate pressure (IP) turbine, and 2 low pressure turbines. In order to improve the turbine efficiency, it is more effective to take appropriate measures especially for HP and IP turbines. The power generating efficiency could be improved by replacement of a diaphragm packing (labyrinth packing) and a shaft packing with new one to reduce the circulate steam leakage area of HP and IP turbines, and of worn out rotating blades (rotors) of HP turbine with new ones. Estimated costs of the measures to improve the turbine efficiency are shown in **Table 11.1**.

If the thermal efficiency is improved by 3% by these measures together with application of strict management, costs from fuel saving will be US$ 2,340,000 annually.

Table 11.1 Costs for Turbine Efficiency Improvement

Replacement	Materials and Equipment		Supervising	Field Work	Delivery
Packings	Shaft & Diaphragm	400,000	200,000	60 days	6 months
Rotors	for HP	4,200,000	200,000	60 days	one year
Total			US$ 5,000,000	80 - 100 days	

Note: Expenses for local people and equipment transportation are excluded.

11.4 Environmental Control Organization in MOE

Recommendation

MOE should expand its Environmental Department with more activities and also establish an environmental control organization in its each power plant. This is to give MOE resources a)to find solutions to various environmental issues related with power plants, b)to deal with a social concern and local requests, c)to increase the efficiency of power generation, and d)to prepare EIA for new power plants, etc.

Demands are locally, nationally, and internationally becoming strong for pollution mitigation nowadays to be carried out by the power generation sector as one of the dominating pollutant emission sources. Apparently the current organization in MOE does not have enough resources to deal with these demands.

As a central organization in Tehran, ED-MOE (Environmental Department in Ministry of Energy) should have groups to handle following tasks in relation with the power generation. ① Planning and studying various environmental issues and countermeasures, ② Managing and auditing environmental information and data, publishing the data, budgeting required funds and planning to improve human resource capabilities, ③ Contacting other authorities for reporting, obtaining permission, ④ Dealing regulations and so on with technologies, and doing research and development for technologies, and ⑤ Assessing environmental impacts on air, waters and others.

ED-MOE should be able to mobilize required experts in other departments of the Ministry in order to prosecute a complicated project such as an EIA Study. ED-MOE should be able to manage the project even if a part of the tasks are carried out in the different departments.

Each power plant should have an independent organization under the general manager of the plant with the following capabilities: ① Monitoring and analyzing emissions, environmental qualities, and energy efficiencies, ② Reporting the above data to the general manager who should consequently report it to ED-MOE and to local municipality, periodically, and ③

Suggesting operational changes to the general manager, if it is necessary to keep operation clean.

11.5 Plant Operator Training

Recommendation

MOE should train its power plant operators and engineers to give pollution control minds and technologies. The main purpose of this recommendation is to give engineers and operators understanding of pollution causes and their countermeasures.

MOE is training its power plant operators in its school at Tabriz. Main purpose of the plant operation is undoubtedly to generate power as demanded. Therefore, the courses of the school are concentrated in equipment operation and maintenance with safety in minds. There is no practical course on the pollution issue.

Deputy of Energy Affairs, MOE, published a book of 337 pages titled "Energy & Environment" in Farsi. This book is probably the first textbook of the training course to give general idea of pollution. Following are courses to be taught: ① What is pollution? ② MOE's efforts to reduce pollution, ③ Kinds and magnitudes of pollution caused by power generation, ④ Counter-measures to reduce pollution, and ⑤ Reduction of pollution by operational controls.

Current management and some of teaching staff of the Tabriz School can be utilized. Additional teaching staff for pollution shall be mobilized from Environmental Department of MOE, DOE, Universities, or else temporally until availability of permanent staff. As there is no suitable pilot facilities for teaching in emphasizing pollution control and energy saving, one unit of 368 MW unit in Tabriz Power Plant may be used for the training with a complete set of monitoring and operational instrument installed. The required investment of foreign currency is US$100,000 for monitoring instrument including spare and consumable parts for one year.

11.6 Stack Gas Monitoring

Recommendation

Each power plant should monitor its stack gases periodically. The purposes of the stack gas monitoring can be divided as follows: ① To obtain quantitative data which provides reliable basis to publicize and to assess the impact of pollutants on air pollution, ② To be used for combustion control and management, ③ To determine target sources for emission controls, in case that there are many emission sources, and ④ To afford data for selection of an appropriate exhaust emission control device and to help evaluation of the benefit after application of such control measure.

A power plant is responsible to control its own emissions not to deteriorate ambient quality. The Standards for Exhaust Gas from Factories and Industrial Working Place drafted by DOE will be authorized and enacted as an effective law near future, with or without changes of the drafted sentences. Specified in the draft are intensities of SO_2, CO, NOx, SPM and Smoke in exhaust gases for power plants. They will be obliged to show whether amounts of emissions are conforming to the standards or not.

Monitoring at three times/year (Winter, Summer, and Spring or Fall) is the major task. It should be carried out at each average generation period of midnight, early morning, daytime, and evening, and also at every time after changing the kind of fuel. Items to be measured are as listed in the DOE's drafted Standards and amounts of O_2, flow velocity, gas temperature, and water contents to obtain pollutant emission rates. Total investment of foreign currency is US$ 100,000 for one set of the analyzers with consumable required for one year operation.

Other tasks involve maintenance and check of analytical equipment, and data compilation. Monitored data shall be compiled as required by regulations or else. It is recommended that the accumulated monitor data of more than 3 years be kept for future use, because they are valuable for check of past data, for comparison with the current data after installation of control measurements, or else.

11.7 Fuel oil Balance Study

Recommendation

MOE should ask a competent authority to organize a committee of a study on residual fuel oil balance, composing of related governmental authorities. The committee has to find out feasible ways of disposition and consumption, most economically and without damaging environment, of residual fuel oil presumably remaining un-used by conversion of fuel to natural gas in the power sector.

MOE has adopted a general policy that all power plant using the fuel oil should convert it to natural gas as fuel for power generation in the future. It had already decided to apply the policy on Tabriz and Esfahan Power Plants. From the standpoint of environmental preservation, natural gas is far better than residual fuel oil, because of far less emission of SO_2 and soot. However, it leaves excess fuel oil un-used in Iran.

The power industry consumed the fuel oil of 7,038,000 m^3 in 1997, showing about 5% of annual average growth from 5,786,000 m^3 in 1993. It has been consuming around 30 % of the fuel oil produced in the Iranian oil refineries. The Tabriz Power Plant, at its full capacity, consumes more than 60% of the fuel oil produced by the Tabriz Oil Refinery. Also it is similar at Esfahan with Tabriz, if the fuel oil is consumed both at Esfahan and Montezari Power Plants. Those amounts of fuel oil will be surplus in the refineries, after the conversion of the power plants to natural gas. The refineries can have three choices or combination of them to get rid of the stock of the surplus fuel oil: 1) sell it as it is, 2) decompose it and reduce its sulfur contents, or 3) reduce its production.

If the surplus fuel oil is sold as it is to consumers in Iran, it will cause pollution there. Possibility of export of the surplus fuel oil is questionable in favorable price and demand in the future. The transportation of viscous oil to other new consumers will need additional investment in piping and lorries. It is less economical to reduce sulfur in fuel oil at refineries than to remove SO_2 at power plants. Rough estimation indicates that Iran has to spend twice more initial investment if sulfur in fuel oil is to be removed at the refineries. It is the last difficult choice of production reduction at the refineries without installation of any desulfurization unit. It means reduction of crude oil processing capacity and reduction of refined oil products such as gasoline.

Tasks to carry out this study are ① list up possible users of fuel oil with their information of oil consumption and for preliminary EIA study, ② estimate possible consumed amount of fuel oil without deteriorating environment by the pre-EIA studies, ③ carry out economic comparison of sulfur removal at refinery and power plant, ④ foresee future trends of fuel oil export market, ⑤ foresee future trends of oil products, ⑥ formulate recommendation on continuation or change of the natural gas conversion policy, and recommend conversion schedule of the power sector, and ⑦ recommend a stage-wise conversion scheme of refineries' processing flows with capacities in meeting with the power sector's schedule.

All the tasks given above should be accomplished in consideration for that the recommended items would be carried out from the year of 2005 and completed in 2015. Therefore, demands, conversion schedule, etc. should be foreseen in the tasks until 2015.

The study committee should be consisted of Plan and Budget Organization, Ministry of Oil, Ministry of Industry, Ministry of Mines and Metals, DOE and MOE. The study should be concluded within four years.

11.8 Regional SPM Monitoring and Source Identification

Recommendation

MOE should ask DOE-Esfahan to organize a project to monitor SPM in the Esfahan region. Also the project should identify each contribution of major sources to the airborne SPM. Monthly average airborne SPM concentration in Esfahan was over than 100 μ g/m^3 during June to October, the peak at 157 μ g/m^3 in August. The Iranian SPM standard has two standards: one for the 24 hours average (260 μ g/m^3) and the other for the annual average (75 μ g/m^3). The 24 hours average seemed to be exceeded in Esfahan. The main purpose of this study is to find out whether SPM exceeds Iranian National SPM standards or not in the region. If it does, the project should point out major sources as the priority targets of SPM emission reduction.

The instrument used in the JICA Study was a low volume sampler and did not use an instrument suitable for 24 hours average samples. Tasks involve in this study are ① Monitor SPM in summer by an automated continuous analyzer, ② List up SPM emission sources in the region and estimate roughly emission amounts from these artificial stationary and mobile sources, ③ Collect samples from artificial and natural sources, ④ Analyze samples, and ⑤ Calculate source contributions.

Required cost for equipment and subcontract work of chemical analyses and contribution calculation is US$510,000, except costs of transportation, custom clearances, and also personal wages, etc. By assuming purchasing of equipment is possible in 2000 to meet the summer in 2001 for SPM monitoring, the work schedule is estimated to be for 2.5 years.

11.9 Improvement of Simulation Model

Recommendation

MOE should ask DOE to improve regional simulation models of the target regions in cooperation with related authorities by inputting more accurate regional data. The purpose is to establish more accurate simulation model and investigate the pollution mechanisms in the target regions. Environmental protection master plans for the regions can be made and adequate countermeasures can be implemented with the established model.

Various emission sources were included as much as possible to improve accuracy of the two simulation models, although accuracy of information and data on sources other than the power plants were insufficient. Those emission sources are factories, vehicles and so on which affect air qualities in the region. Administratively, power plants and MOE are responsible for their own power plants, and DOE is responsible for the regional total environmental protection. Improvement of the models by collection and addition of accurate data is necessary for planning to control regional air pollution.

Tasks involved are as follows:

A) Collection of Emission Source Data

① Other large factories except the power plants, ② Major road vehicle traffic, ③ Other medium and small emission sources, ④ Other emission sources,

B) Collection of Meteorological and Air Quality Data

① Meteorological data, ② Air quality data,

C) Integrated Regional Simulation

The integrated regional simulation has certain difference with the EIA simulation which assesses impacts from a target emission source like a power plant. Generally, EIA for the specific target is conducted with an established regional simulation model. A power plant which generates the majority of emissions in the target region should positively cooperate with a local environmental authority which is responsible for the integrated regional simulation model establishment.

5) Required Resources

If the emission factors for vehicles and the data on factories spatial distributions etc. are provided, the manpower of Iranian experts necessary for the integrated regional simulation of one target region is 30 man-months. The duration of the study is around one year, and foreign consultants will be necessary in some parts. This portion takes ten man-months and costs US$250,000 except transportation and living allowances.

CHAPTER 12 CONCLUSION

The primary objective of this JICA Study was to contribute MOE to increase its technical capabilities. The JICA Team tried to transfer technologies required for the Iranian Counterpart Team to be able to carry out similar air pollution studies for remaining about 20 thermal power plants in Iran which the two target power plants, Tabriz and Esfahan, represented for by mutual selection between MOE and JICA. Principles of EIA procedures for air and waste water were drafted as the second objective of the Study.

This JICA Study revealed that concentrations of SO_2 and NO_2 in ambient air were less than the National Air Quality Standards within 20 km of both Power Plants. Another pollutant monitored, SPM, was below the Standards of the annual average value. However, there is a possibility of exceeding the Standard of the daily average in Esfahan. As SPM is originated from various artificial and natural sources, power plants are not the only source of the SPM pollution. A method was proposed as one of recommendations to clarify major sources of SPM.

Emissions from both power plants were over than the standards proposed by DOE. However, there would be no excess emissions of SO_2, NO_2, and particulates in the future because of MOE's decision on exclusive burning of natural gas as soon as its supply becomes sufficient. Hence, there is no recommendation to control pollutants. As reference to other power plants, the control devices are described in this Report with necessary information for planning.

The JICA Team found that the energy efficiency was low in both plants because of insufficient budgets and lack of foreign currency. Recommendation to save energy is also presented.

Pollution is a product of various factors and sources. One organization can not cope with, or solve it by itself. Cooperation of administrative organizations on monitoring and planning of countermeasures is quite important, in order to avoid further deterioration of the current environmental qualities of both areas. The JICA Team planned recommendations based on this standpoint. All the recommendations are summarized in **Table 12.1**. The JICA Team expects that the Iran Team would materialize these recommendations in the future.

The Study encountered behind the schedule due to delays of transportation and custom clearance of equipment, permission of upper layer observation, construction at the plants, and others. However, those delays were able to be overcome with the help of the Japan Embassy in Tehran, JICA Headquarters, and the Iranian Counterparts. The Counterparts and people at both plants were all eager to receive technology transfer. The JICA Team expresses here its deep appreciation to all these people for their advice, guidance, encouragement, and cooperation.

Table 12.1 SUMMARY OF RECOMMENDATIONS

No.	Title	Proposed Reasons	Organizations in Charge	Costs US$	Work Period	Remarks
1	Maintenance & Management of Power Plants	Lack of minds apt for operation and maintenance	MOE	--	Always	
2	Improvement of Steam Turbine Efficiency	For energy saving	MOE	5,000,000	3 months for Field Work	Cost for 1 Unit
3	Environmental Control Organization in MOE	To cope with complicated environmental issues	MOE	--	As soon as possible	
4	Plant Operator Training	To give basics of environmental control and energy save	MOE	96,500	As required	
5	Stack Gas Monitoring	To use for public relation and combustion control	MOE	--	Always	
6	Fuel oil Balance Study	To consume glut of fuel oil and to stop pollution proliferation	Budget & Planning Organization, DOE, Ministry of Industry, Ministry of Oil, MOE	--	4 years	
7	SPM Monitoring and Source Identification	To confirm SPM in Esfahan with National Standard and to plan countermeasures	DOE, MOE, Ministry of Industry, Ministry of Oil	510,000	3 years	
8	Improvement of Simulation Models		ditto	250,000	1 year	Estimated for 1 area

Note 1 Conversion rate : US$1.00=Rls.8000=¥120

Note 2 Costs exclude local wages, equipment transportation, field expenses, travel expenses from overseas, travel allowances, etc.

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