6.2 Present Environmental Control System in I.R. Iran

6.2.1 Authorities and Administration

The Department of Environment (Environmental Protection Organization, EPO) was established by the Environmental Protection and Enhancement Act of 1974. This Act still governs the environmental policy of I.R. Iran. The Department is attached to the office of the President but is operating under the Environmental High Council established by the same Act. This Council is bestowed with the power and jurisdiction to formulate national environmental policy. The Department of Environment is entrusted with the protection and enhancement of the environment and for the prevention and control of any form of pollution or degradation leading to disturbance in the balance and proportion of the environment.

The functions and duties of the Department of Environment are as follows:

- Draw up the environmental policy in I.R. Iran.
- Carry out assignments to protect and develop the environment and set up procedures and control pollution.
- Monitor all sources of marine pollution except oil pollution (marine pollution resulting from land-based sources and from aircraft and vessels)
- Protect the marine environment from pollution resulting from exploration and exploitation of the natural resources of territorial waters and the continental shelf.
- Authorize the public port authority in I.R. Iran to take necessary measures to prevent and monitor the spread of pollution and supervise the reception facilities.

The Department conducts an environmental policy through legislation and organizational measures, assuming all duties related to the protection of natural and human environments. These include research on air, water and soil quality and emission standards, wildlife preservation, genetic conservation as well as the enforcement of environmental laws and control regulations (Ref: National Report of Rio Conference, 1992, etc.).

Figure 6. 1 shows the organization chart of the Department. The Head of the Department is supported by research assistance from five bureaus: Human Environmental, Environmental

Assessment, Natural History Museum, Natural Environmental Bureaus and Laboratories. Each bureau has some centers. The Air Pollution Research Center is a subdivision of the Human Environmental Bureau. Some 20 local offices of the Department, whose typical organization is shown in Figure 6.2, are located in country towns.

There are also other organizations having responsibilities or tasks in different fields of the environment:

- The Environmental Health Office, Ministry of Health
- Meteorological Organization
- Atomic Energy Organization
- Health Department of the University of Tehran
- The Scientific and Industrial Research Organization
- The Research Institute for Petroleum Industry (RIPI)
- Municipalities

Municipalities are responsible for the control of urban transportation and for formulating policies on the reduction of traffic volume and air pollution as well as the removal of industrial estates and facilities discharging pollutants from the cities to suburbs. The Municipality of Tehran consists of Transportation and Traffic Affairs, Waste Material Conversion Organization, Industrial Re-organization Office and Parks/Green Space Organization.

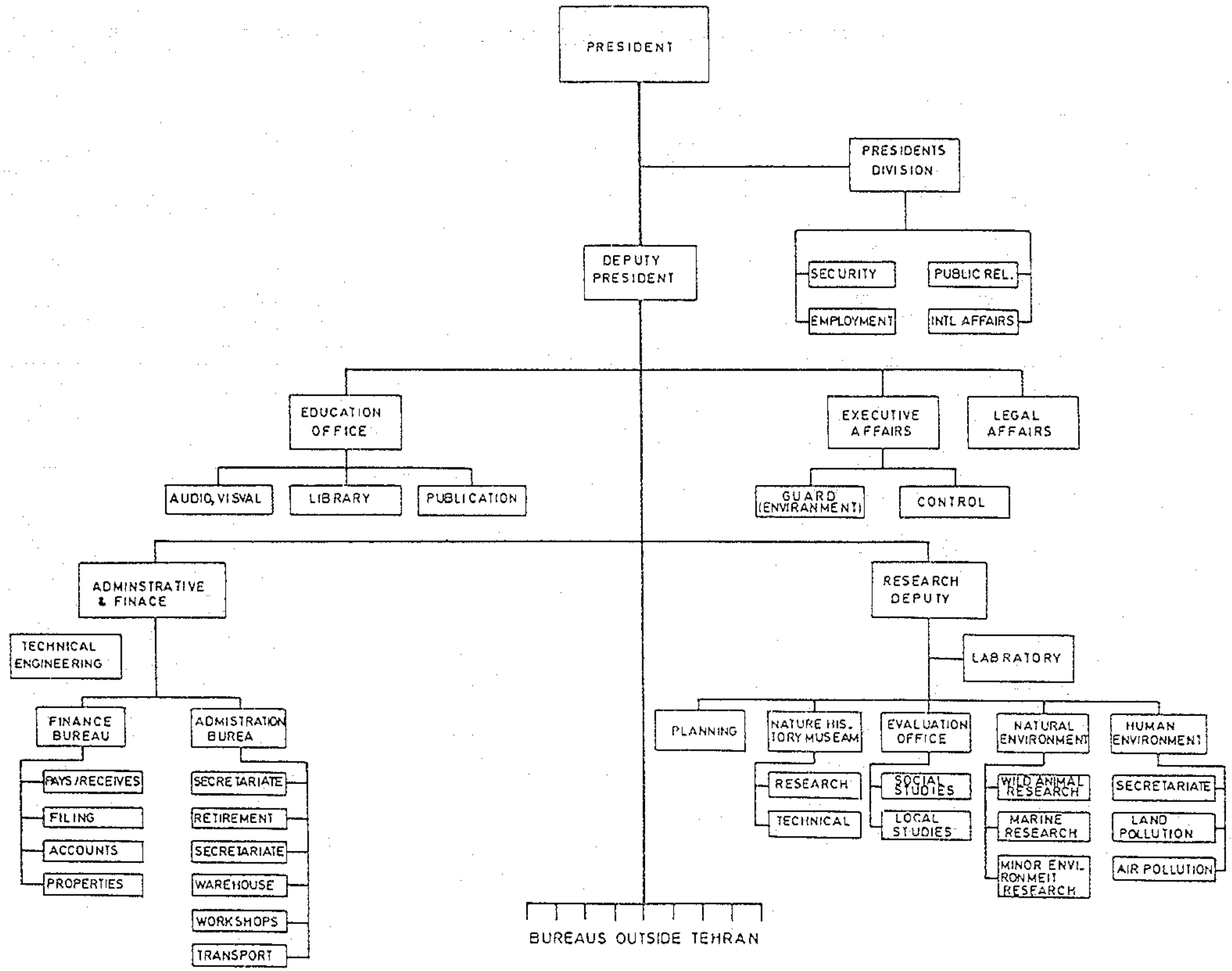


Fig. 6.1 Organizational Chart of Environmental Protection Organization

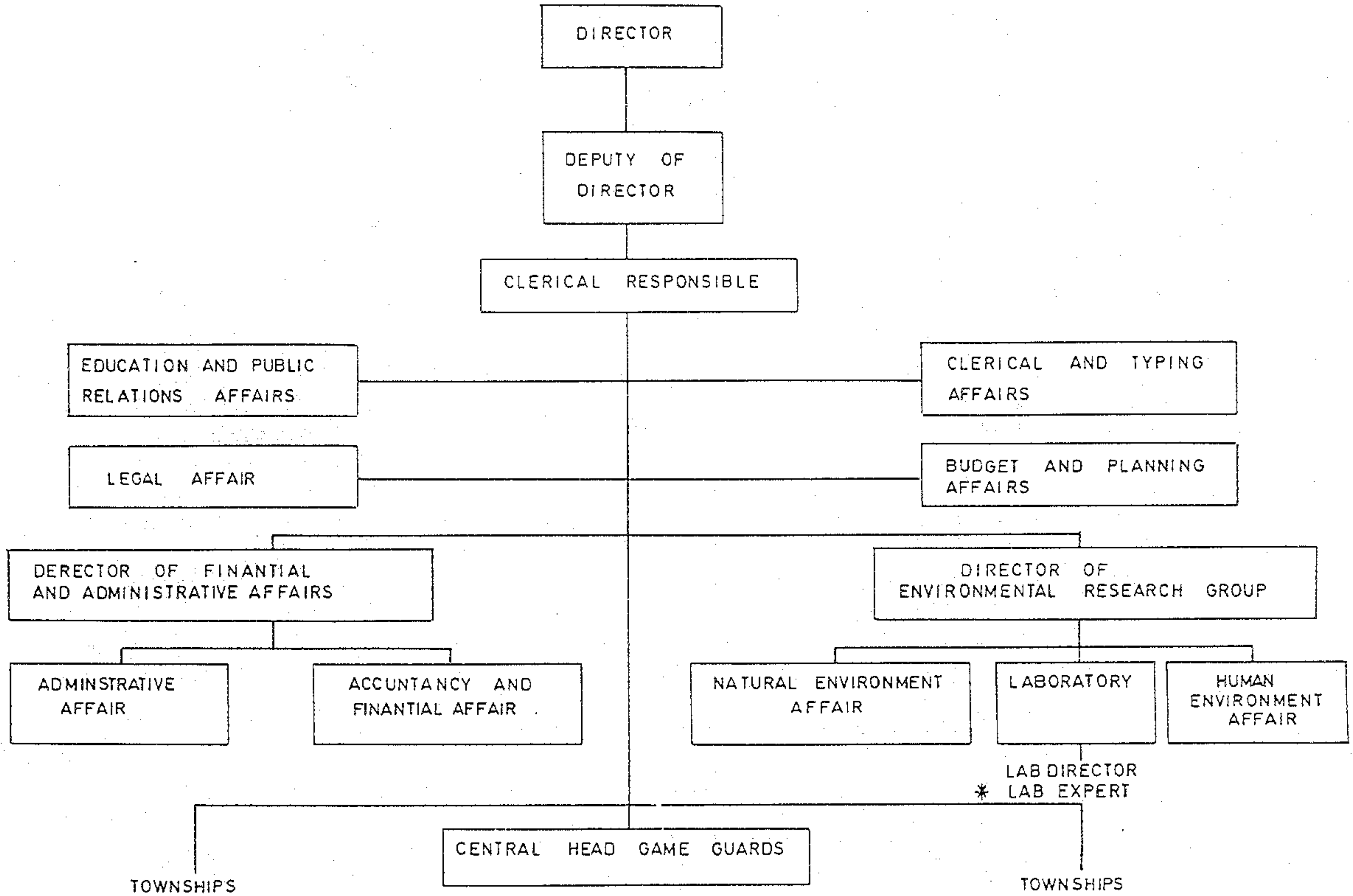


Fig. 6.2 Typical Organizational Chart of Local Office of Environmental Protection Organization

6.2.2 Laws and Regulations for Environmental Protection

(1) Legislation for Environmental Protection

In 1974, the Environmental Protection and Enhancement Act was promulgated by the Parliament of I.R. Iran, followed by the Clean Air Act in 1975. Based on this Act, the following responsibilities were placed with the Department of Environment regarding air pollution control management:

- Surveying and monitoring air quality
- Identification and research on air pollution sources and classification of these emission sources
- Issuance of ambient air quality standards in different regions
- Issuance of emission standards of pollutants for different sources
- Issuance of legislation, criteria and control for emission sources of air pollutant in different areas
- Inspections for enforcement of various standards and criteria

(2) Environmental Standards and Criteria

At present, the Municipality of Tehran applies the air quality standards adopted by the World Health Organization as follows.

Pollutants	Standards (microgram/M^3)	
Sulphur dioxide (SO_2)	50	(annual)
Particulate		
- Smoke	125	(24 hours)
	50	(annual)
- SPM (per weight)	60	(annual)
Lead	0.5-1.0	(annual)

Table 6.1 shows the ambient air quality standards of selected countries compared with the WHO guideline.

Table 6.1 Selected Ambient Air Quality Standards

Nation	Classification	Unit	SPM			SOx			NOx		
			1 hr	24 hrs	Annual	1 hr	24 hrs	Annual	1 hr	24 hrs	Annual
WHO	Guideline	mg/M3		0.15-0.23	0.06-0.09	0.350	0.100-0.150	0.040-0.060	0.400	0.150	
Japan		mg/M3	0.20	0.10		(0.10) 0.286	(0.04) 0.114			(0.04-0.06) 0.082-0.123	
Germany		mg/M3	0.20	0.10		0.400		0.140	0.200		0.080
U.S.A.		mg/M3		0.15-0.25	0.05-0.08		(0.14) 0.400	(0.03) 0.086			0.100
S. Korea		mg/M3	(TSP)	0.30	0.15		(0.15) 0.429	(0.05) 0.143	(0.15) 0.307		(0.05) 0.103
Malaysia		mg/M3	(TSP)		0.09		(0.04) 0.114		(0.17) 0.358		
Indonesia		mg/M3	(TSP)	0.26		(0.10) 0.286				(0.05) 0.103	
Thailand		mg/M3		0.33	0.10		0.300	0.100	0.320		
Philippines		mg/M3	0.25	0.18		0.850	0.369		0.190		
Taiwan	Industrial	mg/M3				(0.50) 1.430	(0.15) 0.429	(0.075) 0.215		(0.10) 0.205	
	Residential	mg/M3				(0.30) 0.858	(0.10) 0.286	(0.050) 0.143		(0.05) 0.103	
China	1st. Class	mg/M3		0.05-0.15		0.150	0.050	0.020	0.100	0.050	
	2nd. Class	mg/M3		0.15-0.30		0.500	0.150	0.060	0.150	0.100	
	3rd. Class	mg/M3		0.25-0.50		0.700	0.250	0.100	0.300	0.150	
India	Industrial(A)	mg/M3		(8 hrs) 0.20			(8 hrs) 0.120			(8 hrs) 0.120	
	Commercial(B)	mg/M3					(8 hrs) 0.080			(8 hrs) 0.080	
	Residential(C)	mg/M3		(8 hrs) 0.50			(8 hrs) 0.030			(8 hrs) 0.030	
Hong Kong		mg/M3				0.800	0.350	0.080	0.300	0.150	0.080
Singapore	Guideline	mg/M3					0.365	0.080			0.100

Note : Unit of figures in ( ) is ppm.

Nation	Classification	Unit	CO			Ozone		HC	Smoke	Lead (microgram/cubic meter)	
			1 hr	8 hrs	24 hrs	1 hr	8 hrs	3hrs		24 hrs	Annual
WHO	Guideline	mg/M3	30	10		0.15-0.20	0.10-0.12		0.04-0.08		0.50-1.00
		ppm	24	8		0.08-0.10	0.05-0.06				
Japan		ppm		20	10	0.06					
Germany		ppm	24		(Annual) 8						(Quarterly) 2
U.S.A.		ppm	35	9		0.12		0.24			(Quarterly) 1.5
S. Korea		ppm			8	0.10					
Malaysia		ppm		9						20	
Indonesia		ppm		20		0.10		0.24		60	
Thailand		ppm	44	18		0.10				10	
Philippines		ppm	28	8		0.06					
China	1st. Class	mg/M3			4.-10.	0.12					0.100
	2nd. Class	mg/M3			4.-10.	0.16					0.150
	3rd. Class	mg/M3			6.-20.	0.20					0.300

Note : SOx; 1 ppm = 2.86 mg/M3, NOx; 1 ppm = 2.05 mg/M3, CO; 1 ppm = 1.25 mg/M3, Ox; 1 ppm = 1.93 mg/M3

Source : Governmental Organizations, UNEP, World Bank

(3) Emission Standards and Criteria

The following standards and criteria concerning motor vehicle emissions have been issued by the Environmental High Council;

- Maximum CO concentration of exhaust gas should not exceed 1.5% by volume.
- Any motor vehicle emitting visible smoke must be taken off the road.
- Driving cycles in Tehran is based on the ECE 15 method of Europe

The standards are as follows:

Engine Capacity	ECE Cycle (gram/test)		
	CO	HC+NOx	NOx
VH < 1.4	45	15	6
1.4 < VH < 2.0	30	8	-
2.0 < VH	25	6.5	3.5

ECE/EC vehicle emission regulations are shown in the APPENDIX. The Department of Environment applies practically the same standards that are widely adopted in EC countries. Emission standards in selected Asian and EC countries, for example, are shown in Table 6.2(a), (b) and (c).

Table 6.2(a) Emission Standards in Asian Countries

Nation Classification	Unit	Dust	SO_x	NO_x	CO
Japan (Existing) (New Facilities)	mg/M^3 mg/M^3	(100-300) (50-150)	K-value and Total Control	Facilities & Total Control	Exhausted Gas Control
Indonesia	mg/M^3	600	300	4600	1000
Thailand Bangkok Others	mg/M^3 mg/M^3	500	400 700	1000	1000
Philippines (Existing) (New Facilities)	mg/M^3 mg/M^3	500 300	2000 (P/P)200 (Others)1500	1000	

Note : P/P = Power Plants
Source : NEDO

Table 6.2(b) EEC SO_2 Emission Standards for Coal-Fired Plants

Plant type (new plants)	plant size, MW	Emission standards*
-combustion plants	50-99	limits to be decided
-combustion plants	100	(2,000 mg/m^3)
-combustion plants	101-499	sliding scale between (2,000-400 mg/m^3)
-combustion plants	>500	(400 mg/m^3)
-combustion plants firing indigenous high or variable sulphur coal	100-166	40% S removal
-combustion plants firing -indigenous high or variable sulphur coal	167-499	sliding scale between 40-90% S removal
-combustion plants firing indigenous high or variable sulphur coal	<300	60% S removal
-combustion plants firing indigenous high or variable sulphur coal	>500	90% S removal

Table 6.2(c) EEC NO_x Emission Standards for Coal-Fired Plants

Plant type (new plants)	plant size, MW	Emission standards*
-combustion plants	>50	(650 mg/m^3)
-combustion plants firing coal with volatiles <10%	>50	(1300 mg/m^3)

* figures in brackets denote emissions standards at 6% O_2, stp (O'C (273K), 101.3kPa) on dry flue gas

Source : IEACR/43 December 1991 IEA Coal Research, London
"Emission Standards Handbook : Air Pollutant Standards for Coal-Fired Plants "

6.2.3 Monitoring of Air Pollution

The Department of the Environment has been carrying out regular air pollution monitoring in cooperation with local public organizations since 1985 in several large cities including Tehran, Khuzestan, Shiraz, Isfahan and Tabriz. The Department has 10 measuring stations in Tehran. The stations are able to measure CO, NO_x, SO_2, O_3, SPM and lead (Pb) content in the air.

In addition to the programs of the Department, the Ministry of Health, the Ministry of Oil and other organizations, for instance, have been involved in determination of air pollutants as follows:

a) The Environmental Health Office of the Ministry of Health also has 10 measurement stations in Tehran. Five stations are located at different parts of the city center, two stations to the south of the city, and three stations are located north, east and west of the city, respectively. The Environmental Health Office can measure SO_2, smoke, SPM and Pb contents. Studies on the effect of CO on blood hemoglobin and of lead levels in the blood are being carried out.

b) The Research Center of the National Iranian Oil Company has been monitoring SO_2, H_2S, NO_2, total hydrocarbon (THC), CO, SPM, dust-fall and soil index in oil and gas refineries, petrochemical complexes and adjacent residential areas since 1969.

c) The Meteorological Organization has two meteorological stations to the west and north of Tehran.

d) The Municipality of Tehran is considering construction of three air pollution measuring stations of which two are fixed and one is movable. The three stations are to measure SO_2, O_3, NO_x, CO, SPM, THC and meteorological parameters. The Transportation and Traffic Affairs office of the Municipality is considering equipping the major mechanical workshops in Tehran with tune-up equipment for engine tune-ups and periodical vehicle engine tests.

6.2.4 Policies and Plans

(1) Current trends

The major plans and countermeasures with regard to the prevention of air pollution in I.R. Iran are summarized as follows:

a) Introduction of lead-free gasoline in order to reduce hazardous pollutants throughout the country
b) Gas supply plans for motor vehicles (taxis) in the cities of Tehran and Shiraz
c) Transferring plans for polluted industries in Tehran (The polluted industries are encouraged to settle at industrial sites)
d) Construction of underground railway in Tehran

According to the Government's proposed Second Five-Year Plan, by allocating a total of Rs.246.8 billion credits, the following special programs regarding environmental affairs are planned:

-Using nonpolluting energies including wind energy (10 MW) and solar energy (2MW)
- Expanding public transportation system (electric bus and subway)
- Change of fuel system of 5,000 heavy vehicles into gas in Tehran and five other cities
- Providing environmental standards in local districts
- Studying quality standards in production of oil products
- Controlling and checking of the fuel system and gases emitted from vehicles in Tehran, Arak, Isfahan, Shiraz, Ahwaz and Tabriz
- Reallocation of polluted industries to 120 kilometers from the city center
- Change production processes of refrigerator and frozen food making industry
- Establishing environmental research centers in 40 cities
- Installing air pollution monitoring stations in 25 cities
- Studying the pollution problems of a total of 300 open mines

(Ref: Kayhan, November 15, 1993. "Environmental Protection: Summary of the Second Five-Year Plan by the Government ")

Starting from the general government policy objectives, the Municipality of Tehran, under the leadership of the Mayor vested with authority on behalf of the Ministry of Interior, has taken the initiative to deal comprehensively and effectively with the air pollution problem in the Tehran Metropolitan Area. Such short-term plans include, among others, the following:

- The prevention of driving non-permitted vehicles within the central zone of Tehran city.
- The prevention of driving smoke-producing vehicles within the city
- The supply of lead-free gasoline
- The construction of highways and loop-roads
- Field car tests for fuel conversion
- The construction of a subway network in Tehran
- The extension of gas distribution network in industrial and residential areas, especially in Tehran and its suburbs
- The expansion and construction of industrial estates with facilities to control industrial pollutants

Some other projects related to these efforts are listed below:

a) The Tehran Transport Emission Reduction Project (Tehran Municipality and the World Bank's Global Environment Facility) comprises a number of studies intended to identify policies and actions which will lead to reduction in the emission of greenhouse gases and local air pollutants from urban transportation systems.

b) Tehran United Bus Company is conducting research in the field of reduction of smoke and soot by diesel vehicles. The first stage of this plan comprises the fuel conversion testing of ten buses; that is, three buses converted to LPG, three buses converted to CNG and four buses converted to dual fuel with CNG and diesel fuel oil. Final decisions will be made after the first stage about choosing one of these three methods, and first 100 and later 1,000 buses will be converted accordingly.

c) The Industrial Reorganization Office, which is a subsidiary of the Technical and Development Department of Tehran Municipality, started operation in 1989 with the aim of reducting environmental pollutants related to the industrial sector. The Office, under close cordination with the Department of Environment, is responsible for removal of facilities from downtown to the suburbs. Factories and workshops are required to obtain the approval of the Department of the Environment.

Since the Municipality of Tehran has important duties for environmental affairs and air pollution is the most important problem, the Air Quality Control Company was established in June 1991 to control air pollution, searching for pollutant sources and finding solutions. The Company is studying such plans as "Engine regulation and its effect on air pollution" and "Motorcycles and their roles in air pollution in Tehran," and has also published general information in the local newspapers to increase people's knowledge of environmental problems, including air pollution. The Company will also try to attract the cooperation of other governmental organizations in this regard. (Ref.: Hamshahri, September 11, 1993. "Tehran: New Efforts to Control Air Pollution").

(2) Medium- and Long-Term Plans for Improving Air Quality

Further, the medium- and long-term plans by the Department of Environment and/or the Municipality of Tehran for improving air quality are described below:

1) Reduction of traffic pollution

- Reduction of traffic flow and number of motor vehicles
- The possibility of using motor vehicles that run on electric energy
- Conversion of motor vehicles running on fuel and gasoline to motor vehicles running on liquid gas
- Setting up liquid gas filling stations for motor vehicles
- Equipping motor vehicles with pollution reducing devices
- Ways of testing motor vehicles for pollution generation

2) Reduction of industrial pollution

- Use of filtering devices
- Devices for absorbing suspended particles
- Chimney filters

- Industrial waste cleaning

3) Reduction of household pollution

- Energy source diversification
- Efficient use of energy

4) Rules and regulations

- Decentralization
- Urban development codes
- Building codes

6.3 Present Status of Environment in I.R. Iran

6.3.1 Present Status of Air Pollution

Issues related to air pollution have mainly arisen in many of the large cities of I.R. Iran. The present situation and historical trends of air pollution, especially in Tehran, are described below:

(1) Historical Trends of Air Pollution in Tehran

Figures 6.3(a) through 6.3(d) show a summary of the results of measuring the concentrations of SO_2, SPM, smoke and lead in the air of Tehran. The figures are plotted by use of data which were published by UNEP*1) and the World Bank*2) and some was also quoted from the Iranian newspapers. In the figures, the air quality values mean their annual average values.

1) Sulfur Oxides

Figure 6.3(a) shows the past trend of SO_x concentrations in Tehran. In the figure, solid diagonal lines drawn from the top right to the bottom left show the annual average values of the results measured at various monitoring points (according to the World Bank). The top line within the limit of the range represents the average value at city center, and the bottom line represents suburban residential districts of Tehran. The number of monitoring points is 14, and the monitoring locations are classified into city center commercial, city center residential and suburban residential*2).

The solid diagonal lines drawn from the top left to the bottom right are plotted by data from 1980 to 1984 measured in the Air Quality Monitoring Project of WHO/UNEP. The ranges express the averages of annual arithmetic mean values. Three monitoring points were located at city center commercial, suburban industrial and suburban residential areas*1). The dotted lines show the ranges of annual averages of individual monitoring points. The upper parts of the ranges represent the maximum values of annual averages at monitoring points, and the lower parts represent the minimum values. The data are quoted from a publication of WHO/UNEP*1).

Bar graphs express the mean values of annual averages measured at various monitoring points.

As shown in the figure, it is considered that the historical trend of SO_2 concentration in Tehran has a decreasing tendency to a limited extent. After all, these measured values exceed considerably the WHO guideline of 0.04 - 0.06 mg per cubic meter at present.

2) Suspended Particulate Matter

Figure 6.3(b) shows the past trend of SPM concentration in the air. The diagonal lines, dotted lines and bar graphs are drawn as described above. As can be seen on the graph, it is not clear whether recent SPM concentration has a decreasing tendency or not. The standard of WHO Guideline is 0.06 - 0.09 mg per cubic meter. The results monitored are three or four times the standard.

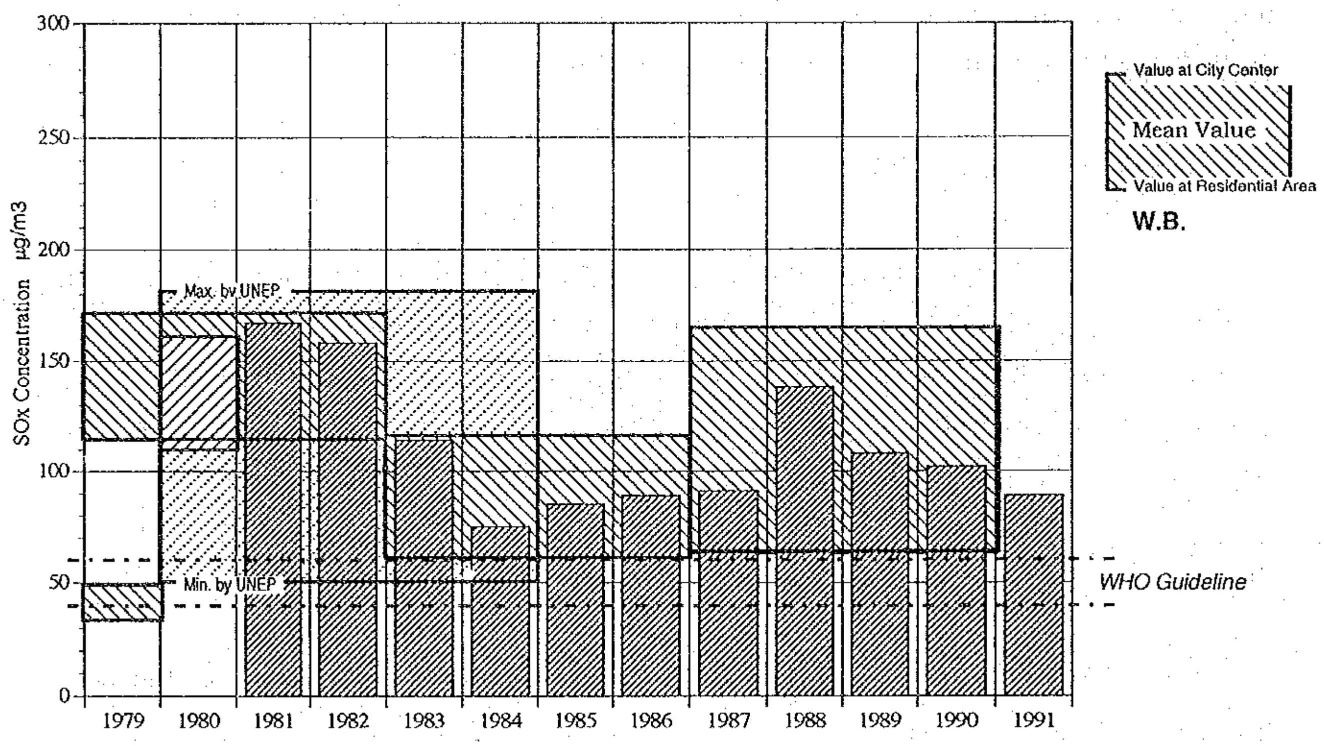
3) Smoke

Figure 6.3(c) shows the past trend of smoke concentration in the air. The figure is also plotted from the data quoted from reports of WHO/UNEP*1) and others. The upper parts of ranges enclosed by diagonal and dotted lines represent the maximum values of annual averages measured at individual monitoring points and the lower parts of the ranges represent the minimum values. Bar graphs are plotted by use of a newspaper article (Hamshahri, "New Efforts to Control Air Pollution," Sept. 11, 1993). As shown in the figure, smoke concentration has decreased gradually. The annual mean value in 1991 was slightly over the WHO Guideline of 0.04 - 0.08 mg per cubic meter.

4) Lead

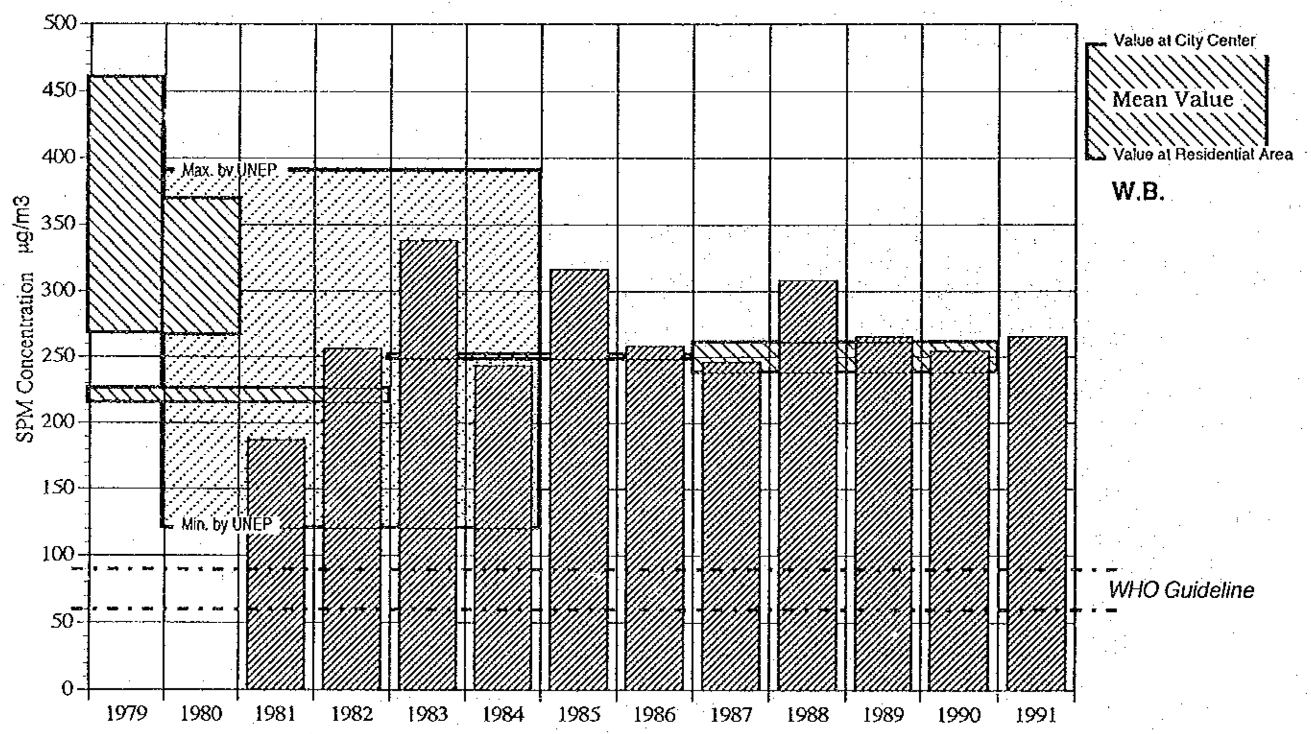
Figure 6.3(d) shows the past trend of lead concentration in the air. Data plotted in the figure are also quoted from the newspaper as mentioned above. As shown in the figure, lead concentration has increased rapidly. The annual mean value in 1990 was around 3.3 mg per cubic meter, although the standard of WHO Guideline is 0.5 - 1.0 mg per cubic meter.

Fig. 6.3(a) SO_x Concentration in Tehran (Annual Averages)



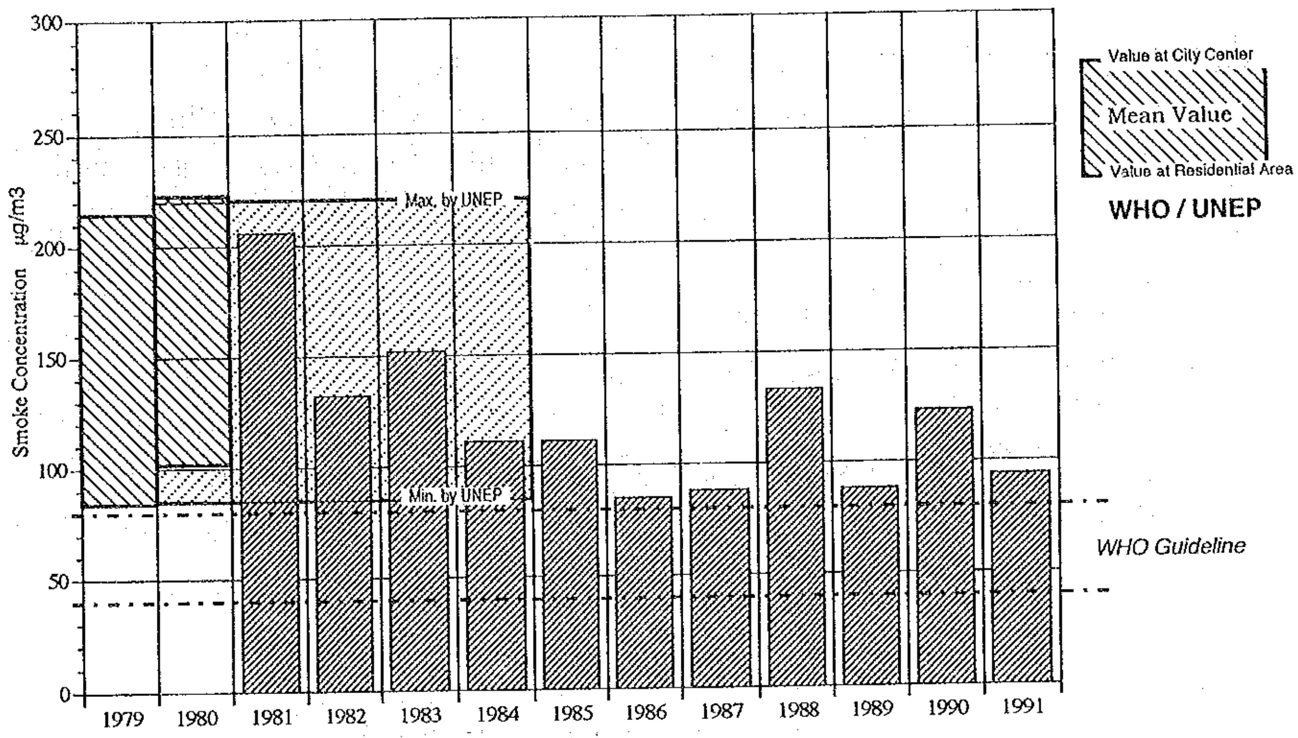
Source ; UNEP, WHO, WB and Others

Fig. 6.3(b) SPM Concentration in Tehran (Annual Averages)



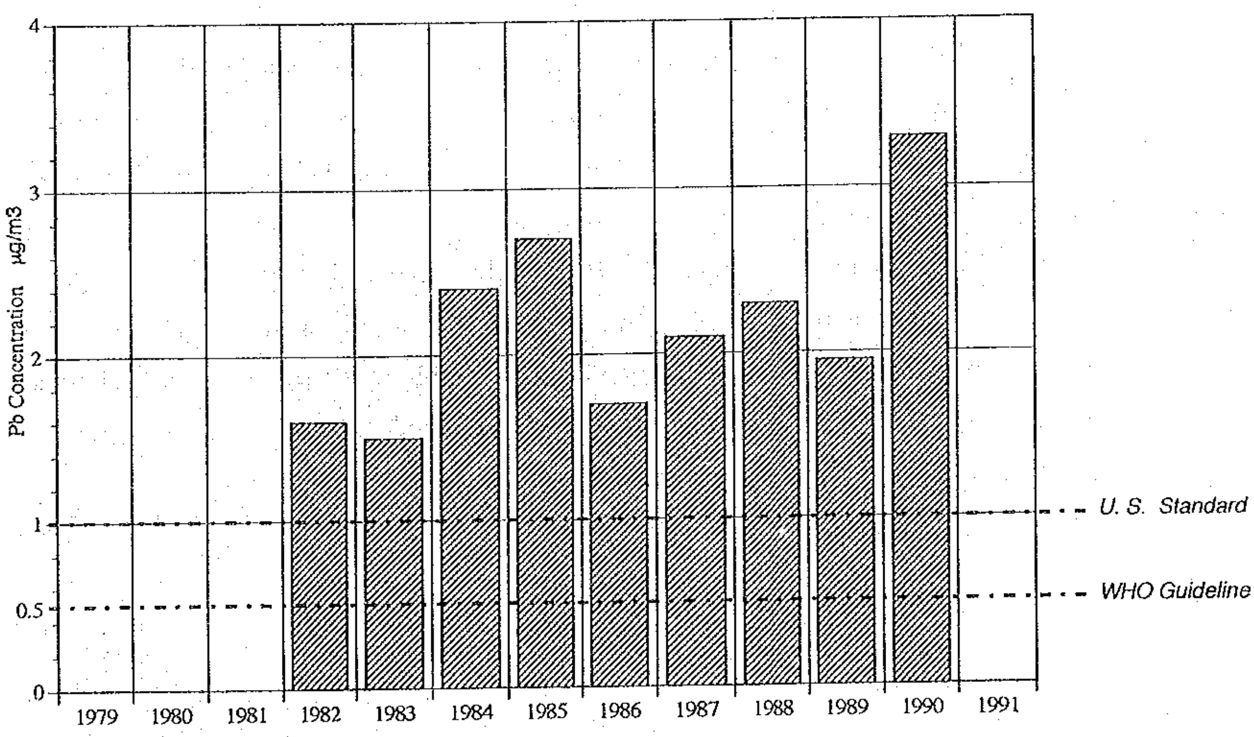
Source ; UNEP, WHO, WB and Others

Fig. 6.3(c) Smoke Concentration in Tehran (Annual Averages)



Source ; UNEP, WHO and Municipality of Tehran

Fig. 6.3(d) Pb Concentration in Tehran (Annual Averages)



Source ; Municipality of Tehran

(2) Monthly and Daily Trends of Air Pollution in Tehran

According to a local newspaper (Ref: Hamshahri, "Air Pollution Crisis in Tehran," Nov. 30, 1993), the weather of Tehran causes an inversion phenomena of the air layer around 240 days in the year under the characteristic meteorological conditions because the Alborz Mountains in the northern part of the city prevent wind from blowing frequently. The most polluted days are in the late fall and early winter seasons. In the city, all weekdays are polluted, especially between the hours of 8:00 to 11:00 and 16:00 to 20:00. Pollutants in the air move north and northeast in the morning and south and southwest in the afternoon.

Table 6.3 shows monthly averages of selected ambient air quality in the daytime (6:00 - 18:00). Although NO_x concentration is not included in the table, it is recognized that a lot of hydrocarbons are emitted in the autumn and winter seasons.

Table 6.3 Monthly Average Values of Selected Ambient Air Quality (1988)

	SO_2 (ppm)	THC (ppm)	SPM (mg/m^3)
July	0.014	6.81	48.00
August	0.010	8.65	48.50
September	0.017	10.14	36.00

Source : Municipality of Tehran

Table 6.4 shows the results of the measurement values (July, August and September in 1988) by weekdays and Thursday. The table indicates that the average values on Thursday are higher than those on weekdays, except SO_2 concentration. Regarding hydrocarbons and SPM, effects of traffic control applied in the city center might be observed from these data. From Saturday through Wednesday, traffic is controlled in the center of Tehran City, accepting only cars with a special license in the daytime. On Thursday and Friday, the entrance of all kinds of cars into the city is allowed (Municipality of Tehran, "Comprehensive Plan for Controlling the Air Pollution in Tehran," February 1993). The reduction of SO_2 concentration is considered to be dependent on industrial activity of small and medium factories in the city.

Table 6.4 Average Ambient Air Quality of Weekdays and Thursday (1988)

	SO_2 (ppm)	THC (ppm)	SPM ($\mu g/m^3$)
Saturday to Wednesday	0.014	8.90	41.30
Thursday	0.014	9.50	47.60

Source: Municipality of Tehran

The results of measurements of the ambient air quality monitored by the Department of Environment in 1989 are briefly summarized as follows:

a) THC: The measurement value recorded 23.5 ppm in the winter season and 9.4 ppm in mid spring on the 24 hours average basis. The lowest values were for the hours between 2 and 4 in the morning and for the weekend. These lower recordings may suggest an inverse relationship between pollutant concentration and traffic flow. Traffic during early morning hours is light.

b) CO: Data, revealing a 24 hour average of 6.9, 6.13, and 7.4 ppm per cubic meter, were for autumn and winter seasons only. Measurements for Fridays and early morning were considerably lower.

c) SO_2: Recordings of the gases showed a 24 hour average value of 0.011 - 0.072 ppm for the autumn and winter seasons. The lowest recordings were on Fridays and early mornings.

d) NO: Measurements varied between 0.076 - 0.046 ppm during autumn and winter seasons with peak values recorded during weekdays and working hours when traffic was heavy.

e) NO_2: The concentration in 1989 varied between 0.09 ppm in the month just before spring and 0.021 ppm at the end of autumn.

(3) Evaluation of Air Pollution in Tehran by International Organizations

1) World Bank

According to the World Bank's "Selected Ambient Air Quality Indicators for Various Cities" (See APPENDIX), concentrations of SO_2 and SPM in Tehran record high values. Regarding SO_2, values of CCC (City Center Commercial) and SR (Suburban Residential) districts in 1987 - 1990 show a very large figure compared with other middle-income countries. Tehran is also the worst city among low-income countries including Beijing and Shenyang, which use coal as major energy for all sectors.

As for the values of SPM concentration in 1987 - 1990, the values in CCC and SR districts are also the worst ones in middle-income countries. Comparing with low-income countries, the figure in CCC district is fourth, following Xian, Shenyang and Beijing. The figure in SR district is second, following Lahore in the Table.

2) WHO/UNEP

A WHO Air Quality Monitoring Project began in 1973, supported by the Environment Fund of the United Nations Environmental Programme (UNEP). Data gathered from member states of WHO were stored and disclosed as Global Environmental Monitoring System (GEMS).

Looking at GEMS data in 1980 - 1984, the annual average value of SO_2 concentration in Tehran ranks third, following Shanghai and Shenyang. The annual average value of SPM ranks seventh, following Kuwait, Shenyang, Xian, New Delhi, Beijing and Calcutta. The annual average value of smoke ranks first.

Table 6.5 shows the number of days that exceeded the critical values of selected pollutants.

Table 6.5 Number of Days per Year with Levels Exceeding Critical Values (1980-1984)

	SO2 (μg/m3)		SPM (μg/m3)		Smoke (μg/m3)	
exceeded		150		230		150
	Shenyang	236	Shenyang	347	Santiago	299
	Milan	167	Tehran	347	Tehran	249
	Tehran	163	Delhi	338	Madrid	126
	Beijing	157	Beijing	338	Wroclaw	73
	Seoul	121	Calcutta	330	Sao Paulo	52

Source : WHO/UNEP

Table 6.6 Number of Days per Year with Levels Exceeding Critical Values (as of 1992)

	SO2 (μg/m3)		SPM (μg/m3)		Smoke (μg/m3)	
exceeded		150		230		150
	Shenyang	236	Tehran	347	Tehran	249
	Tehran	162	Shenyang	347	Santiago	220
	Milan	157	Xian	327	Madrid	126
	Seoul	121	Jakarta	268	Wroclaw	73
	Xian	114	Manila	225	Sao Paulo	52

Source : Hamshahri, Jan. 19, 1993

A summary of the recent WHO report is mentioned in the newspaper (Hamshahri, "Tehran is the Most Polluted City," Jan. 19, 1993) as shown in Table 6.6. In the WHO report, large cities of the world are listed by dust (SPM), SO_2 and THC. Tehran was the world's most polluted city in 1992. Tehran is the first in THC concentration and also in SPM together with Shenyan in northern China, and is the second in SO_2 concentration, following Shenyan.

The critical value of THC (smoke) is 150 micrograms per cubic meter as shown in Table 6.6. In Tehran, 249 days per year exceeded this level. The SPM concentration in the air in Tehran is also more than the critical value during 347 days of the year. The SO_2 concentration exceeded the critical value during 162 days of the year. It is worth noting that Athens and Kuala Lumpur which were in the list of polluted cities four year ago are no longer listed in the table of the 1992 WHO report (Hamshahri, "Tehran is the Most Polluted City," Jan. 19, 1993).

(4) Results Measured by Simplified Samplers

In order to determine the general situation of the SO_2 and NO_2 concentrations in the air of some large cities in I.R. Iran, the Study Team has tried to place a number of simplified capsule-type samplers at strategic points in the cities of Tehran, Tabriz, Ahwaz and Mashhad. Analyses were carried out in Japan after the measurement. The results of each measurement are shown in Table 6.7. Though the measurement procedure and the figures obtained might not be fully reliable due to the limits of time and period exposed (4 - 5 weeks only), and scope of coverage and manner of caring for each sample (most of them were located in residential areas for reasons of being dependent on reliable persons and organizations), some trends were expected to be observed.

It can be seen that NO_2 concentrations were within the values of both WHO Guidelines and the U.S. Standard except for those of Tehran and Mashhad. As for SO_2 concentrations, the figures are relatively small, except for some values in Tehran, in light of the WHO Guidelines. This trend might have been different, if the samples were taken more in downtown areas under heavy traffic conditions and industrial areas with high economic activities or during seasons other than summer, especially the autumn and winter seasons, in which the meteorological condition is more unstable and air quality could be relatively more deteriorated because of household heating.

<References>

*1) WHO/UNEP : "Air Quality in Selected Urban Areas, 1979-1980"
: "Assessment of Urban Air Quality, 1989"

*2) World Bank : World Table,"Selected Ambient Air Quality Indicators for Various Cities"

Table 6.7 SO_2 and NO_2 Concentrations in Major Cities
(Results measured by use of the Simplified Air Samplers)

Name of City	NO. of Sampler	Measurement Period	Area located	NO2		SO2		
				(ppb)	(mg/M3)	(ppb)	(mg/M3)	
Tehran	1	1992. 9.28- 10.28	Commercial	120	0.246	6	0.017	Rammtin Hotel
	2	ibid.	Residential	94	0.193	21	0.060	Driver's house
	3	ibid.	Administrative	57	0.117	18	0.051	Project Office(1992)
	T-1	1993. 8. 9- 9. 5	Residential	58	0.119	3	0.009	Jomhuri-Kargar cross road
	T-2	1993. 8.17- 9.21	Residential	40	0.082	1	0.003	Nirdamd-nahsen Sq. Shahnazan Ave.
	T-3	1993. 8.11-10.17	Administrative	55	0.113	4	0.011	Bucharest Ave. Corner of 5th Street
	T-1	1993. 8. 1- 9. 1	Residential	21	0.043	1	0.003	Shahrak Chods, Saveh Crossway
	T-2	1993. 8. 4- 9. 7	Administrative	45	0.092	3	0.009	PBO, Bahavesteen Sq.
Tabriz	1	1993. 7.18- 8.23	Residential	18	0.037	1	0.003	Valiasr
	2	ibid.	Residential	17	0.035	1	0.003	Eimamieh
	3	ibid.	Residential	20	0.041	1	0.003	Vighting
	4	ibid.	Residential	29	0.059	1	0.003	Faranak
Ahwaz	A-1	1993. 8.12- 9.12	Residential	17	0.035	1	0.003	Ahamadi Ave. - Azimand
	A-2	ibid.	Residential	31	0.064	4	0.011	Zibashahr - Zargarmaradi (B)lane
	A-3	ibid.	Residential	15	0.031	1	0.003	Mellat quarier 3face-5strret
	A-4	ibid.	Residential	11	0.023	4	0.011	Behzad Shahr-4th Ave.
Mashhad	M-1	1993.10. 9-11.13	Commercial	45	0.092	1	0.003	Tabarcy crossroad
	M-2	1993.10. 9-11.13	Commercial	19	0.039	1	0.003	Water and Elec. Street
	M-3	1993.10. 9-11.13	Residential	60	0.123	1	0.003	Sarakhse road
	M-4	1993.10. 9-11.13	Commercial	55	0.113	1	0.003	Elect.Sq.
	M-5	1993.10. 9-11.13	Commercial	43	0.088	1	0.003	Water Organization Street

Note : WHO Guideline NOx=0.150 mg/M3=73 ppb (24hrs), SOx=0.040-0.060 mg/M3=14-21 ppb (Annual value)
: US Standard NOx=0.100 mg/M3=50 ppb (annual Value)
: Correct values for Calculations of NO2 Concentrations;

Tehran Aug.-Sept. : Temperature=26.65 C, Moisture=21.5 %
Oct. -Dec. : Temperature=14.45 C, Moisture=38.5 %
Tabriz July-Aug. : Temperature=29 C, Moisture=20 %
Ahwaz Aug.-Sept. : Temperature=31.15 C, Moisture=63.5 %
Mashhad Aug.-Sept. : Temperature=22 C, Moisture=29.5 %

6.3.2 Pollutants and Emission Sources

Main emission sources in energy consuming sectors are generally listed as follows:

- Oil field, flaring, or burning some 10 to 15% of production
- Petroleum refineries with some 5 to 10% loss of feed
- Oil-burning power boilers of more than 100 t/h rating
- Gas turbine generators burning low grade (high sulfur) fuels
- Small and medium-scale industries burning low grade fuel oil
- Large-scale iron and steel mills
- Big cities having a population of more than one million
- Motor vehicles

6.3.2.1 Stationary Sources

The following newspaper articles reported the status of pollution generated by stationary sources.

"In Hamadan Province (located in the western part of Tehran), the operation of 1,200 brick-making kilns has made the area the second most polluted area of the country, followed by Tehran. This number of kilns burns about 70 million liters of fuel per year. In Charmahal Province (Southwest of I.R. Iran), about 200 brick-making kilns have expanded air pollution besides spreading industrial wastes, changing agricultural lands to useless land and desert. The local office of the Department of the Environment decided to offer credits and loans to the kiln's owners in order to change their combustion systems and also import modern equipment for the industry. Statistics show that about 17% of workers in this industry suffer from disease. In Arak City, 20 large-scale industries and 1,000 medium- and small-scale factories have given rise to environmental problems, especially air pollution. 1.2 million tons of carbon monoxide contaminate the city every year. This is three times the figure in Tehran. About 20% of the total area of Arak is occupied by industrial factories, and the rate of incidence of respiratory diseases is the greatest among all diseases" (Hamsahri, September 30, 1993; "Air Pollution in Three Provinces of Iran").

"Recently, Tehran has suffered from air pollutants originating from stationary sources. For example, November 29 and 30 were the most polluted days of the current year in Tehran and the Environment Protection Organization (EPO) notified people in the city to stay in their homes. The same warning was also announced on December 1. The EPO office requested the closure of 36 production units including cement, asphalt, leather & shoes, soap and textile factories in Tehran, Qam, Varamin and Karaj. The EPO office notified another 15 units to remove air pollutants emitted from their factories (Ref: Hamshahri, December 1, 1993; "Thirty-six Pollution Industries Closed in Tehran").

According to another report (Hamshahri, August 4, 1993; "Tehran; Breathing Gets More Difficult Day by Day"), Mashhad, Isfahan, Shiraz, Tabriz and Arak are the most polluted cities in I.R. Iran following Tehran.

(1) Pollutants Discharged from Stationary Sources

Pollutants, stationary emission sources and the countermeasures thereof to be supposed are classified as shown in Table 6.8.

Table 6.8 Emission Sources and Countermeasures

1) Iron and Steel Industry

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Sinterer, Furnace	Reduce S content in feed & fuel
	NOx	Sinterer, Furnace	Low-NOx burner, Low-air ratio burning
	Dust	Various places	Water spray, Collector, Cover, Closed space dust collecting
Water	COD	Coker, Rolling mill	Bio-treating, Coagulation precipitation, Floating
		Cold mill pickling	Separation, Neutralization
	Oil	Hot, Cold rolling mill	Natural(Coagulation, Pressurizing) floating separation
Waste	Slag	Blast, Rolling, Electric furnace	Re-utilization(for Cement, Civil materials)
	Dust	After collection	Recycle to applicable feed
Noise		Various places	Curtailing at sources, Shelter, Enclosure
Others			Plantation on premises, Telemetering system

2) Electric Power Generation

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Boiler	Reduce S content in fuel, Flue gas desulfurization, High stack
	NOx	Boiler, Gas turbine	Low-NOx burner, 2-stage burning, Flue gas denitrification, High Stack
	Dust	Boiler	Electrostatic precipitator
	CO2	Boiler, Gas turbine	Comprehensive efficiency improvement(introducing cogeneration)
Water	Heat	Condenser	Cooling tower
Noise		Various places	Curtailing at sources, Shelter, Enclosure
Others			Plantation on premises, Telemetering system

3) Petroleum Refinery

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Boiler, Furnace	Reduce S content in fuel, Flue gas desulfurization, Integrated high stack, Sulfur recovery
	NOx	Boiler, Furnace	Low-NOx burner, Modified burning, Flue gas denitrification
	CO2	Boiler, Furnace	Energy saving
	Smoke	Flare stack	Smokeless burning, Waste gas recovery
Water	Oil	Process, Ballast, Seal	Oil separator, Biochemical treatment
Waste	Oil	Oil separator	Recycle to feed, or fuel
	Sludge	Water treater	Dewatering and utilization as cement feed, etc.
Noise		Various places	Curtailing at sources, Shelter, Enclosure
Others			Plantation on premises, Telemetering system

4) Petrochemicals

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Boiler, Furnace, Reactor	Reduce S content in fuel, Integrated high stack, Flue gas desulfurization
	NOx	Boiler, Furnace, Reactor	Low-NOx burner, Modified burning, Flue gas denitrification
	CO2	Boiler, Furnace, Reactor	Energy saving
	Smoke	Flare stack	Smokeless burning, Waste gas recovery
Water	Oil	Process, Seal	Oil separator, Biochemical treatment
	COD	Process	Neutralization, Biochemical treatment
	Settlement	Well	Decrease well water use
Waste	Oil	Oil separator	Dewatering and Incineration
	Sludge	Water treater	Dewatering and Incineration
Noise		Various places	Curtailing at sources, Shelter, Enclosure
Others			Plantation on premises, Telemetering system

5) Gas Processing

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Process	Feed conversion(Coal->Heavy oil->LPG ->LNG)
	NOx	Process	Feed conversion(Coal->Heavy oil->LPG ->LNG)

6) Pulp and Paper Industry

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Boiler	Reduce S content in fuel, Fuel conversion to gas
	NOx	Boiler	Low-NOx burner, Modified burning
Water	SS, Color	Wood Preparation, Digesting, Paper machine	Coagulation precipitation
	COD	Digesting, Breaching	Neutralization, Biochemical treatment
Waste	Sludge	Water treater	Dewatering and Incineration
Others			Plantation on premise

7) Cement Industry

Category	*Pollutant*	*Process Source*	*Countermeasure*
Air	SOx	Negligible	Production process absorbs sulfur
	NOx	Cement kiln	New suspension preheater, Modified burning
	Dust	Various places	Water spray, Collector, Cover, Closed space collecting
	CO2	Cement kiln	Energy saving
Noise		Various places	Curtailing at sources, Shelter, Enclosure
Others			Plantation on premises, Telemetering system

8) Sugar Industry

Category	Pollutant	Process Source	Countermeasure
Air	SOx	Boiler	Reduce S content in fuel, Fuel conversion to gas
	NOx	Boiler	Low-NOx burner, Modified burning
Water	SS	Flume discharge	Coagulation precipitation
	COD	Steffen process	Biochemical treatment
Waste	Sludge	Water treater	Dewatering and Incineration

9) Glass Industry

Category	Pollutant	Process Source	Countermeasure
Air	SOx	Melting Furnace	Reduce S content in fuel, Fuel conversion to gas
	NOx	Melting Furnace	Low-NOx burner, Modified burning

(2) Estimation of Emission Volume by Factory

In order to collect data and information and appreciate the general conditions of the stationary sources associated with environmental concern, the Study Team conducted a survey of 28 factories from February through August 1993, mainly targeting such energy intensified industries as power plants, iron and steel mills, petroleum refineries, sugar factories and brick-making factories.

Table 6.9 shows some estimates of the emission volumes of SO_x and NO_x at the factories visited. The emission rates of pollutants such as CO_2, SO_2, and HC were estimated by the use of fuel requirements and emission factors in each factory as far as the actual operation data of energy management was made available. The main emission sources are power plants, petroleum refineries and steel plants. The estimated emission volume of SO_x and NO_x in Table 6.9 accounts for about two thirds of the total in I.R. Iran. Most of the NO_x emission is presumed to come from other sources than industry.

Table 6.10 and Table 6.11 show the result of estimation from the power plants and petroleum refineries which are considered the main pollutant sources.

In the estimation, the formation of CO gas is considered negligible in ordinary fuel combustion equipment under the recent combustion technologies applied to such major industries. However,

NO_2 gas formation in the combustion may vary not only by N content in fuel but also by types of equipment employed and modes of operation, so that the emission rates of NO_2 are assumed referring to the experimental data obtained by different types of fuel and operation. The following are the main assumptions to be considered for the calculations of emission rates of various industries:

1) Power Station

a) In principle, emission rates of exhaust gas shall be estimated from actual consumption of fuel gas and oil, but it may also be estimated from the total generation capacity and operation efficiency as a conventional method depending on the availability of actual data.

b) Exhaust from fuel gas is estimated by actual gas composition and capacity in a state of permanent combustion.

c) Exhaust from fuel gas is estimated by standard carbon content and actual sulfur content in a state of permanent combustion.

2) Refinery

a) Emission rates of the pollutants, CO_2, SO_2, H_2S, hydrocarbon, etc., are estimated from a energy balance in each refinery operation, i.e. the management of fuel and losses.

b) Exhaust from combustion of fuel gas and condensate is estimated by their composition and consumption rate.

c) Exhaust from combustion of fuel oil such as middle distillates, residue and wastes is estimated by the standard contents of carbon and the actual content of sulfur in relevant fuels. A state of permanent combustion may be assumed as an actual operation.

3) Gas Processing Plant

a) Emission rates of pollutants are estimated from the composition of fuel gas and condensates used for the operation by a state of perfect combustion.

b) Blow off gas and losses as total hydrocarbon are estimated from the material balance of feed and product if operation data is not available.

4) Flared Gas in Oil/Gas Field (on/off shore)

a) A perfect combustion is assumed to estimate CO_2 and SO pollutants according to the actual gas composition to be burnt.

b) Blow off gas to atmosphere is based on actual operation data.

c) Crude oil burning for off-specification shall be estimated based on the assumption that the emission rates of CO_2 and SO_2 are determined by perfect combustion as a conventional method according to the actual operation data.

5) Booster Station of Oil/Gas Transportation Pipeline

Exhaust gas from equipment such as gas turbines and gas engines shall be estimated according to the actual fuel consumption and its properties by a permanent combustion.

6) Petrochemical Industry

Emission rates of pollutants are estimated from the feed and product balance, management of energy balance, etc. in the actual operation with similar analysis to that mentioned for Gas Processing Plant and Refinery.

Table 6.9 Estimation of Emission Volume from Factories

Factory Name	Location	Fuel Comsumption Gas Oil (1000L)	HFO (1000L)	N.G. (1000m3)	Coal (Ton)	SOx Emission 1992 (1000t/yr)	Share (%)	NOx Emission 1992 (1000t/yr)	Share (%)
Tabriz Power Station	Azarbayjan(East)	181,932	889,857	57,706		56,063	24.84	12,741	24.36
Tabriz Refinery	Azarbayjan(East)		198,000	5,280		14,520	6.43	863	1.65
Soufian Cement Plant	Azarbayjan(East)		114,810			0	0.00	617	1.18
Iran Tractor Manufacturing Co.	Azarbayjan(East)		24,870			1,487	0.66	134	0.26
Sofina Gas Turbine Power Plant	Azarbayjan(East)	60,006	0	0		940	0.42	1,429	2.73
	Azarbayjan(East)Total					73,010	32.35	15,783	30.17
Ourmia Cement Plant	Azarbayjan(West)		73,688			0	0.00	396	0.76
Pakdis Drinks Factory	Azarbayjan(West)		1,200			72	0.03	6	0.01
	Azarbayjan(West)Total					72	0.03	402	0.77
Esfahan Steel Company	Esfahan				1,465,000	45,415	20.12	10,988	21.00
Sabet Fariman Sugar Factory	Khorasan		47,601			2,847	1.26	256	0.49
Touss Power Plant	Khorasan	159	16,951	730,529		1,022	0.45	2,973	5.68
Torbat-e-Jam Sugar Factory	Khorasan		14,000			837	0.37	75	0.14
Khorasan Sugar Factory	Khorasan		52,560			3,143	1.39	282	0.54
Khangiran Gas Processing Plant	Khorasan			17,700		0	0.00	3	0.01
	Khorasan Total					7,849	3.48	3,590	6.86
Haft Tappeh Cane Sugar A/I Co.	Khuzestan		6,540			391	0.17	35	0.07
Ramin Thermal Power Plant	Khuzestan	0	0	767,752		6	0.00	2,957	5.65
Ahwaz Steel Company	Khuzestan			297,977		2	0.00	59	0.11
Kaavian Steel Co	Khuzestan	575		10,190		10	0.00	7	0.01
Khuzestan Pipe Manufacturing Co.	Khuzestan					0	0.00	0	0.00
	Khuzestan Total	19,218	1,024,375	63,309		409	0.18	3,057	5.84
Montazer Ghaem Power Station	Tehran		668,156			61,559	27.28	10,126	19.36
Tehran Refinery	Tehran	27,210	0	1,174,039		33,380	14.79	2,374	4.54
Ray Power Plant	Tehran		82,566	132,998		436	0.19	5,169	9.88
Tehran Cement No.1 Factory (Total)	Tehran			59,388		0	0.00	470	0.90
Tehran Cement No.2 Factory	Tehran	400	5,360			0	0.00	12	0.02
Varamin Sugar Refinery	Tehran			17,966		327	0.14	32	0.06
Sobat Brick Company	Tehran			35,640		0	0.00	4	0.01
Bafkar Textyle Co.	Tehran					0	0.00	7	0.01
	Tehran Total		54,000	3,240		95,702	42.40	18,193	34.78
Ghazvin Glass Co.	Zanjan			40,654		3,229	1.43	291	0.56
Abguineh Glass Manufacturing Co.	Zanjan					0	0.00	8	0.02
	Zanjan Total					3,230	1.43	299	0.57
	All Total					225,687	100.00	52,312	100.00

Table 6.10 Estimation of Emission Volume from Power Plants

Power Plant	Province	Production 1992 (MWH)	Fuel Consumption Gas Oil (1000L)	HFO (1000L)	N.G. (1000m3)	SOx Emission 1992 (1000t/yr)	Share (%)	NOx Emission 1992 (1000t/yr)	Share (%)
Tabriz	Azarbayjan-East	3,615,670	906	889,857	0	53,228	17.57	8,208	7.94
Tabriz	Azarbayjan-East	181,026	23,405	0	57,706	367	0.12	780	0.75
Soufian	Azarbayjan-East	144,934	60,006	0	0	940	0.31	1,429	1.38
	Azarbayjan-East Total	3,941,630	84,317	889,857	57,706	54,534	18.00	10,417	10.08
Urmyeh	Azarbayjan-West	81,072	38,043	0	0	596	0.20	906	0.88
Besat	Boyehrahmad/Kohkiloyeh	1,302,883	4,015	80,498	309,104	4,879	1.61	2,027	1.96
Besat	Boyehrahmad/Kohkiloyeh	625,379	5,467	0	223,893	87	0.03	992	0.96
	Boyeh/Kohkil Total	1,928,262	9,482	80,498	532,997	4,967	1.64	3,019	2.92
Boushehr	Bushehr	223,916	104,784	0	0	1,641	0.54	2,495	2.41
Islam Abad	Esfahan	3,967,365	2,962	729,908	283,270	43,697	14.42	7,877	7.62
Islam Abad	Esfahan	42,726	14	0	16,896	0	0.00	65	0.06
	Esfahan Total	4,010,091	2,976	729,908	300,166	43,698	14.42	7,942	7.69
Zarqan	Fars	590,056	0	0	169,115	1	0.00	651	0.63
Zarqan	Fars	157,815	0	0	63,229	1	0.00	243	0.24
Shiraz	Fars	906,401	1,802	0	390,821	31	0.01	1,548	1.50
Hsa	Fars	46,620	14,757	0	112	231	0.08	352	0.34
Panahr	Fars	208,701	113,820	0	0	1,782	0.59	2,710	2.62
Abadeh	Fars	1,140	470	0	0	7	0.00	11	0.01
Lar	Fars	3,487	3,261	0	0	51	0.02	78	0.08
Lamard	Fars	9,737	12,667	0	0	198	0.07	302	0.29
	Fars Total	1,923,957	146,777	0	623,277	2,304	0.76	5,895	5.70
Lousban	Guilan	1,730,231	191	0	425,998	6	0.00	1,645	1.59
Loushan	Guilan	541,112	0	0	183,393	1	0.00	706	0.68
Rasht	Guilan	232,774	17	0	100,212	1	0.00	386	0.37
	Guilan Total	2,504,117	208	0	709,603	9	0.00	2,738	2.65
Firouzi	Hamadan	107,331	0	0	47,218	0	0.00	182	0.18
Shahid Firouzi	Hamadan	255,092	0	2,560	97,319	154	0.05	398	0.39
	Hamadan Total	362,423	0	2,560	144,537	154	0.05	580	0.56
Bandar Abas	Hormozgan	6,511,240	1,527	185,787	1,503,403	11,146	3.68	7,535	7.29
Bandar Abas	Hormozgan	20,811	0	0	14,863	0	0.00	57	0.06
Qeshm	Hormozgan	0	0	0	0	0	0.00	0	0.00
Kish	Hormozgan	36,666	21,217	0	0	332	0.11	505	0.49
	Hormozgan Total	6,568,717	22,744	185,787	1,518,266	11,479	3.79	8,097	7.84
Zarand	Kerman	222,460	6,445	73,767	0	4,512	1.49	832	0.81
Mashhad	Khorasan	428,552	358	4,985	142,307	305	0.10	602	0.58
Tous	Khorasan	2,642,667	159	16,951	730,529	1,022	0.34	2,973	2.88
Sarbisheh	Khorasan	21,205	11,502	0	0	180	0.06	274	0.27
Mashhad	Khorasan	649,440	4,525	0	262,569	73	0.02	1,119	1.08
Shirwan	Khorasan	321,397	1,909	0	149,987	31	0.01	623	0.60
Qaen	Khorasan	200,245	84,642	0	0	1,325	0.44	2,015	1.95
Tous	Khorasan	2,642,667	159	16,951	730,529	1,022	0.34	2,973	2.88
Ashknan	Khorasan	1,091	1,091	0	0	17	0.01	26	0.03
	Khorasan Total	6,907,264	104,345	38,887	2,015,921	3,976	1.31	10,605	10.26
Ramin	Khuzestan	3,438,558	0	0	767,752	6	0.00	2,957	2.86
Dorud	Lorestan	47,116	26,075	0	0	408	0.13	621	0.60
Nekah	Mazandaran	8,665,740	0	672,202	1,707,788	40,212	13.27	12,761	12.35
Nekah	Mazandaran	1,383,777	779	0	484,247	16	0.01	1,883	1.82
	Mazandaran Total	10,049,517	779	672,202	2,192,035	40,228	13.28	14,644	14.17
Zahedan	Sistan/Baluchestan	235,348	97,272	0	0	1,523	0.50	2,316	2.24
Montazer Ghaem	Tehran	3,944,134	7,807	1,024,375	0	61,380	20.26	9,610	9.30
Montazery	Tehran	4,409,121	4,222	1,172,019	0	70,153	23.15	10,883	10.53
Rajai	Tehran	638,366	0	0	146,591	1	0.00	565	0.55
Montazer Ghaem	Tehran	24,885	10,205	0	0	160	0.05	243	0.24
Montazer Ghaem	Tehran	224,635	1,206	0	63,309	19	0.01	273	0.26
Rei	Tehran	3,127,199	27,210	0	1,174,039	436	0.14	5,169	5.00
Kilan	Tehran	539,486	0	0	155,359	1	0.00	598	0.58
Shariaty	Tehran	410,480	2,234	0	186,999	36	0.01	773	0.75
	Tehran Total	13,318,306	52,884	2,196,394	1,726,297	132,187	43.63	28,114	27.20
Kermanshah	Yazd	58,285	27,731	0	0	434	0.14	660	0.64
Yazd	Yazd	49,535	21,170	0	0	332	0.11	504	0.49
	Yazd Total	107,820	48,901	0	0	766	0.25	1,164	1.13
	All Total	55,870,574	746,032	4,869,860	10,588,557	302,986	100.00	103,342	100.00

Table 6.11 Estimation of Emission Volume from Petroleum Refineries

Refinery	Province	Crude Processing Capacity (BPSD)	Share (%)	SOx Emission 1992 (1000t/yr)	Share (%)	NOx Emission 1992 (1000t/yr)	Share (%)
Tehran	Tehran	220,000	21.85	33,800 *	20.76	2,374	21.85
Bakhtaran	Bakhtaran	27,000	2.68	4,371	2.69	291	2.68
Tabriz	Azarbayjan-East	80,000	7.94	14,520 *	8.92	863	7.94
Isfahan	Isfahan	240,000	23.83	38,853	23.87	2,590	23.83
Shiraz	Fars	40,000	3.97	6,476	3.98	432	3.97
Abadan	Khuzestan	380,000	37.74	61,518	37.79	4,101	37.74
Lavan	Hormozgan	20,000	1.99	3,238	1.99	216	1.99
	Total	1,007,000	100.00	162,775	100.00	10,868	100.00

Note : Following assumption was made on estimation

SOx emission rate	3.6 kg/ton crude,	* Estimated based on actual fuel consumption
NOx emission rate	0.24 kg/ton crude	
Operating efficiency	0.9(330 days/y)	
Crude specific gravity	0.857	

6.3.2.2 Mobile Sources

There are also articles in newspapers reporting the current status of air pollution generated by mobile sources.

"Tehran has two million vehicles of all kinds plus 800 thousand motorcycles. The annual gasoline consumption of Tehran is 150 million liters. Gasoline and gas oil are the main sources of pollutants. Sixty-five percent of the air pollution is caused by these nearly two million vehicles moving in Tehran. Passenger cars emit 1.32 million tons, and public buses emit 14.4 thousand tons of pollutants. The amount of lead released in the air is 1,800 tons per year, mostly from gasoline engines. Each citizen receives about 0.5 grams of lead, which is much too dangerous. Lack of public transportation facilities force the people to use old private cars with incomplete fuel combustion. Unfortunately, "Paykan," which is the national car manufactured for 25 years, is not equipped with an advanced fuel system and produces 7 to 9 times more pollutants than modern cars. Based on UN report in 1992, Tehran was ranked first in THC and SPM concentration, and second in SO_2 concentration in the air (See Table 6.6). The concentration of hydrocarbon in the air reached 249 grams per cubic meter. Besides the 65% of vehicle pollution, 26% comes from industries and 11% from household heaters." (Ref. Hamshahri, Aug. 4, 1993: "Breathing Gets More Difficult Day by Day")

According to the report prepared in February 1993, titled "Comprehensive Plan for Controlling the Air Pollution in Tehran" by the Teheran Traffic Control Center affiliated with the Municipality of Tehran, there are 1.5 million motor cars moving in Tehran in a day which are responsible for 70% of total air pollution, and incomplete combustion, which is the result of a shortage of spare parts and the height of the city from sea level, contributes greatly to the air pollution in Tehran. And according to the survey by "Urban Development Organization and Tehran University" (1990) regarding sound pollution in Tehran, " the source of the sound in Tehran is 2 million vehicles running daily, of which 260 thousand are motorcycles....."

(1) Emissions of Pollutants from Mobile Sources

SO_2 is emitted through combustion of fuel which contains sulfur, and the extent of emission is ruled by the amount of sulfur content. The actual emission is composed of various forms of sulfur-oxygen compounds, the so-called SOx (Sulfur oxides), and among them SO_2 is usually regarded as a representative substance because of its stronger effects on the respiratory organs.

NO_2 is emitted through combustion of any type of fuel, the so-called "Thermal NOx (Nitrogen oxides)". In addition, the so-called "Fuel NOx" is released in the gas phase of fuel which contains organic nitrogen. Among the NOx family compounds, NO_2 is usually regarded as a representative substance because of its relatively stronger effects on the respiratory organs. The "Thermal NOx" formation is highly temperature dependent; the higher the combustion temperature, the better the energy efficiency. Therefore, it is necessary to investigate sophisticated combustion equipment with less NOx emission.

CO is emitted through combustion of fuel with insufficient oxygen supply. CO emission is mainly controlled by good combustion control with well arranged engines, which also brings an economic benefit in the use of vehicles. The vehicle owners are responsible for taking these measures.

THC is emitted not only through the combustion of fuel, but also through the refining, delivery and consumption processes of oil and its derivatives, which contain volatile solvents. Among these emissions, fuel consumption by motor vehicles is considered major. Because of the difficulty in eliminating THC emission from motor vehicles, it may be inevitable to allow a certain amount of emission.

SPM is emitted through either imperfect combustion of any type of fuel or the fuel's inflammable content. In addition, there are many other sources of generation, such as soil dust, pollen of plants and other natural and artificial phenomena.

Smoke is emitted through combustion of any type of fuel by a mechanism similar to SPM emission, though smoke particiles are larger than those of SPM. Measures to control smoke emission are almost identical to those of SPM.

Pb is emitted from motor vehicles which use a special gasoline with tetraethyl lead additives.

This substance is reported to cause a cerebral injury in infants.

(2) Estimation of Motor Vehicle Stock

Energy consumption in the transport sector is shared by four different modes; ship, airplane, railway and motor vehicle. Among these modes, the first three are generally operated in remote locations from urban areas, and may affect human life less seriously. Most environmental concerns related to the transport sector are focused on air pollution as a result of energy consumption along the shuttle lines of the transport network. Therefore, in this study, the influence of the motor vehicles is mainly discussed.

1) Vehicle Stock in Iran

No comprehensive statistics regarding the vehicle stock in I.R. Iran are available. According to some published statistics available in I.R. Iran and Japan, the total number of motor vehicles has been increased up to about 2.6 million in 1990, seven times as much as 20 years ago, of which passenger cars account for 74%, and buses and trucks account for 26%. This figure gives an impression of underestimating the number of vehicles which is widely spoken of.

In this study, the vehicle stock is presumed based on the fuel consumption of the transport sector in I.R. Iran, which is separately estimated in the energy balance table (See APPENDIX). Given the average fuel consumption and average annual travel distances of the motor vehicle, the number of motor vehicles can be estimated by the following equations:

$$N = F / AF$$

$$AF = UF * AT \text{ (kcal /y * Vehicle)}$$

where,

N: Number of motor vehicles(Vehicle)

F: Fuel consumption of national total (kcal /y)

AF: Annual fuel consumption per vehicle on average (kcal /y)

UF: Unit fuel consumption per vehicle average (kcal /km)

AT: Annual travel distance per vehicle average (km /y)

"UF" in I.R. Iran has not been announced officially, so it is inferred as follows from 1970 Japanese data when the regulations on exhaust gas emission were not yet in effect. This assumes that the present situation of vehicles in I.R. Iran is much similar to that of the year 1970 in Japan, since almost no exhaust gas regulations have been enforced yet in I.R. Iran.

Passenger car:	954 kcal /km	(by gasoline)
Bus:	2,943 kcal /km	(by gas oil)
Large truck:	2,484 kcal /km	(by gas oil)
Small truck:	1,121 kcal /km	(by gasoline)

Then, assuming that the ratio of the number of passenger cars to small trucks is given at 4:1, and the ratio of buses to large trucks is given at 1:1, the complex average "UF" by fuel type is calculated as follows, since the classification by fuel type is necessary to apply the formula to deduce the number of vehicles based on the energy balance tables.

Gasoline car:	987 kcal /km	(=(4 * 954 + 1 * 1,121) / 5)
Gas oil car:	2,714 kcal /km	(=(2,943 + 2484) / 2)

"AT" by the type of vehicle in Japan is given by "Outline of Energy Statistics in Transport Sector, Ministry of Transportation of Japan" as of 1970. According to this, average travel distance of motor vehicles throughout the year(AT) in Japan shows very little change for the past 20 years, which is around 11,000 km /y, as if it were an inherent index of the country. The same index of the USA is about 16,000 km /y. "AT" of the other Western countries in 1988 are presented in "Fuel Efficiency of Passenger Cars, IEA 1991" as follows:

Japan:	11,000 km/y
USA:	16,000 km/y
Australia:	15,800 km/y
Canada:	17,200 km/y (as of 1987)
Denmark:	15,800 km/y

Italy:	11,700 km/y
Netherlands:	16,100 km/y
Portugal:	8,800 km/y
Spain:	14,200 km/y
Sweden:	14,000 km/y
Switzerland:	15,000 km/y
UK:	16,000 km/y

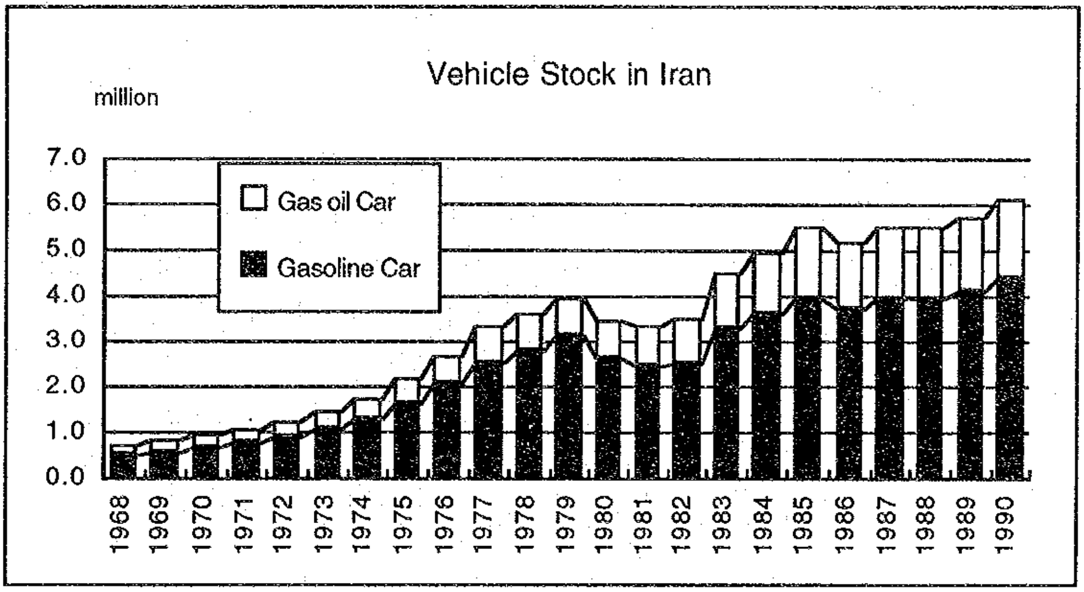
The index of "AT" in I.R. Iran was assumed as 14,000 km/y by averaging the figures of Japan and the USA. Firstly, an analogy of the national vehicle distribution was drawn between I.R. Iran and Japan. I.R. Iran has an more uneven vehicle distribution between urban and rural areas. Most vehicles run in urban areas where an average journey tends to be shorter, whereas an average journey naturally becomes longer as the size of the country gets bigger. Secondly, both I.R. Iran and the USA do not have sufficient mass transit facilities for commuter traffics which may cause "AT" bigger than that of Japan.

Thus, "AF" by fuel type in I.R. Iran is calculated according to the aforementioned formula of "UF" and "AT" as follows.

Gasoline car: 13.82 Gcal /y (=987 (Kcal /km) * 14,000 (km /y)
Gas oil car: 38.00 Gcal /y (=2,714 (Kcal /km) * 14,000 (km /y)

Then, the vehicle stock in I.R. Iran is estimated by applying the above "AF" values to the annual fuel consumption data shown in the energy balance table, where the energy requirement for trains is considered negligible small compared with road transport, though the figures in the table represent the "Road and Train" division overall. The result is shown in Figure 6.4.

Figure 6.4 Vehicle Stock in I.R. Iran



The vehicle stock in the whole nation of I.R. Iran is estimated at about six million, and has increased 8 times over the past 22 years. The vehicle type composition in the year 1990 is assumed as follows:

Passenger car: 3.5 million (58 %)
Small truck: 0.9 million (14 %)
Large truck: 0.8 million (14 %)
Bus: 0.8 million (14 %)

2) Vehicle Stock by Province

The vehicle stock by province is estimated by assuming that the numbers of vehicles are distributed in proportion to the urban population of each province according to the following regression:

$$\log Y = m * \log X + b$$

where

Y: Vehicle number by province (1,000 Vehicle)

X: Population of urbanized area (1,000 People)

m and b: Exponential regression coefficients

According to this estimation with some modifications on Tehran City as explained later in this chapter, the Tehran Metropolitan Province has a remarkably large share of 34%, about 2 million in the Province overall and 1.8 million in Tehran City, followed by Khorasan with the capital city of Mashhad, Isfahan and Azarbayejan-e-Sharqi with the capital city of Tabriz(Table 6.12).

Besides the motor vehicles estimated above, a lot of motorcycles are commonly used in the urban areas. For example, it is reported by Hamshahri on Aug 4, 1993 that approximately 800 thousand motorcycles are now in use in Tehran.

Table 6.12 Vehicle Stock by Province

(as of 1990)

Province	Urban Population	Gasoline Car Stock	Gas Oil Car Stock	Vehicle Stock
Tehran	6,650,665	1,754,400	298,581	2,052,981
Khorasan	1,701,869	416,298	135,700	551,998
Esfahan	1,359,057	325,408	119,140	444,548
Azarbayejan-e-Sharqi	1,354,134	326,011	118,890	444,901
Fars	848,289	190,974	90,704	281,678
Khuzestan	836,033	189,592	89,943	279,535
Markazi	808,488	184,069	88,217	272,286
Mazandaran	623,300	135,860	75,890	211,751
Bakhtaran	560,514	120,796	71,368	192,164
Zanjan	463,852	96,558	63,965	160,523
Azarbayejan-e-Gharbi	416,089	85,561	60,067	145,628
Lorestan	392,471	81,102	58,070	139,172
Hamadan	376,139	78,616	56,660	135,275
Hormozgan	302,463	60,602	49,946	110,547
Gilan	290,897	59,406	48,831	108,238
Sistan-va-Baluchestan	281,923	58,913	47,954	106,867
Kerman	257,284	54,177	45,483	99,660
Yazd	230,483	48,856	42,678	91,534
Kordestan	204,537	43,767	39,829	83,596
Bushehr	201,642	44,919	39,502	84,421
Chaharmahal-va-Bakhtiyar	63,495	9,448	20,242	29,690
Semnan	61,021	10,714	19,782	30,496
Ilam & Boyerahmad-va-Kol	58,211	9,953	23,557	33,511
TOTAL	18,342,856 *1	4,386,000	1,705,000	6,091,000 *2

Sources:

*1 : A Statistical Reflection of the Islamic Republic of Iran, No. 9 (Census of 1986)

*2: Motor Vehicle Statistics of Major Countries, Japan Motor Industry Assoc. and Iran Yearbook '93

(Note) Correlations between the vehicle stock and urban population appear very impressive, much more intensive than those of the vehicle stock and the total population according to the analysis by regressions for 47 Prefectures in Japan as shown in Figure 6.5.

Figure 6.5 Correlation between Vehicle Stock and DID Population in Japan

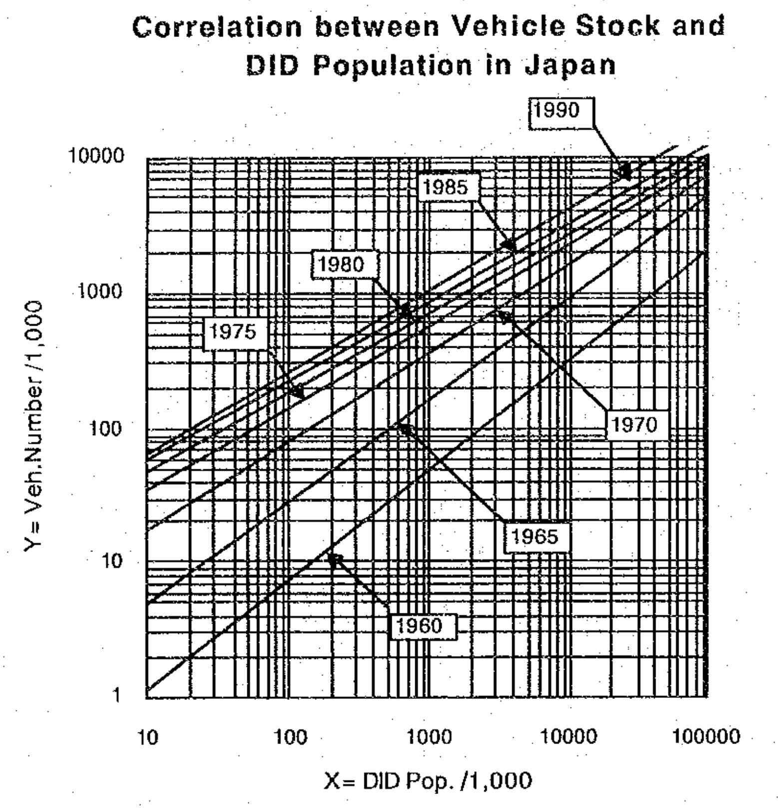


Table 6.13 Regression of Coefficients

Year	logY= m * logX + b			Veh. Stock Rate/1,000	
	R	m	b	Total Pop.	DID Pop.
1960	0.951659	0.818576	-0.778097	20	46
1965	0.953576	0.761698	-0.078385	70	146
1970	0.951867	0.659048	0.576853	158	295
1975	0.948035	0.607138	0.930702	246	432
1980	0.942128	0.585632	1.100327	315	528
1985	0.943919	0.584706	1.183054	376	621
1990	0.949886	0.602652	1.204787	460	728

R= Correlation coefficient

The above formulas are drawn from the statistical records of seven years with five year intervals in between, which show a gradual change in the growth of vehicle stock rate per capita. The vehicle stock rate per capita has steadily grown from 20 per thousand people of the total population in 1960 to 460 in 1990 and 46 per thousand people of DID (Densely Inhabitant District or Area) population in 1960 to 728 in 1990.

In I.R. Iran, on the other hand, the vehicle stock rates are estimated at 123 per thousand of the total population and 332 per thousand of DID population in 1990, which resembles the situation in Japan in 1970.

3) Vehicle Stock in Tehran

Applying directly the regression formula of Japan in 1970, $\log Y=0.659*\log X+0.577$, to the estimation of provincial distribution of vehicle stock in I.R. Iran, the share of Tehran City occupies about 20% of all types of vehicles; this share corresponds to 1.2 million vehicle stock, but seems too small compared to the frequently quoted figure of a total stock of about 2 million in Tehran City.

Other information related to vehicle stock by province is that Tehran shares 40% of the whole gasoline consumption in I.R. Iran, whereas Tehran shares at most 18% of the total population and 36% of DID population. This excessive share over demographic parameter implies that there are some unidentified factors that drive gasoline cars to concentrate on Tehran more densely than a normal distribution trend. This conspicuous characteristic of Tehran may be caused by her outstanding size among all the cities of I.R. Iran, such as that the population of Tehran City was about six million in 1988 whereas Mashhad City, the second largest, has a mere 1.4 million, which is only one fourth of Tehran. Extreme concentration of urban population usually brings the city a dominant function as the center of administrative and intellectual activities which are often categorized as the tertiary or service industry. This category of industry, in general, requires a large amount of manpower that increases the need for personal travel in urban areas. This is a presumption why Tehran attracts so many gasoline cars, though there is no direct key available at this moment to identify the exact distribution of the vehicle stock by province.

Therefore, the vehicle stock by province is estimated by assuming that the distribution pattern of vehicle is separated into two categories, gasoline cars and gas oil cars, and the gasoline car stock can be estimated by modifying provincial distribution of DID population in order that the share of Tehran meets 40%. The rest of vehicle stock, gas oil cars, is estimated by applying the same regression formula as that of Japan in 1970, as shown below:

$$\log Y = 0.57858 * \log X - 0.38764$$ (Correlation Coefficient: 0.947)

6.4 Emission Analysis on Air Pollutants and Carbon Dioxide

6.4.1 Past Trends of Emission Volume

(1) Method of Estimation

1) Emission by Energy Consumption

Past trends of the emission volume of various pollutants were estimated on the basis of the energy balance table that is shown in the APPENDIX. On the energy balance table, production of energy is shown in the upper part of the table and the energy consumption in conversion sector and final demand is placed on the lower part so that the production, conversion and final demand can be compared on a yearly basis.

To estimate the total emission of air pollutants and carbon dioxide from the economic activity of the country, the final energy demand for the various sectors and the energy supply to the conversion sectors were featured. The sectors which consist of the final energy demand are classified into the industrial sector, transportation sector, agricultural sector, and residential and commercial sector. The conversion sector includes refineries and power plants. Each energy requirement of these sectors was picked up by fuel type from the energy balance table.

The emission volume was computed as the product of the energy consumption and the emission factor, or emitted volume of pollutant for unit fuel consumption, defined by fuel for each sector. By using this method of calculation, the emission volumes of two kinds of air pollutant, SO_x and NO_x, and one greenhouse-effect gas, CO_2, were estimated. The emission factors used for calculations are shown in the APPENDIX.

Figure 6.6 shows the energy consumption by sector in the country. The graph indicates that the total energy consumption has been increased about 4 times during the period from 1971 to 1990. In recent years, the energy consumption in the conversion sector and the industrial sector show a tendency to increase rapidly.

Figure 6.7 shows the energy consumption by fuel type. As shown in the figure, the share of petroleum product in the total energy consumption has always been the biggest. However, recently its rate of growth has become smaller than that before 1985. In contrast to the growth rate of petroleum product, the energy consumption of natural gas has been increasing at higher rates since 1985 though its share of total energy consumption is still small.

2) Emission from Flared Associated Gas in Oil Field

Separate from the calculation described above, emissions from the flared associated gas in oil fields has been estimated and compared with emissions from economic activities of the country.

The volume of flared natural gas was taken from the OPEC Annual Statistical Bulletin. The contents of H_2S in the flared gas was assumed to be 4% for the SO_x emission calculation. For the other emissions, NO_x and CO_2, the emission factors for natural gas shown in the APPENDIX were used for calculation.

3) CO_2 Emission from Cement Industry

In addition to this calculation, the emission volume of CO_2 from the cement industry was also calculated and compared with the volume from the other sources. The specific consumption of limestone as a raw material for the production of cement was taken from the Japanese average value of 1.14 tons limestone / 1 ton cement. Then, the CO_2 emission factor through the processing of limestone was set to 0.2 ton CO_2 / 1 ton limestone .

(2) Emission Volume by Sector

The historical trends of SO_x, NO_x and CO_2 emissions calculated in the country by sector are shown in Figure 6.8 through Figure 6.10. All the calculated values are also shown in the APPENDIX as a reference.

Fig. 6.6 Energy Consumtion by Sector ; I.R. Iran

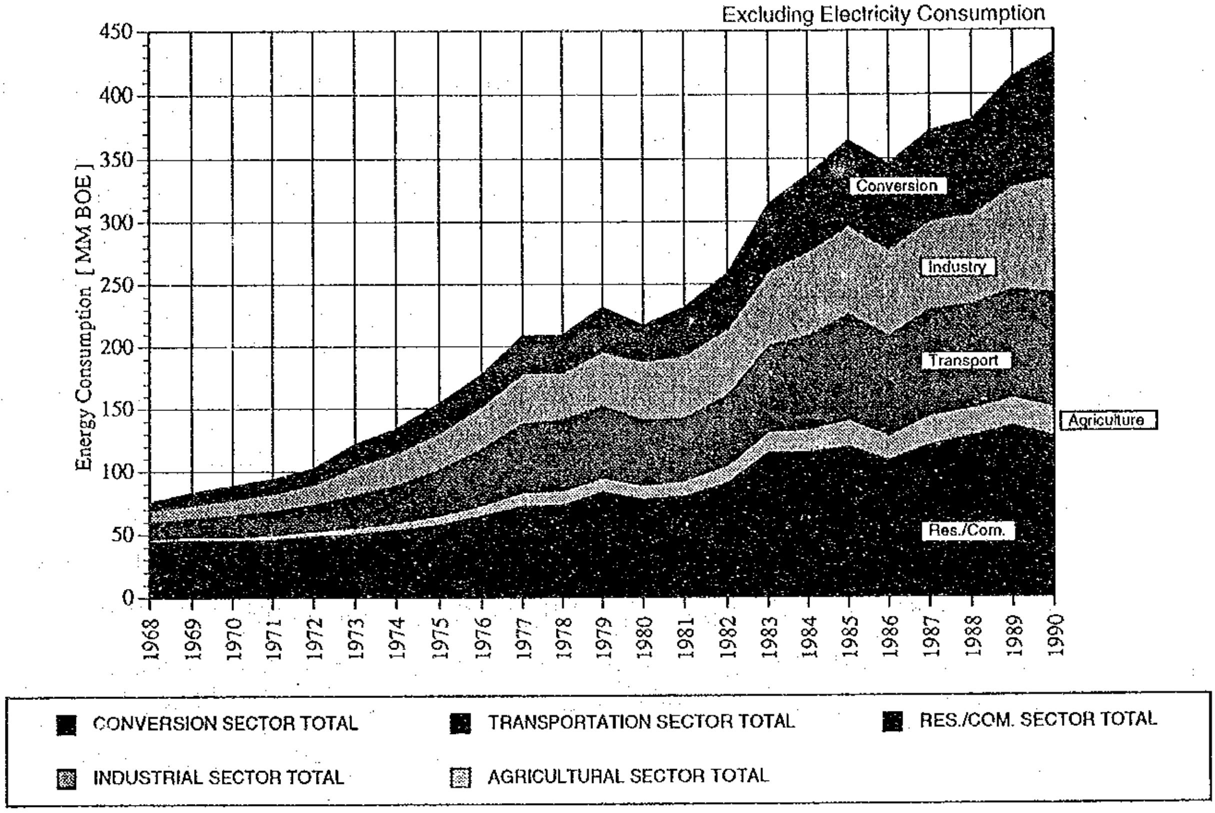
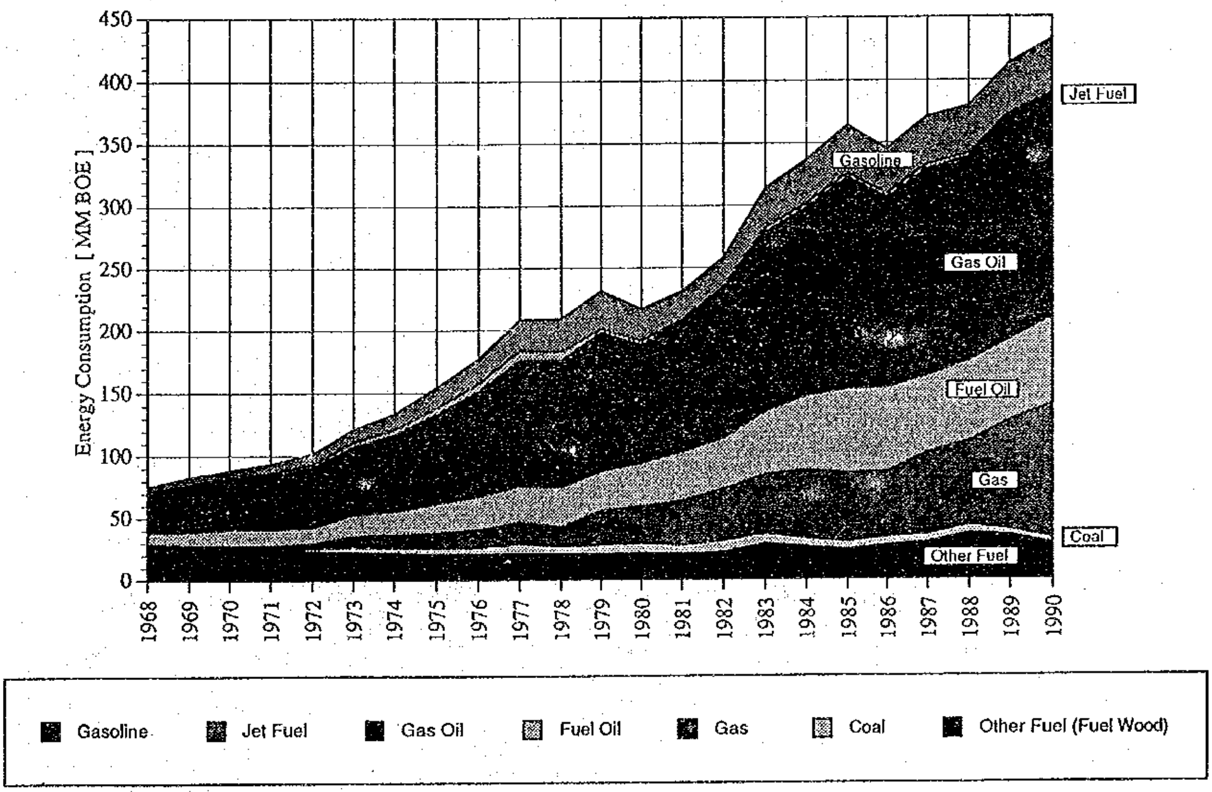


Fig. 6.7 Energy Consumption by Fuel Type ; I.R. Iran



1) SO_x

As shown in Figure 6.8, total emissions increased about 6 times during the period from 1970 to 1990. The industrial sector and the conversion sector showed extreme growth in SO_x emissions. In 1990, the emission volume from these two sectors represented 60% in the total. In the agricultural sector and the residential/commercial sector, SO_x emissions are increasing as energy consumption in these sectors rises.

2) NO_x

As shown in Figure 6.9, total emissions increased about 5 times during the period from 1970 to 1990. The most significant increase in NO_x emissions is recognized in the transportation sector. This single sector has about 60% of the total. The conversion sector is the big contributor to NO_x emissions next to the transportation sector. The volume of emissions from the conversion sector is increasing moderately. In the industrial sector, the volume of emissions has been constant in recent years.

3) CO_2

As shown in Figure 6.10, total emissions increased about 4 times during the period from 1970 to 1990. The emission volume in every sector increased in accordance with the rise in fuel consumption. Regarding CO_2 emission volume, the trend shows a different aspect from those of SO_x and NO_x emissions; that is, the share emitted from residential and commercial sectors is still relatively large.

(3) Emission Volume by Fuel

The historical trends of SO_x, NO_x and CO_2 emissions calculated by fuel type are also shown in the APPENDIX. Figure 6.11 through Figure 6.13 plot results of the emissions calculations.

Fig. 6.8 SO_x Emission by Sector ; I.R. Iran

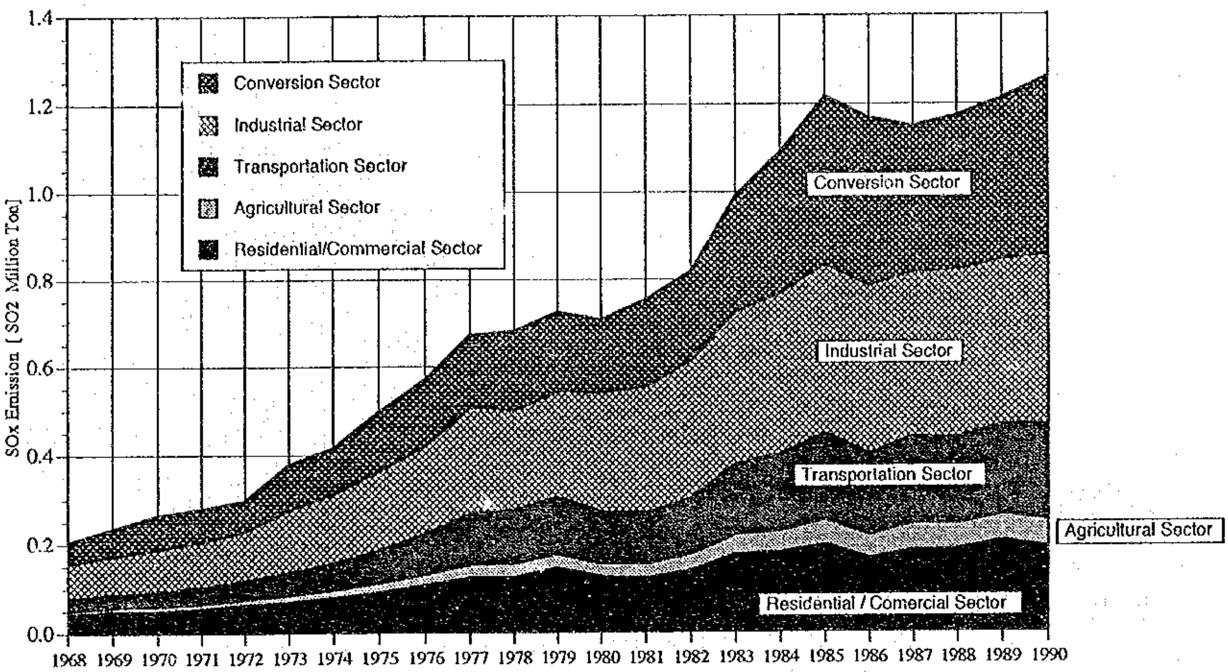


Fig. 6.9 NO_x Emission by Sector ; I.R. Iran

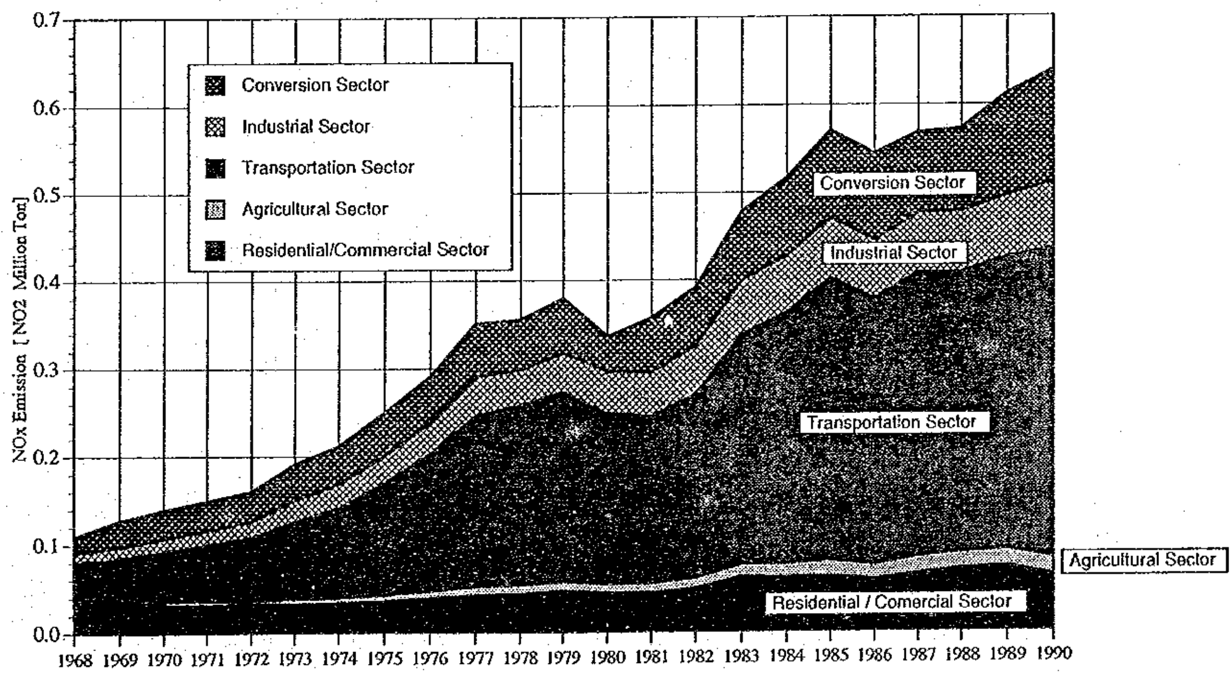
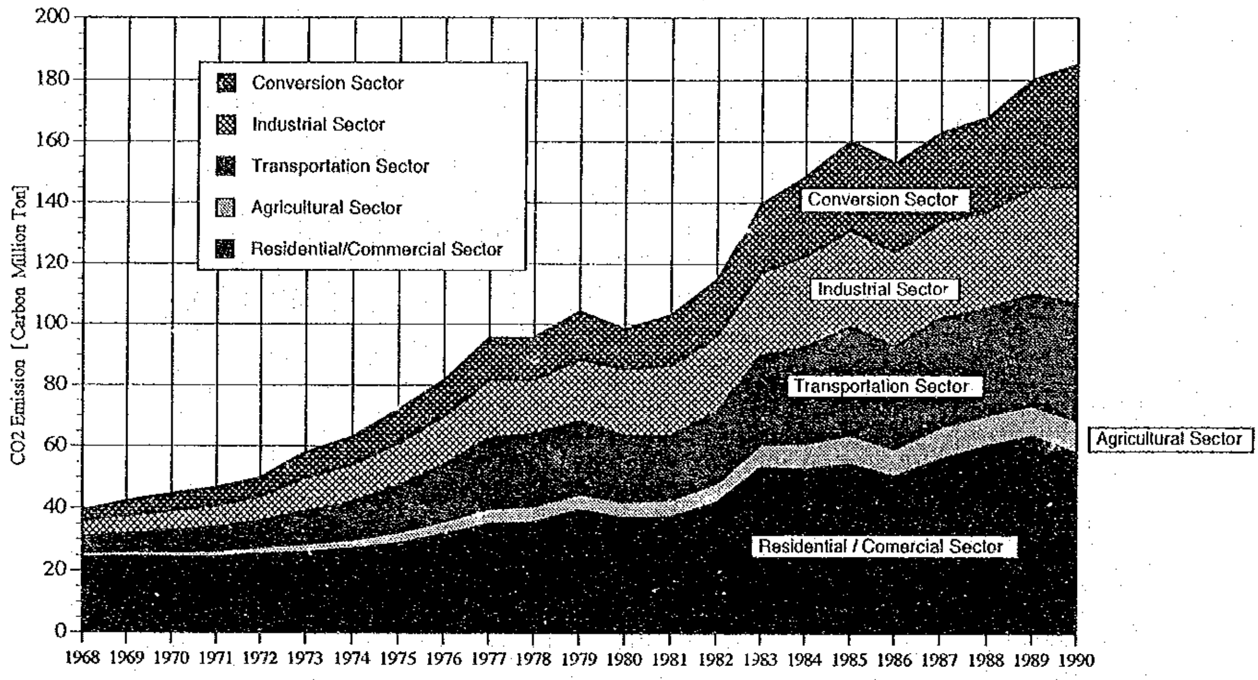


Fig. 6.10 CO_2 Emission by Sector ; I.R. Iran



1) SO_x

The upper graph of Figure 6.11 shows SO_x emissions by fuel (solid fuel, petroleum, natural gas and non-commercial fuel). As can be seen, almost all of the SO_x emissions are caused by the consumption of petroleum products. The lower graph (on enlarged scale) of the Figure shows SO_x emissions from fuels, excluding petroleum products and solid fuel.

2) NO_x

The upper and lower graphs of Figure'6.12 show NO_x emissions by fuel and from fuels excluding petroleum products and solid fuel. As in the case of SO_x emissions, most of the volume is emitted by the combustion of petroleum products. However, in contrast with the case of SO_x emissions, the share of natural gas has increased in accordance with the recent growth in consumption.

3) CO_2

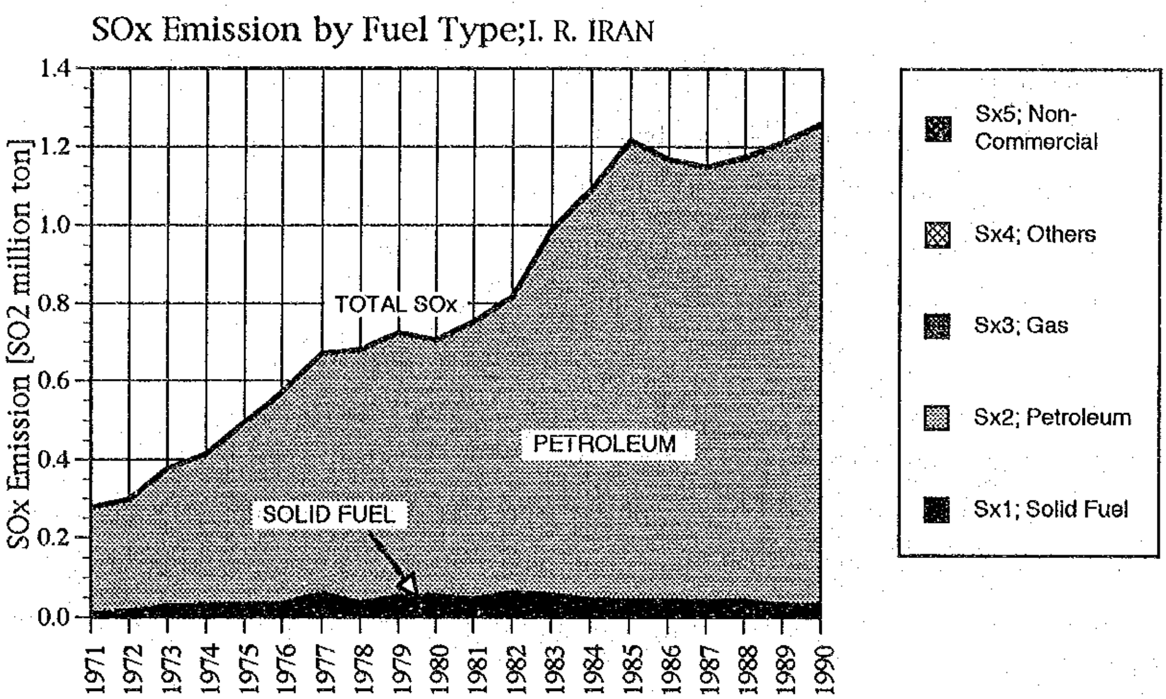
Figure 6.13 shows the historical trend of CO_2 emission by fuel. Like in the case of SO_x and NO_x emission, the most part of the emission volume is emitted by the combustion of petroleum products. The share of natural gas has a tendency to increase recently.

(4) Emission Volume from Flared Gas in Oil Field

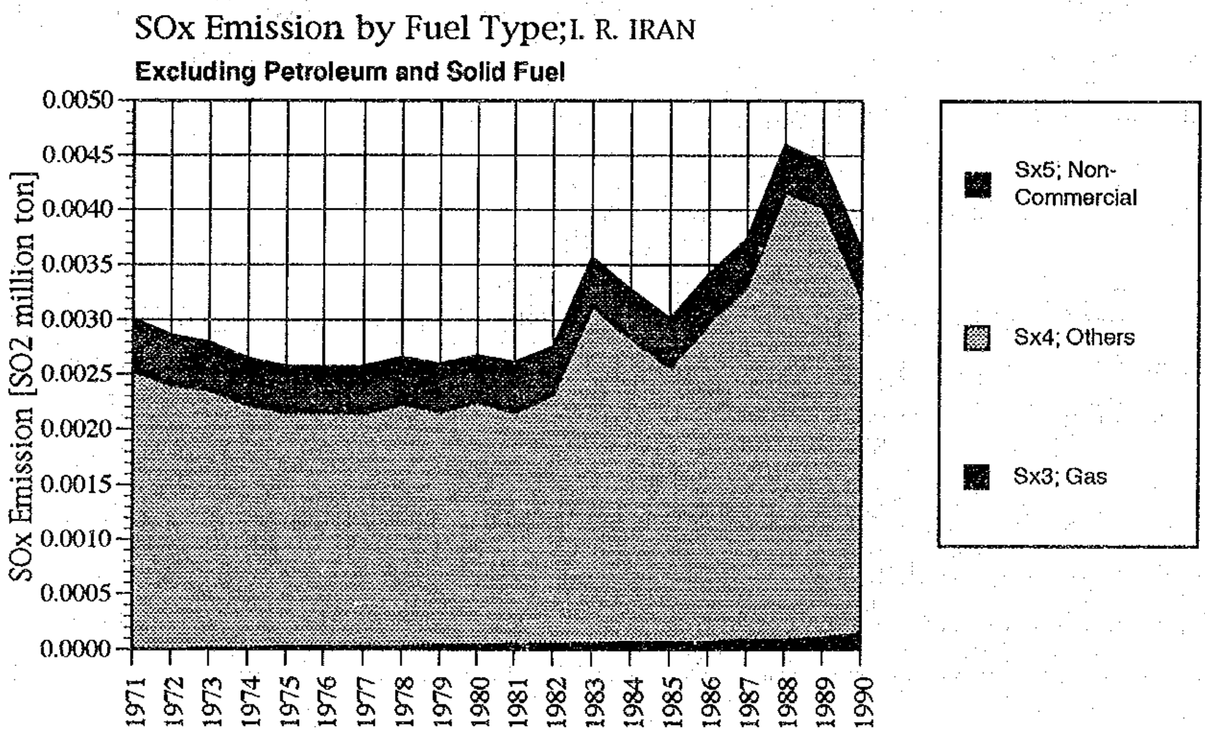
The flared associated gas in oil fields of the country is estimated to be one of the emission sources which can not be overlooked. Figure 6.14 shows the historical trends of primary energy requirement flared associated gas.

When the volume of flared associated gas is evaluated as energy consumption, it is comparable to the total energy requirement in all the economic activities of the country. Due to the efforts of utilization of associated gas, the growth rate of flared volume has been recently kept smaller than that of energy consumption in the economic activities of the country. As a result of this effort, now the

Fig. 6.11



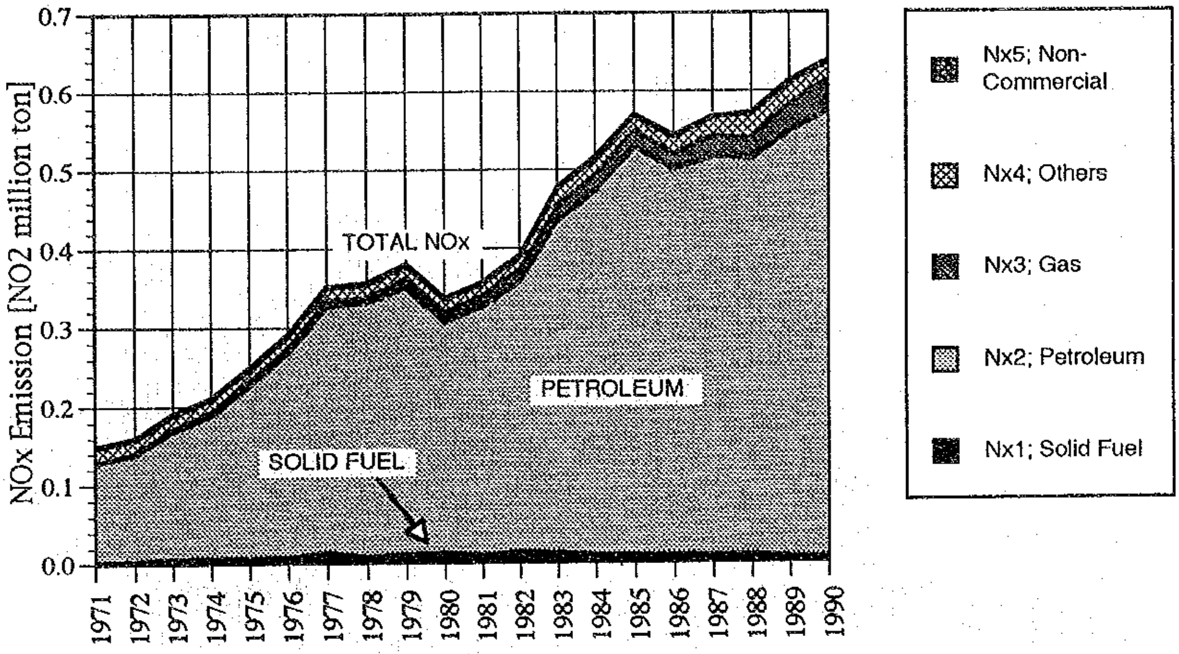
SOx Emission by Fuel Type;I. R. IRAN
SOx Emission [SO2 million ton]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
TOTAL SOx
PETROLEUM
SOLID FUEL
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Sx5; Non-Commercial
Sx4; Others
Sx3; Gas
Sx2; Petroleum
Sx1; Solid Fuel



SOx Emission by Fuel Type;I. R. IRAN
Excluding Petroleum and Solid Fuel
SOx Emission [SO2 million ton]
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Sx5; Non-Commercial
Sx4; Others
Sx3; Gas

Fig. 6.12

NOx Emission by Fuel Type;I. R. IRAN



NOx Emission by Fuel Type;I. R. IRAN

Excluding Petroleum and Solid Fuel

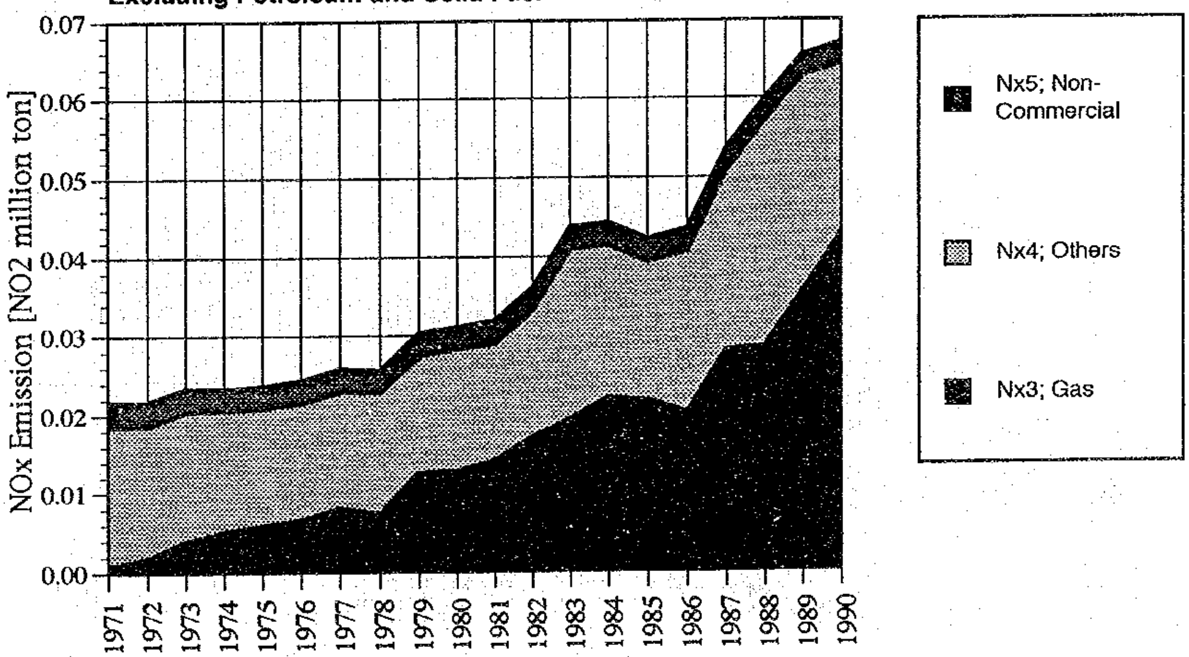


Fig. 6.13

CO2 Emission by Fuel ; I.R. Iran

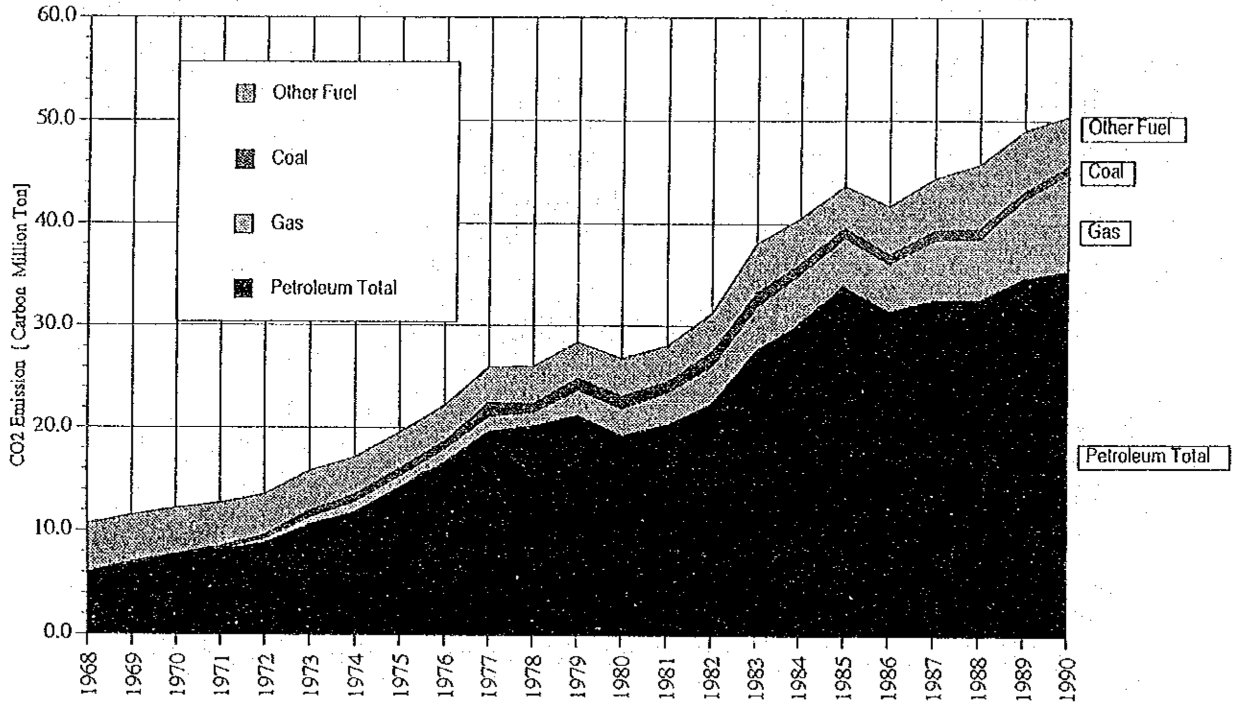
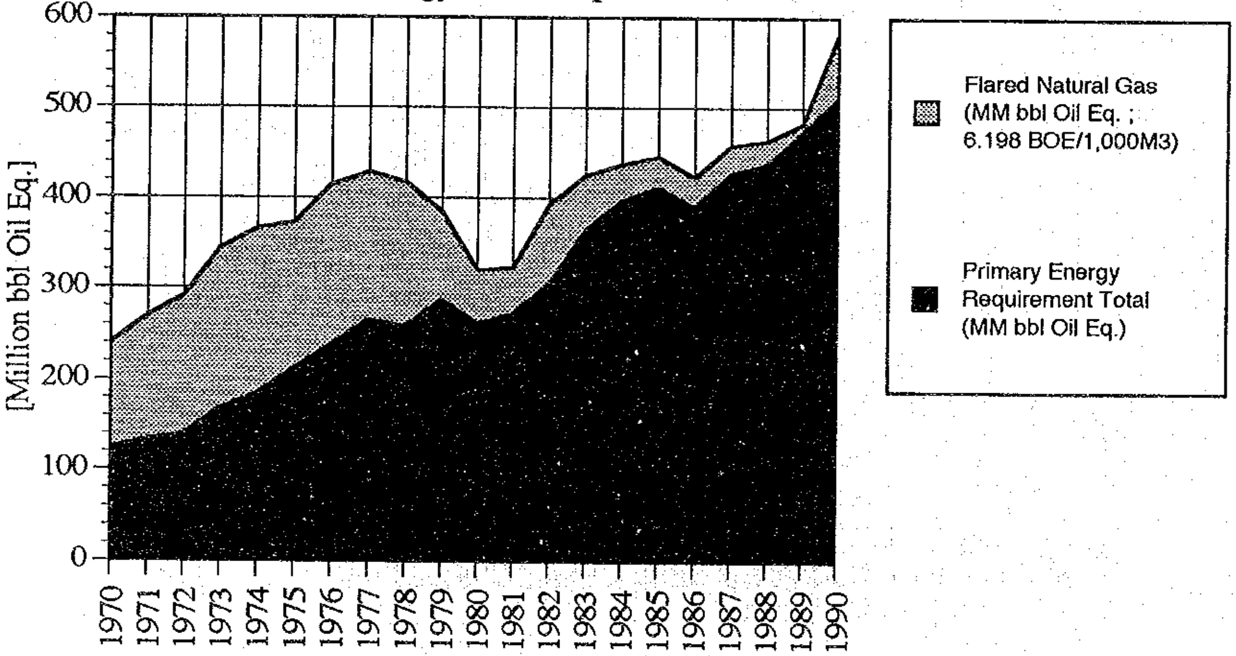


Fig. 6.14

Flared Gas *vs* Energy Consumption / I. R. IRAN



Flared Gas Volume;

After OPEC ... (Estimated before 1976 from Oil Production) amount of wasted energy of flared associated gas is very small in comparison with total energy consumption in the country. In 1990, the wasted energy from the flaring was about 10% of the total energy consumption in the country. The flaring will be relinquished when the planned facilities to remove H_2S from sour associated gas and to utilize it are completed.

1) SO_x

Figure 6.15 shows the historical trend of SO_x emission volume from flared gas. The most critical emissions from flared gas are SO_x emissions. Most of the produced associated gas is either consumed or re-injected to oil reservoirs. The associated gas which has a high content of H_2S has to be flared because it can not be utilized at the moment. Therefore, SO_x emissions from flared gas are supposed to be serious.

For the estimation of SO_x emission from flared associated gas, the averaged content of H_2S in the gas was assumed to be 4% as described before. The result of the calculation shows that the volume of SOx emitted from the flaring associated gas is estimated to be almost the same as that from the total energy consumption in the country in 1990.

2) NO_x

Figure 6.16 shows the historical trend of NO_x emission volumes from flared gas. In estimating NO_x emissions from flared gas, the emission factor of flared associated gas was assumed to be the same as that of natural gas. On the basis of the results of calculation, it is estimated that total emissions of NO_x from flared gas is very little compared with that from other sources.

3) CO_2

Figure 6.17 shows the historical trend of CO_2 emission volume from flared associated gas in the country. CO_2 emissions are estimated to be equivalent to about 10% of the total CO_2 emissions from other sources in 1990.

Fig. 6.15

SOx Emission from Flared Natural Gas and Other Sources / I. R. IRAN

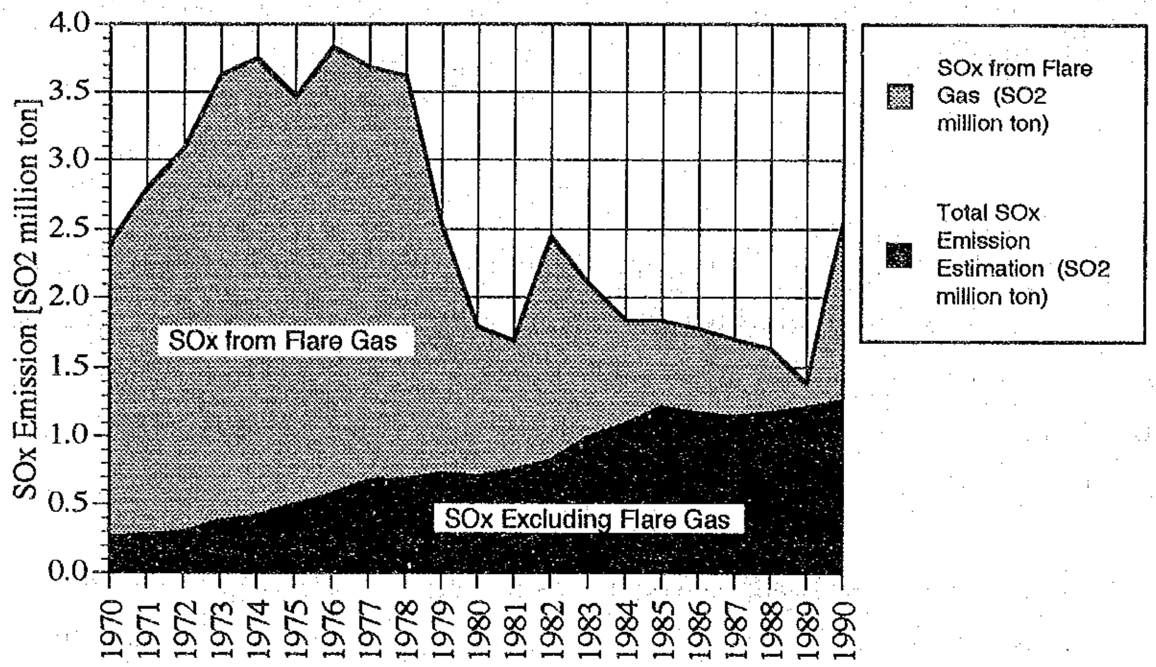


Fig. 6.16

NOx Emission from Flared Natural Gas and Other Sources / I. R. IRAN

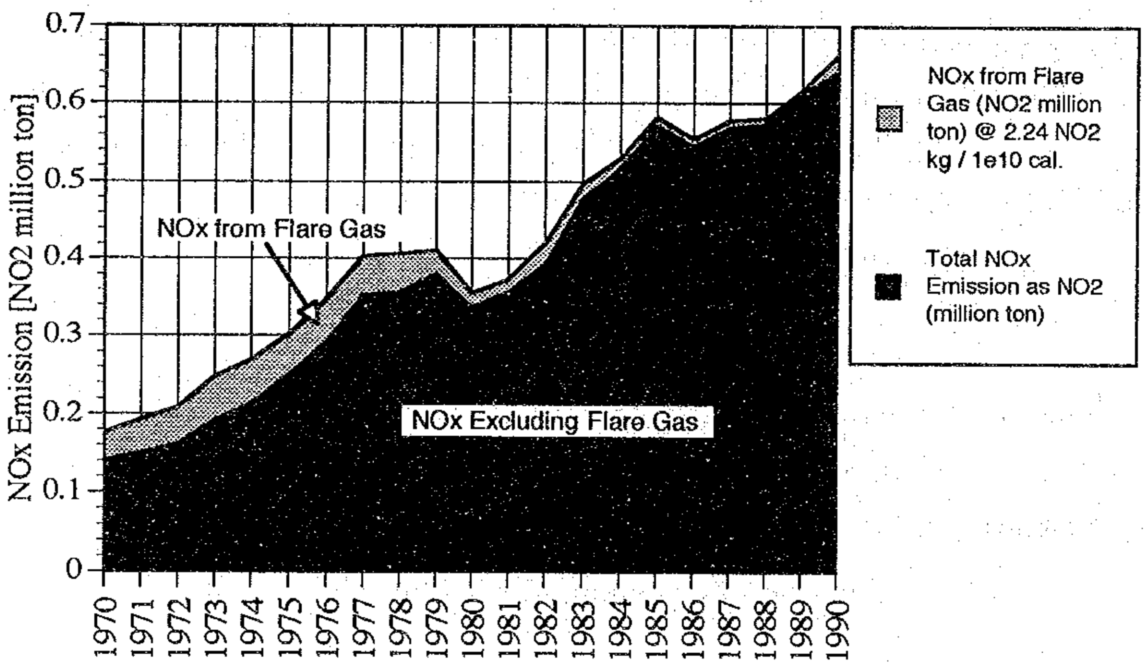
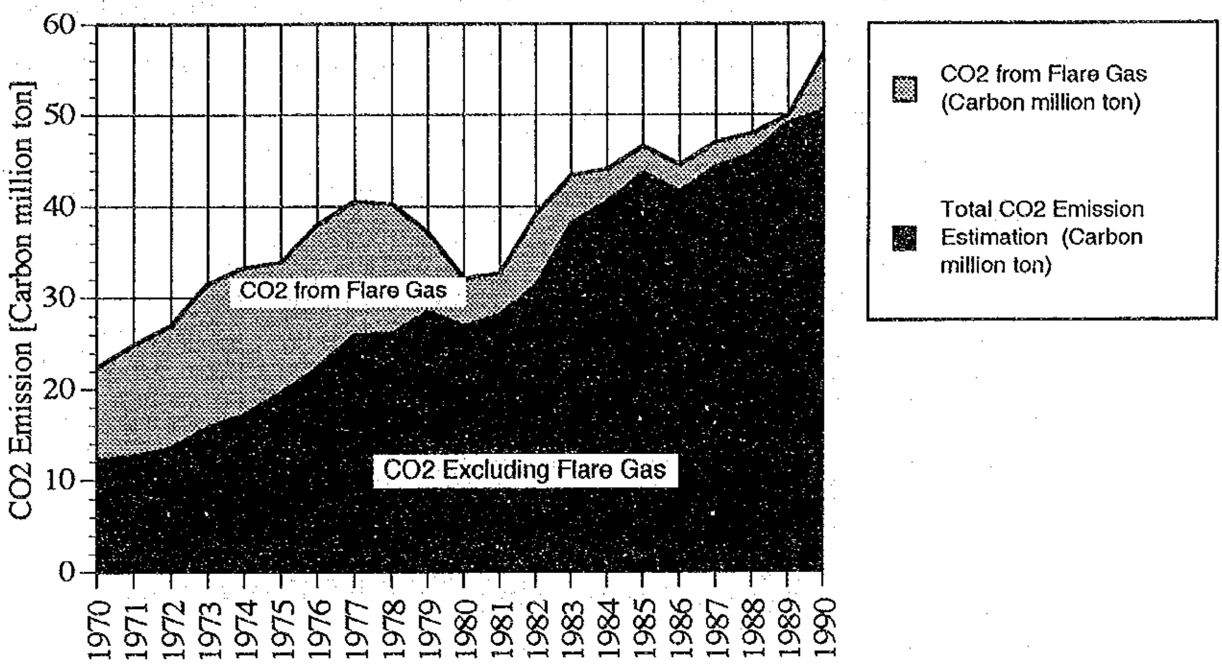


Fig. 6.17

CO2 Emission from Flared Natural Gas and Other Sources / I. R. IRAN



4) CO_2 Emissions from the Cement Industry

In considering CO_2 emissions in the country, the process of cement production has to be counted as one of the major sources. Table 6.14 shown below and a graph on Figure 6.18 show CO_2 emissions from cement production in the country.

Table 6.14 CO_2 from Cement Production

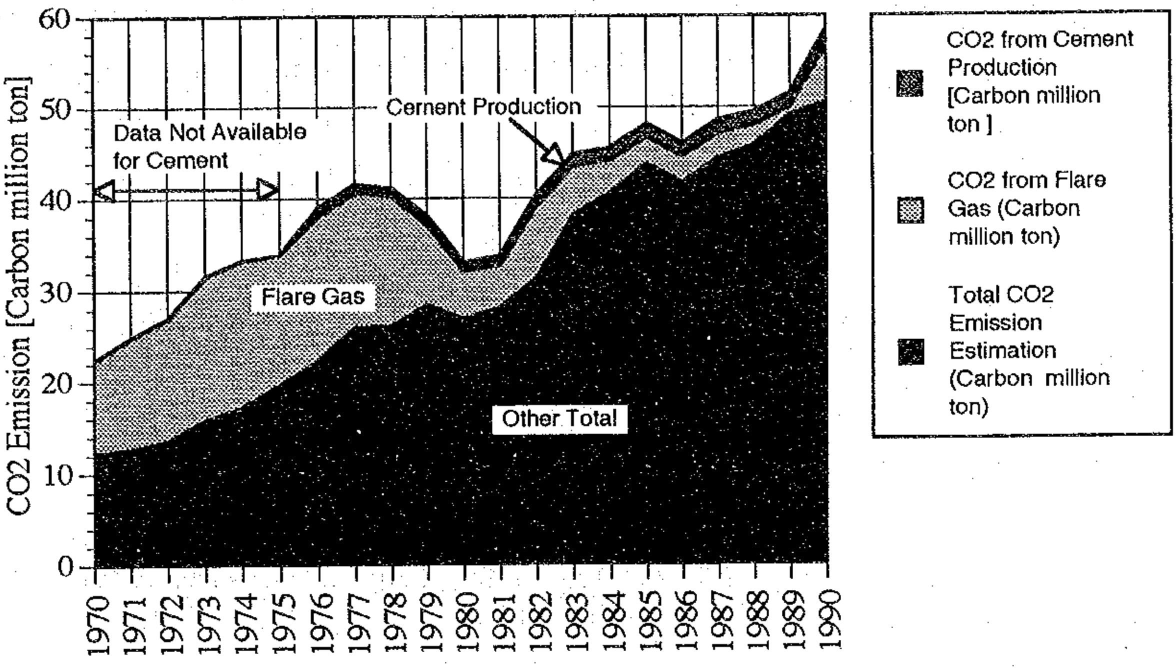
Year	Cement Production (Million ton)	CO2 from Cement (0.12 Carbon ton / Cement ton)
1976	7.375	0.885
1977	7.706	0.925
1978	7.150	0.858
1979	7.620	0.914
1980	7.895	0.947
1981	9.231	1.108
1982	10.001	1.200
1983	10.912	1.309
1984	11.803	1.416
1985	12.095	1.451
1986	11.273	1.353
1987	12.618	1.514
1988	12.118	1.454
1989	12.830	1.540
1990	15.150	1.818

Source : Ministry of Industry (I.R.Iran)

CO_2 emissions from cement production can be estimated from the volume of production of cement and the unit consumption of limestone through the process. In this study, the annual cement production record in I.R. Iran and the Japanese example data of unit consumption of limestone were used for the estimation.

Fig. 6.18

CO2 Emission from Various Sources / I. R. IRAN



Flared Gas Volume;

After OPEC ... (Estimated before 1976 from Oil Production)

CO2 from Cement Production;

After Ministry of Industry (Data not available before 1976)

6.4.2 Factor Analysis

The emission histories of SOx, NOx and CO_2 were analyzed by means of a factor analysis. The factors of fuel type, energy intensity, economic growth and population growth were selected for the analysis.

6.4.2.1 Air Pollutants

The basic equations for factor analysis on SOx and NOx emission are shown below. The basic equation one for factor analysis on SOx emission is as follows;

$$dSOx(i)/SOx(i) = dF/F + dS/S + dI/I + dG/G$$

(SOx(i)/F)*dF	: Fuel Control Factor (Fuel Improvement and Sulfur Intensity)
(SOx(i)/S)*dS	: Fuel Conversion (Switching) Factor
(SOx(i)/E)*dI	: Energy Intensity Factor
(SOx(i)/G)*dG	: Economic Growth Factor
F = SOx(i)/E(i)	(E(i): Energy Consumption of i-fuel)
S = E(i)/E	(E :Total Energy Consumption)
I = E/GDP	
G = GDP	

The equation for factor analysis on NOx emission is as follows;

$$dNOx(i)/NOx(i) = dF/F + dS/S + dI/I + dG/G$$

(NOx(i)/F)*dF	: Fuel Control Factor (Burning Efficiency)
(NOx(i)/S)*dS	: Fuel Conversion (Switching) Factor
(NOx(i)/E)*dI	: Energy Intensity Factor
(NOx(i)/G)*dG	: Economic Growth Factor

F	= NOx(i)/E(i)	(E(i): Energy Consumption of i-fuel)
S	= E(i)/E	(E : Total Energy Consumption)

I = E/GDP

G = GDP

As can be seen above, the fuel control factor means the factor of emission per unit energy consumption for each type of fuel. And, the fuel switching factor means the factor of the share of energy consumption in the total energy for each type of fuel. Energy intensity factor and economic growth factor mean the factor of energy consumption per GDP and the factor of GDP growth, respectively.

(1) Sulfur Oxides

1) General trend of SOx emission

Figure 6.19 shows results of the factor analysis for total SOx emission in the county for the period from 1971 to 1990. Due to the rapid increase of energy intensity, or energy consumption per GDP, the annual SOx emission started increasing rapidly from 1980. The increase rate of annual SOx emission has declined since 1985. This tendency to decline is estimated to be the result of fuel switching. The fuel switch in the country means switching from petroleum products to natural gas. The factor had been almost constant until 1986,but started decreasing in the following years, showing the advancement of switching.

The energy intensity factor is based on average energy consumption per unit GDP. It shows a constant rise in accordance with the growth of consumption of petroleum products. In the period of 1989-1990, it shows an exceptional decrease. However, it is difficult to interpret it as a change in the trend. The additional time-series data after 1990 is required for further evaluation. The main positive contributor to SOx emission in 1990 is the factor of energy intensity, that means a 88% contribution to the total. The main negative contributor is the factor of fuel switching, which is a -14% contribution to the total.

2) SOx emission from petroleum products

Figure 6.20 shows results of factor analysis on SOx emission from petroleum products. As petroleum products are the major source of SOx emission, the characteristics of the results of factor analysis are almost the same as that of the total emission.

3) SOx emission from natural gas

Figure 6.21 shows results of the analysis on SOx emission from natural gas consumption. Due to the completion of fuel switching, the consumption of natural gas has been growing since 1986. However, the growth rate of total energy consumption is still greater than that of natural gas, which means that the share of natural gas in total energy consumption has increased only slightly.

For 1990, the factors contributing to SOx emission from natural gas are the factors of fuel switching and energy intensity. The shares of the contribution of these factors are 46% and 33%, respectively. There are no factors accounting for a negative contribution.

4) Japanese example

The Japanese example of factor analysis on SOx emission from 1970 to 1990 is shown in Figure 6.22. In Japan, the total emission volume decreased rapidly from 1970 to 1980. Although it continued to decline in the following years as well, the rate at which it declined has been moderate.

The biggest contributing factor forward the decline is fuel switching from high-sulphur to low-sulphur fuel oil. The decline in energy intensity a already been saturated in Japan and therefore not been a major factor of negative contribution. The contributier share of fuel switching, energy intensity and economic growth factors to SOx emission were -111%, -12% and +22% in 1990, respectively.

In contrast with Iran, the factors of fuel switching and energy intensity have shown opposite trend in Japan. The trends of these two factors have been major negative contributor to SOx emission in Japan, while they have been positive contributors in I.R. Iran.

(2) Nitrogen Oxides

1) General trend of NOx emission

Figure 6. 23 shows a general trend of NOx emission in the country. The graph shows that the general trend of NOx emission is similar to that of SOx emission. The major cause of increase in total NOx emission is the increase of energy intensity. It has been growing throughout the period indicated on the graph except during 1989 to 1990.

The factor of burning efficiency which means NOx intensity (emission volume per unit energy consumption) has been almost constant throughout the period. Although the effect of fuel switching can be recognized during the period, it is not as significant as in the case of SOx emission.

The main factors contributing to NOx emission in 1990 are the factor of energy intensity on the positive end and the factor of fuel switching on the negative end. The shares of contribution are +84% and -11%, respectively.

2) NOx emission from petroleum products

Figure 6.24 shows the results of the analysis on NOx emission duet petroleum products consumption. As in the case of SOx emission, the trend of NOx emission from petroleum products is almost the same as the general trend because it accounts for a major part of total energy consumption in the country.

3) NOx emission from natural gas

Figure 6.25 shows the results of the analysis on NOx emission due to natural gas consumption. As in the case of SOx emission, there is no factor that reduces NOx emission due to natural gas consumption. Though its burning efficiency has been improved since 1987, natural gas' contribution to NOx emission in 1990 was still a positive value of 8%. The factor of fuel switching has shown a positive shift since 1986 because switching involves the conversion to natural gas from petroleum products. The contribution share of the factor was +48% in 1990. It accounts for the greatest share among all the factors. The second biggest contributing factor is the factor of energy intensity. Its contribution share in 1990 was +35%.

4) Japanese Example

The factor analysis on NOx emission from 1970 to 1990 in Japan, is shown in Figure 6.26. Total NOx emission in Japan has been decreasing since 1970. However, its rate is not as big as that for SOx emission. This indicates that the effect of fuel switching on NOx emission is not as great as that on SOx emission.

The factors accounting for a negative contribution to NOx emission in 1989 are the completion of fuel switching and the improvement of energy intensity. The shares of these factors are -191% and-111%, respectively. These negative contributions overcame the big positive contribution of +203% accounted for by the of economic growth factor.

6.4.2.2 Carbon Dioxide

A factor analysis for CO_2 emission in the country was conducted using the following factor analysis model.

$$dC/C = dS/S + dI/I + dG/G + dP/P$$

(C/S)*dS : Fuel Switching Factor
(C/I)*dI : Energy Intensity Factor
(C/G)*dG : Economic Growth Factor
(C/P)*dP : Population Growth Factor
$S=CO_2/E$ (E: Total Energy Consumption)
I= E/GDP
G=GDP/Capita
P=Population

Where, the factors represent the following:

S: Fuel switching factor (CO_2 emission per unit energy consumption)

I: Energy intensity factor(energy consumption for unit GDP)

G: Economic growth factor(GDP per capita)

P: Population growth factor

The result of the analysis is shown on Figure 6.27. The graph shows that the fuel switching factor hardly contributes to reduction of total CO_2 emission at all, expect towards the end of the graph where the factor decreases during 1989 - 1990 . If the trend continues beyond this time period, that means fuel switching (from petroleum products to natural gas) will be effective in reducing CO_2 emission in the country.

Looking at the graph, the increase in the energy intensity factors is the greatest positive contributor to CO_2 emission in 1990. Its total contribution share is +85%. The second biggest contributor is the population growth factor, whose share of positive contribution to CO_2 emission in 1990 is +59%.

Data on Japan are also shown as reference. The factor analysis for CO_2 emission in Japan is shown on Figure 6.28. The graph shows that total emission was almost constant from 1973 to 1986 owing to the reduction of energy intensity and the effect of fuel switching in spite of rapid economic growth. However, the effect of these factors reached their maximum in 1986 and the total CO_2 emission started increasing after that.

The factor analysis on CO_2 emission for the Japanese industrial sector was conducted using a different model from that for total emission in Iran. The factor analysis model is as follow:

$$dC(i)/C(i) = dS(i)/S(i) + dI(i)/I(i) + dG(i)/G(i)$$

$(C(i)/S(i))*dS(i)$: Fuel Switching Factor

$(C(i)/I(i))*dI(i)$: Energy Intensity Factor

$(C(i)/G(i))*dG(i)$: Economic Growth Factor

$S(i) = CO_2/E(i)$ (E(i):Energy Consumption in Industry)

$I(i) = E(i)/IIP$

$G(i) = IIP$

The result of the analysis is shown on Figure 6.29(a). The figure indicates that the factors that fuel switching factor and energy intensity factor are still effective in the industrial sector, and the emission of CO_2 from the industrial sector has been constant since 1973.

These results of the analysis show that the industrial sector has not been a main contributor to CO_2 emission since 1986. The graph on Figure 6.29(b) shows that the power generation sector and transportation sector have recently become the major contributors to CO_2 emission in Japan.

6.4.2.3 Summary of the analysis

(1) Contributions of the factors on SO_x, NO_x and CO_2 emission

The contributions of the factors on SOx, NOx and CO_2 emissions are summarized in the tables below.

Table 6.15 (a) Factors Contributing to SOx and NOx Emission

[%]

	SOx				NOx			
	I. R. Iran			Japan	I. R. Iran			Japan
	Total	Petroleum	Gas	Total	Total	Petroleum	Gas	Total
Fuel Control	13	13	12	-111 *	12	12	9	-191 *
Fuel Conversion	-14	-8	33	-	-11	-8	48	-
Energy Intensity	88	83	46	-12	84	82	35	-111
GDP Growth	13	12	9	22	15	14	8	203

NOTE: Fuel Control Factor mean Sulphur Intensity for SOx and Burning Efficiency for NOx

*) In case of Japan, Fuel Control Factor includes Fuel Conversion Factor.

Table 6.15 (b) Factors Contributing CO2 Emission

[%]

	I. R. Iran	Japan	
		Total	Industrial Sector
Fuel Swithing	(0)	-17	-27
Energy Intensity	85	-41	-136
GDP Growth	-44	130	263
Pop. Growth	59	28	-

(2) Past Experiences in Japan and the World

As described before, contributions of the factors from 1975 to 1987 in Japan are re-written as follows.

Change of Factors (%)	SO_x	NO_x	CO_2
Fuel Switching Factor	-111	-191	-17
Energy Intensity Factor	-12	-111	-41

In order to achieve changes in the factors, the past experiences in environmental protection against pollutants emission in Japan and world need to be studied. Past trends of CO_2 emission are summarized as follows.

1) Past Trends against SO_x emission

- 1st stage : Fuel Improvement

In the middle of the 1960s, the utilization of low-sulphur fuels reduced the volume of SO_x emitted. Efforts to reduce SO_x concentration in the atmosphere have.

- 2nd stage : Flue gas control

In the 1970s, the number of FDG facilities increased established drastically. The utilization of natural gas expanded at the same time.

-3rd stage : Energy intensity improvement

After 1975, improvements in energy efficiency has brought about a remarkable reduction in energy intensity.

2) Past trends against NO_x emission

-1st stage : Flue gas control

In the 1970s, following the utilization of FDG facilities for SO_x reduction, flue gas De-NO_x control for stationary emission sources was introduced.

-2nd stage : Exhaust gas control

After 1975, problems concerning air pollution problem from mobile sources intensifies. Exhaust gas control for automobile was introduced.

-3rd stage : Combustion control

In the 1980s, combustion control techniques such as Low NO_x Burner (LNB), Two Stage Combustion Method (TSC), Flue Gas Recirculation Method (FGR) and the use of catalyst s(OSC) have been introduced as the most effective countermeasure for NO_x reduction.

3) Past trends against CO_2 emission

Past efforts on reducing CO_2 emission in the world is summarized as follow.

	Improvement of Carbon Intensity	Improvement of Energy Intensity
Japan	Since 1960s	Since 1973
Industrialized Countries	Since 1970	Since 1973
Developing Countries	Since 1975	Since 1978

Fig. 6.19 Factor Changes in SO_x Emission ; TOTAL

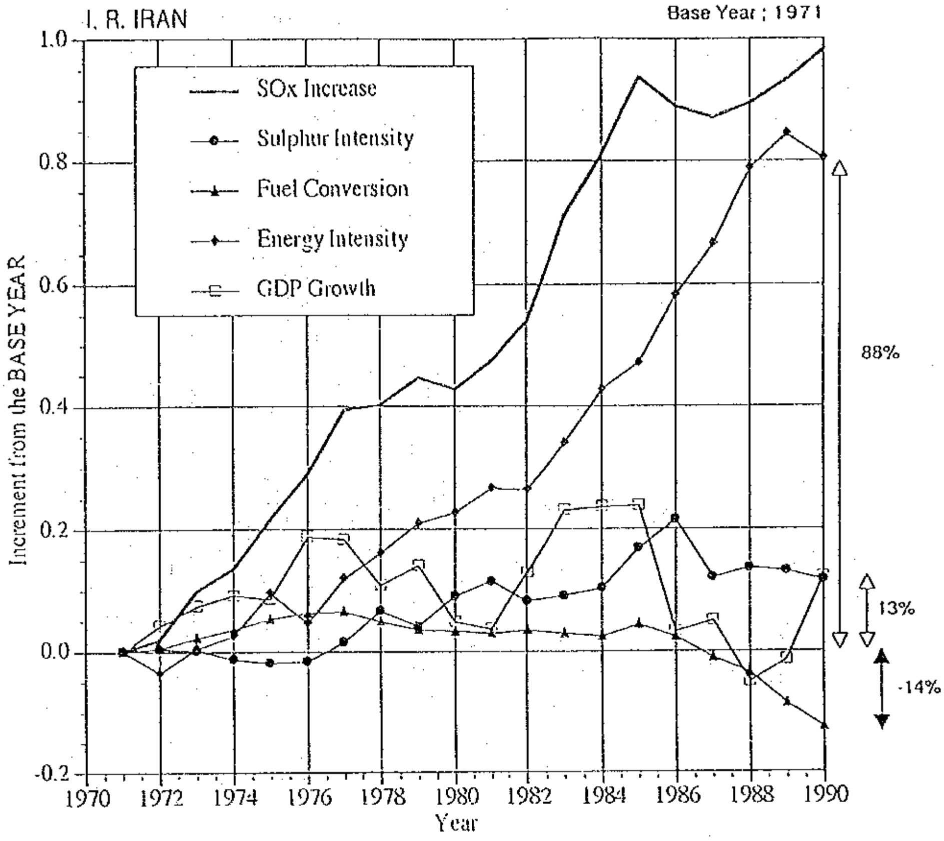


Fig. 6.20 Factor Changes in SO_x Emission ; Petroleum

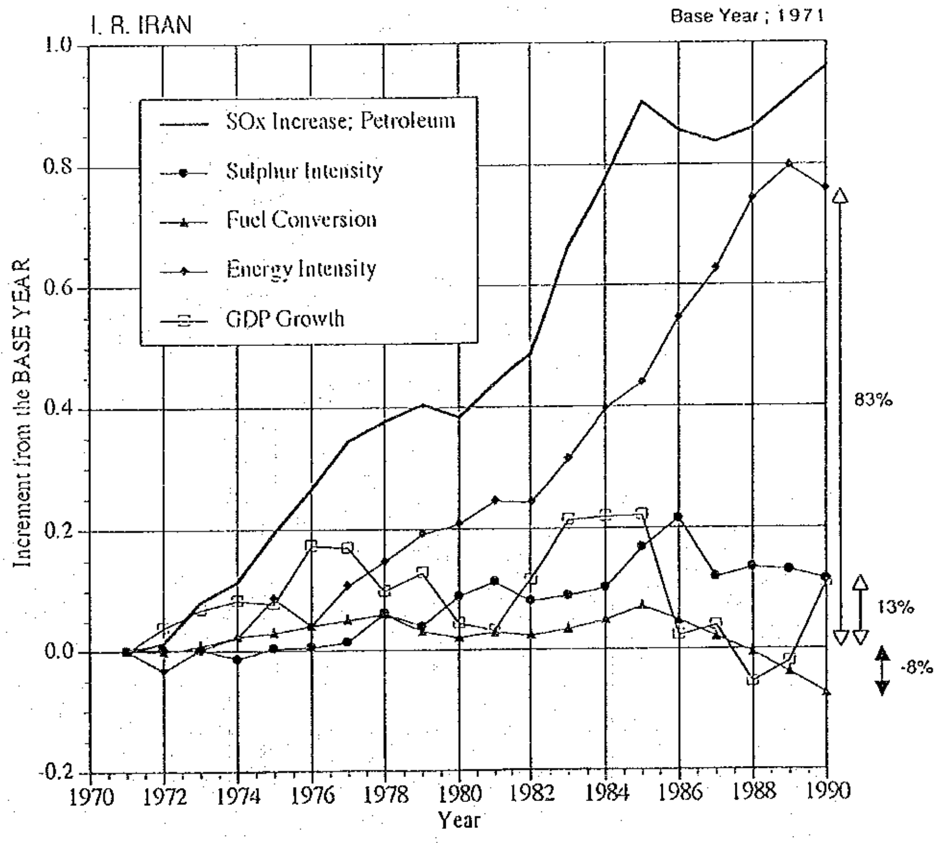


Fig. 6.21 Factor Changes in SO_x Emission ; Gas

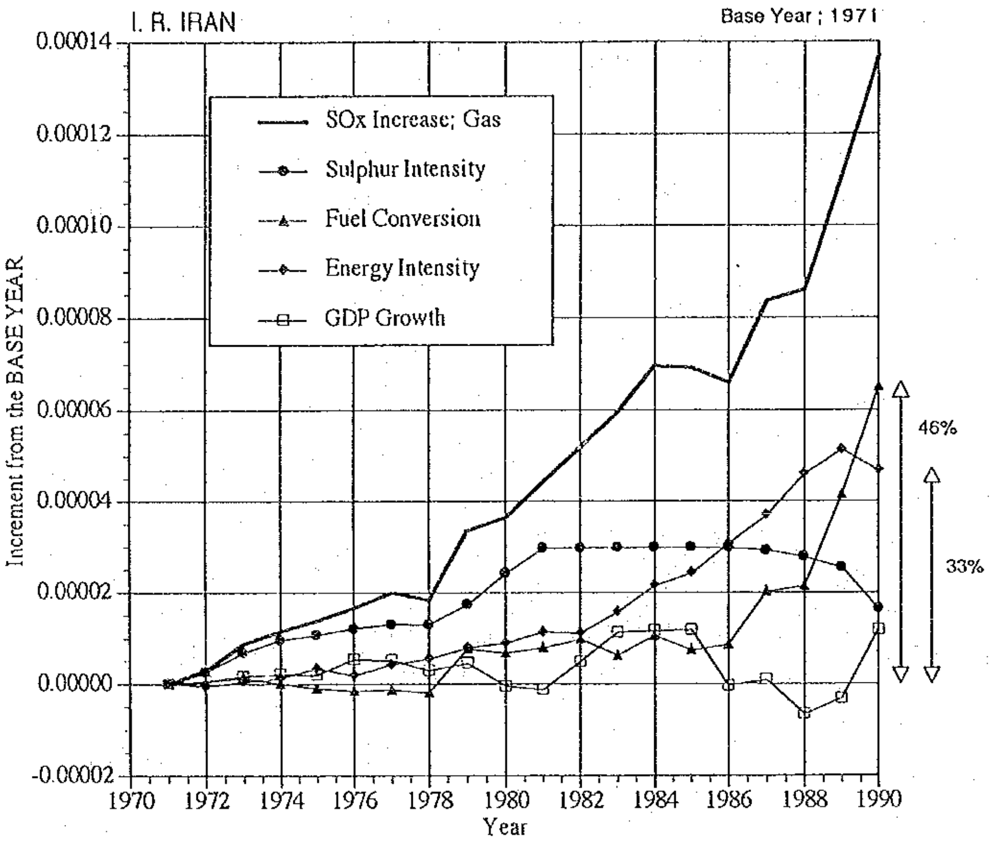


Fig. 6.22 Factor Changes in SO_x Emission / JAPAN

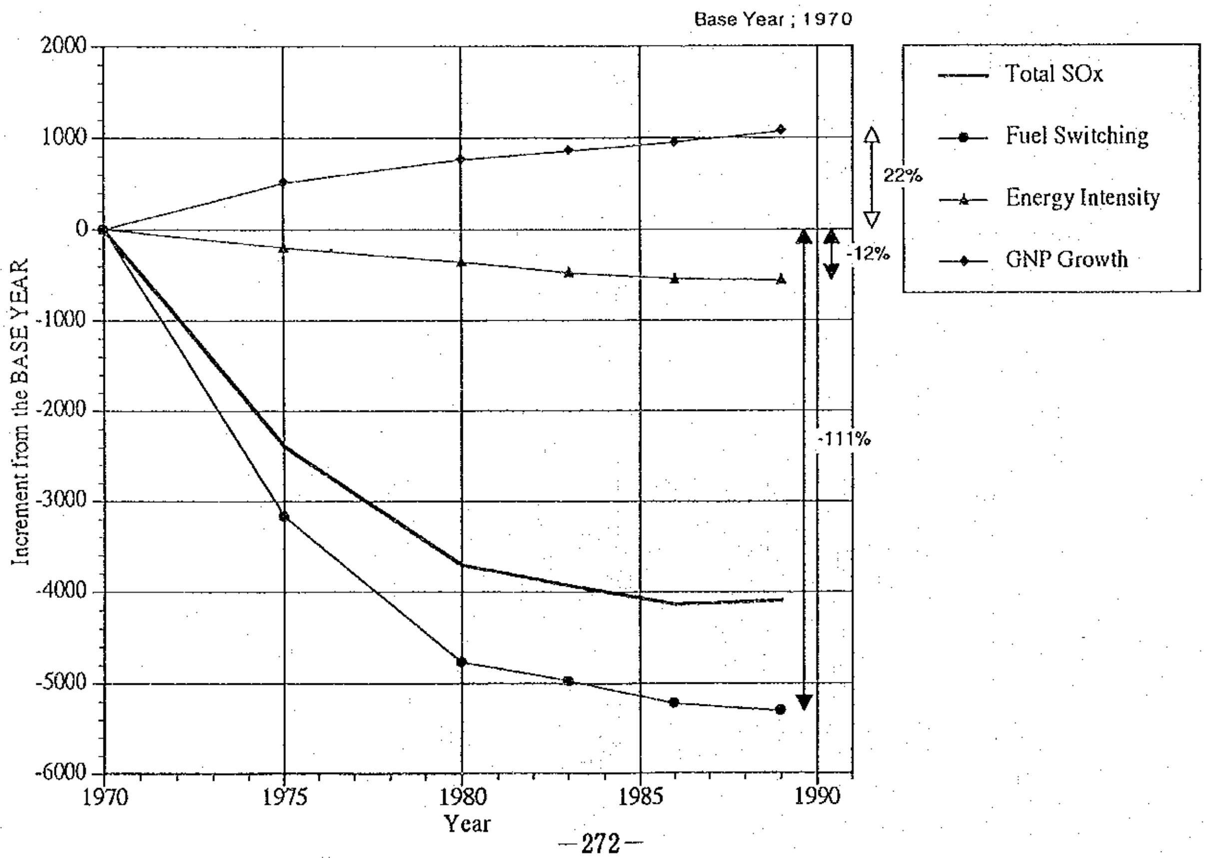


Fig. 6.23 Factor Changes in NO_x Emission ; TOTAL

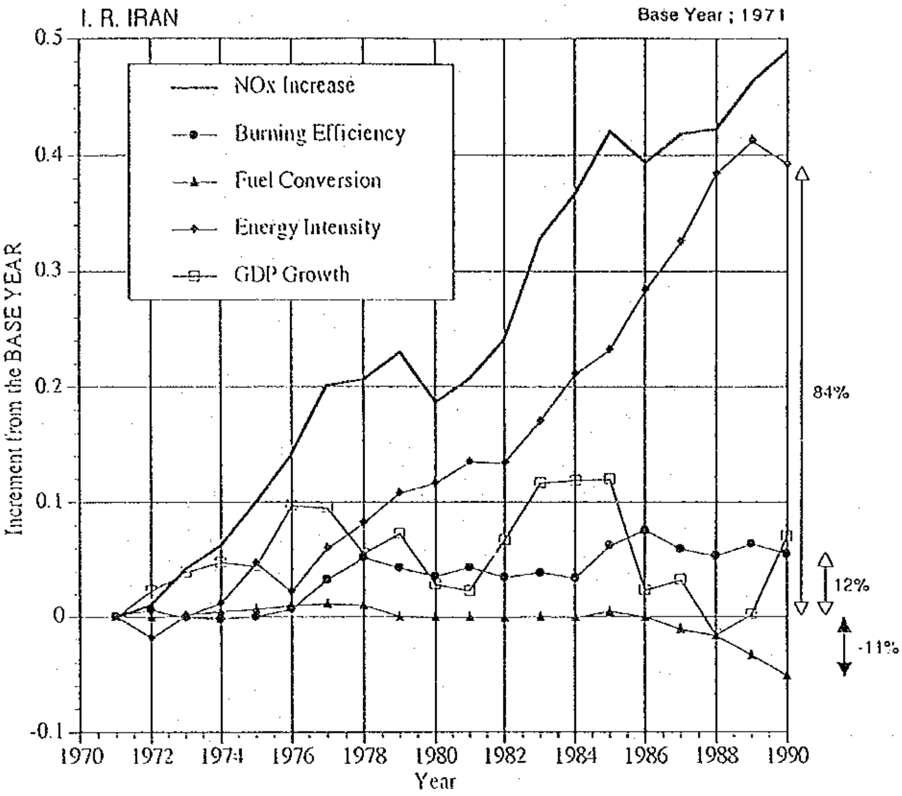


Fig. 6.24 Factor Changes in NO_x Emission ; Petroleum

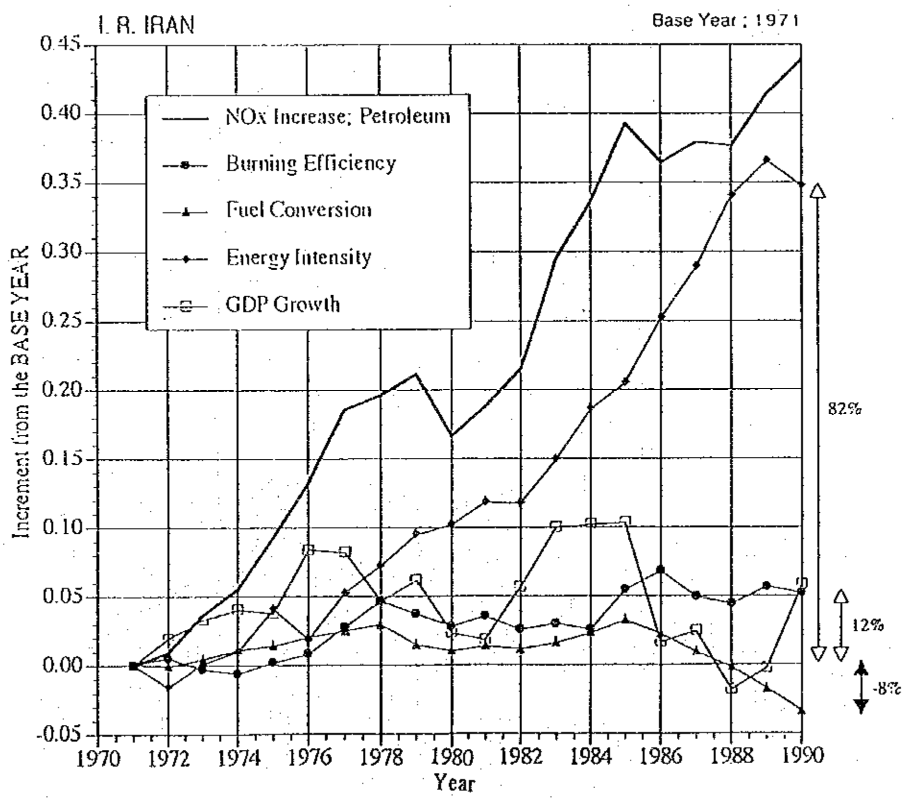


Fig. 6.25 Factor Changes in NO_x Emission ; Gas

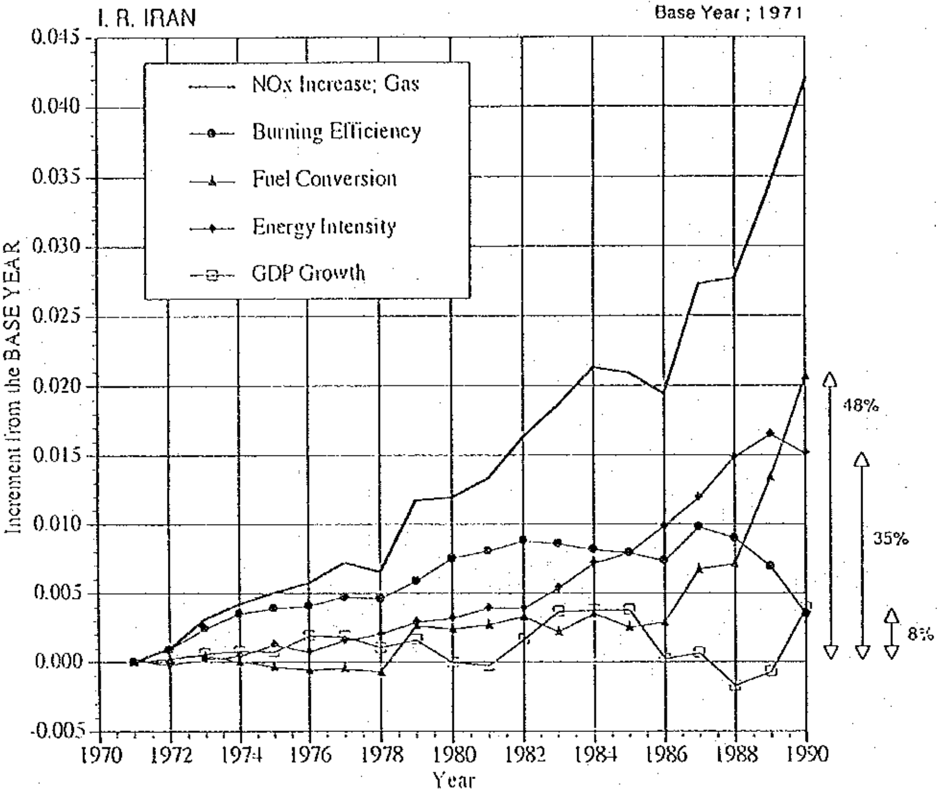


Fig. 6.26 Factor Changes in NO_x Emission / JAPAN

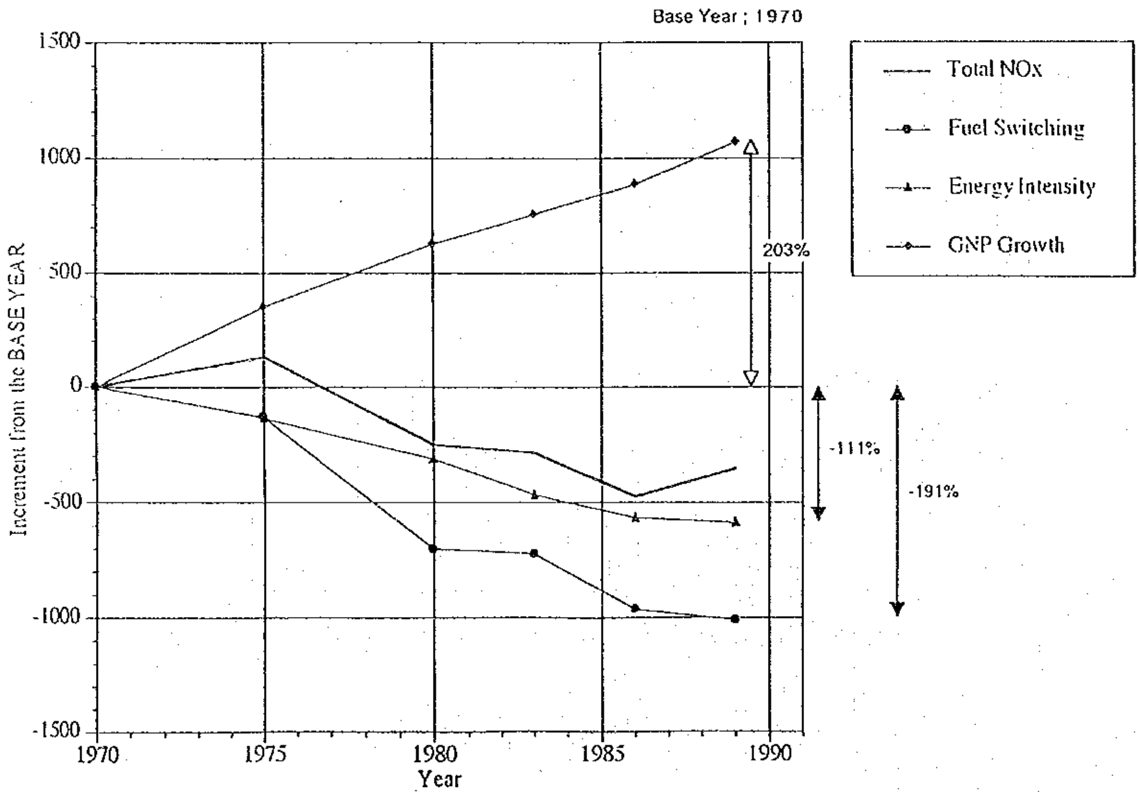


Fig. 6.27 Factor Changes in CO_2 Emission / I.R. Iran

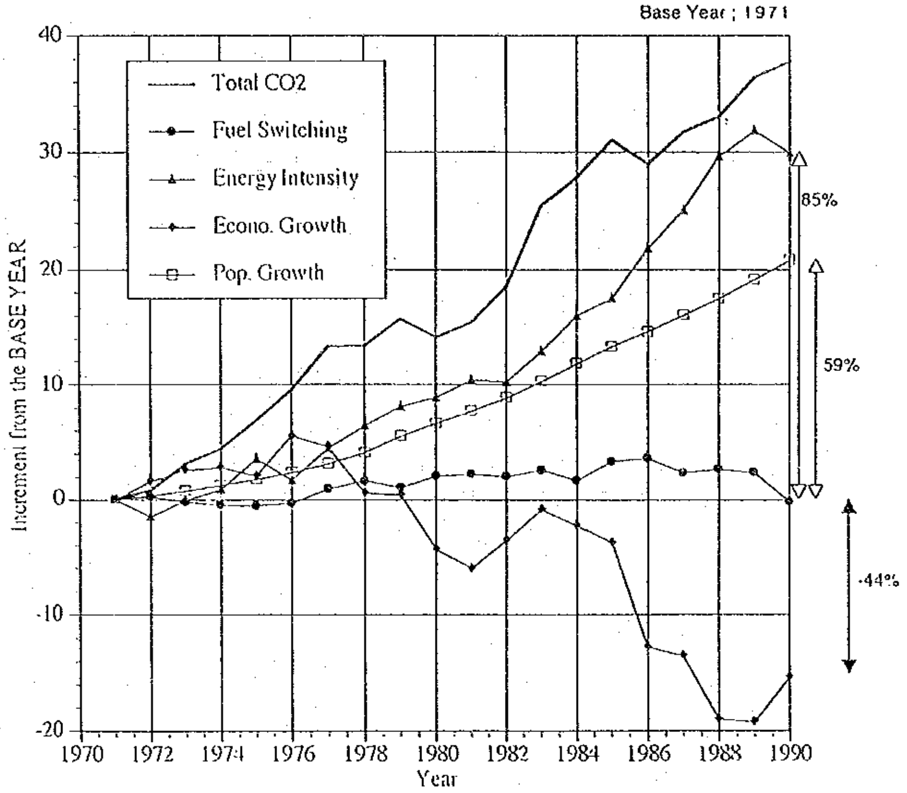


Fig. 6.28 Factor Changes in CO_2 Emission / JAPAN

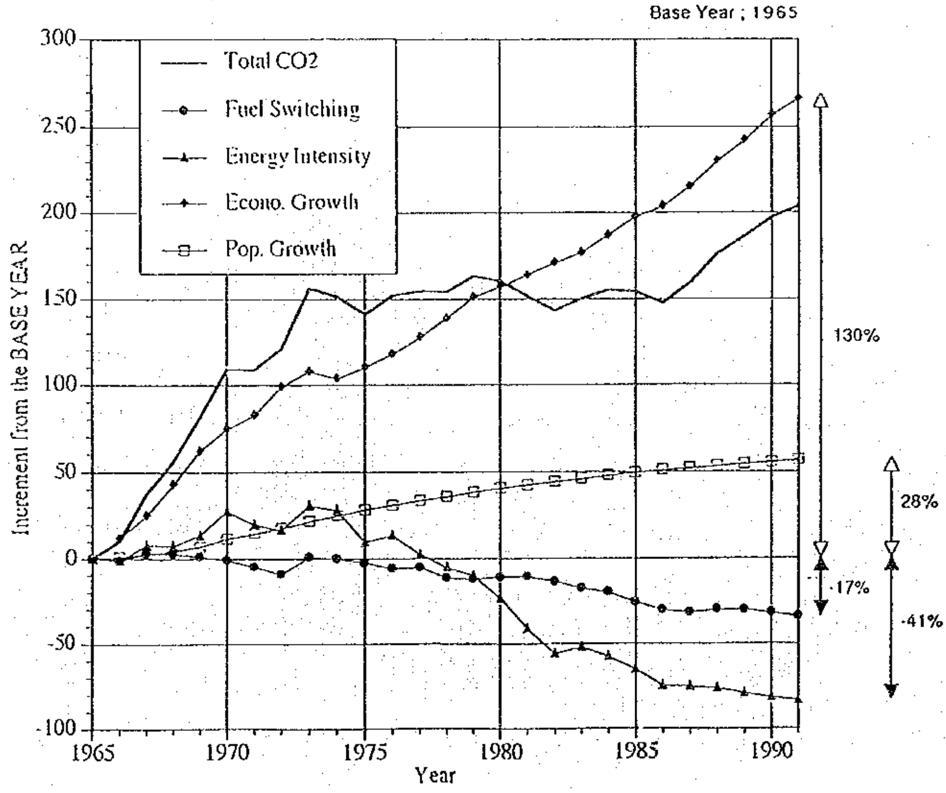


Fig. 6.29(a) Factor Changes in CO_2 Emission / JAPAN, Industrial Sector

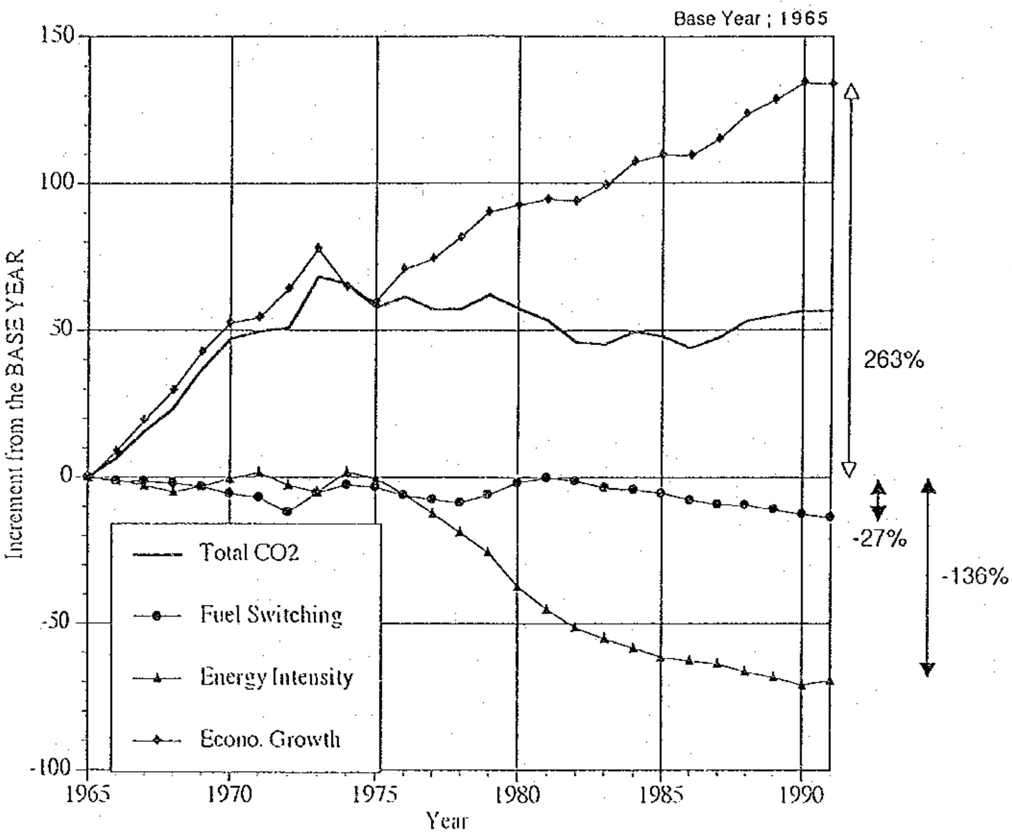


Fig. 6.29(b) CO_2 Emission by Sector / JAPAN