THE ADVANCES OF CHINESE NON-FERROUS METAL MINERAL INDUSTRY AND ITS ENVIRONMENTAL MANAGEMENT[1]

by

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Abstract With the steady growth of Chinese economy, the nonferrous metal industry of China was also developed quickly. The gross output of ten main non-ferrous metals reached 4.25 million tons in 1995 so that China ranks the fourth in the world. However, a series of environmental problems also occurred, which relate to characteristics of mineral resources, techniques for mining, dressing, smelting and processing, equipment and their management level. The major pollutants include sulphur dioxide, industrial powder-dust and smoke-dust, water containing heavy metal ions as well as solid wastes. Air, water body, soil, vegetation and people's health were polluted and damaged to different extent due to the above pollutants.

For the purpose of environmental management and pollution control, some of measures must be taken: (1) to strengthen environmental planning, accelerate and perfect environmental laws and related regulations as well as spread the consciousness of environmental protection energetically; (2) to extend cleaner production and adopt advanced technologies so as to reduce environmental pollution; (3) to turn the concept of the end-of-pipe management to the whole- process control; (4) to recovery or reuse the wastes fully.

In addition, general situation and polices on reclamation of mining land as well as theory, methods and techniques of restoration of waste land were also stated in the paper.

Key words: Advance, Chinese non-ferrous metal mineral industry, Environmental management

The Advances Of Mining Nonferrous Metal Industry Of China

In China, there are abundant nonferrous metal resources with various strains and grades including tungsten, tin, stibium, zinc, titanium, tantalum, thulium lead, nickel, mercury, molybdenum, niobium, aluminum and so on. Since the foundation of new China, a great achievement of Non-ferrous Metal Industry is made. So far, it becomes a very important department and takes rather significant role in promoting the national economical development. In 1983, China's central government establish the Chinese National Nonferrous Metals Industry Corporation (CNNC) to improve the advance of the nonferrous metal industry of China and ventures. Through a long-term development, the enlarge their the exchanges among domestic and abroad productivity of nonferrous metal industry has increased by 8.86% annually. In 1949, the output of non-ferrous metal amounted to just 13,000 tons, through a thirty-year development, the output reached 952,400 tons in 1978. The production of ten key non-ferrous metals rose to 2,000,000 tons in 1988. During the periods of "the 7th Five-year Plan"(1986 to 1990) and "the 8th Five-year Plan" (1991 to 1995), the rapid development of non-ferrous metal industry of China was achieved. The output of ten main non-ferrous metals broke through the limit of 300,000 tons in 1993. In 1994, the output of the ten major nonferrous metals reached 3.7 million tons, which increased by 2.47 million tons before the establishment of the CNNC(illustrated in Fig 1). Consequently, the output of the ten metals ranked the fourth in the world in 1995, reaching 4.25 million tons. Currently China is one of the biggest countries in the production of nonferrous metal in the world. So far, in China, there are 477 state owned nonferrous metal mines. Of them, 147 mines are run by the national government and 330 mines by local government. There are 510 thousand total miners, 380 thousand of them are employed by the national government. The annual output of ore is 70 million tons. So far, underground mining is the principal mining

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method, taking 70% of the total ore production. The annual capacity of comprehensive mining is 2.58 million tons and 1.98 million tons is produced by the national government. By now, a relative perfect industrial system for nonferrous metal production including mining, dressing, smelting and processing, etc., has been created, which propel the development of national economy.

Nonferrous metal industry ,including town and township enterprises have also made much progress in production. The yield of the ten major nonferrous metal reached 1.53 million tons in 1994, about 41.4% percent of the total national production. Among them, the production of electrolytic aluminum accounted for 48.7%, and lead and zinc ore account for 60.4%. Up to now, the nonferrous metal industry has been the main part of the public economy in China with the coexistence of collective economy, town and township enterprises and joint ventures.

The Characters Of Chinese Non-Ferrous Metal Industry And Their Concerning Environmental Problems

At present, many countries including China are undergoing industrialization which is strengthening the exploitation of mineral resource. With the rapid development of Chinese national economy and great improvement of people's living standard, demands for mineral resources has increased, which will force the metal industry to develop rapidly. The rapid development of China is based on exploitation and consumption of energy resources. However, in the process of exploitation and utilization of mineral resources, the comprehensive recovery rates are very low, only 30-50%. Additionally, consumption of raw material per unit gross domestic production value(GDP) is 2-4 times higher than that of developed countries. That is why the Chinese non-ferrous metal industry causes severe negative impacts on environment.

The Characteristics of Non-ferrous Metal Industry of China

In view of its effects on environment, its major features are presented as follows:

(1) Being associated with many metals, the composition of most mineral ore is rather complicated. In the process of production, some additives such as Hg, Cd, As, Pb, Ni, Po, F(Fluorine) and cyanide, etc., have certain toxicity. When discharged into environment, they can just be transferred, diluted or change their forms, but can not be decomposed completely.

(2) In China, mineral resources are dominated by lean mineral ore rather than rich one. Grades of most minerals are lower than 1-10%. In other words, more mineral sources are exploited, more "three-waste" (waste gas, waste water and solid waste) are discharged.

(3) In the process of exploitation of mineral resources, a large amount of water and energy resources, e.g., electricity, coal and so on, were consumed.

(4) Because of diversified product of CNNC, complicated production process and various technical systems for mining, dressing and smelting, a variety of pollutants are formed and lots of arable land is destroyed and polluted.

(5) Most of enterprises directly under CNNC were founded in 1950s and 1960s, and have not been innovated systematically in the past few decades. Therefore, a series of problems such as backward techniques, low level of equipment, inferior quality of products, fewer varieties, high consumption of energy, severe environmental pollution, etc., have existed generally.

The Impacts of Numerous Pollutants on Environment

The main pollutants discharged from non-ferrous metal industry are comprised of sulphur oxide, industrial powder-dust and smoke-dust, fluoride, hazardous solid waste and waste water containing heavy metal ions, and so on (shown in table 1 and 2)

According to statistics, pollutants from non-ferrous metal industry occupy a considerable proportion to total output of pollutants over China. Considering data released in 1990, industrial waste water, waste gas and waste slag amounted to 0.56 billion tons, 297 billion m^3 and 600 million tons respectively with 3.5, 11 and 10.6 percent of gross domestic discharge(GDD) separately. In 1990, the discharge of sulphur oxide contained in industrial waste gas from Chinese non-ferrous metal industry was 568,600 tons. Although it only takes 3.8 percent of gross discharge of pollutants, its damage to some area is rather serious. Industrial waste gas contained as many as over 6000 tons of fluoride and 1000 tons of Pb, which impacted environment remarkably. Moreover, the amount of heavy metal drained into environment with industrial waste water is also very considerable. For instance, the yearly gross

discharge of Hg, Cr, Se, and Pb is 56,000 tons with 16, 48.8, 11.3 and 20 percent of GDD respectively. The data show that discharge of "three waste" from Chinese non-ferrous metal industry is enormous, thus it is an important task of national environmental protection to eliminate "three waste" from non-ferrous metal industry. Much dust raised by truck transporting mineral ore often causes serious pollution, which approximately occupies 70-90 percent of total dust of a mine. As much as 50 m away from the sides of the road, the air concentration of dust may reach 750-800 mg/m^3. However, in driver's cab, the concentration of dust may amount to 6.0-15.0 mg/m^3. In general, dust qualified rate in non-ferrous metal mine and smelter is about 40-60%.

In non-ferrous metal smelter of China, 1.12 tons of smoke containing sulphur will be emitted from one ton copper produced; 0.85 ton of smoke containing sulphur will be discharged from one ton Zinc. Although in 1995 the output of sulphur acid made by smoke containing sulphur reached 2.76 million tons, and the rate of use of sulphur amounted to over 62%, a large amount of sulphur was still spewed into atmosphere. Farmers and their land around smelting factory still suffer from damage of sulphur dioxide and acid rain, and payment for the agricultural loss has been also rising year by year. Fluoride emitted from anode of electrolysis cell is over 20 kg and from fore-roast electrolysis cell amounts to more than 16-23 kg per aluminum produced respectively. Fluoride hydrogen is the fundamental component of gas fluoride together with a little tetrafluoride and carbon fluoride.

In addition, a large deal of solid waste including tailings, rock, mud, etc., are produced in the course of stripping and digging, especially in open-pit mine. Ratio of stripping to mining in non-ferrous metal mines ranges from 5 to 10 or 13 to 16 in bauxite mines. So far, accumulated total waste has already reached 1 billion tons with 60 million tons of annual discharge of solid waste from Chinese non-ferrous metal industry. Based on statistical data, pileup of solid waste caused several accidents recently, so it has been a key problem facing environmental protection workers. A great deal of solid waste occupies a large area of land, especially arable land. It is proved statistically that in 1952, the area of cultivated land was 108,000 hectares with 0.15 hectare of cultivated land per capital, however, in 1987, the total area of arable land remained 95,866 hectares, with average 0.089 hectare arable land per capital. Over the past 35 years, the area of cultivated land was reduced by 12,000 hectares. For instance, in Shouwangfen Copper Mine, Hebei Province, more than 36 million tons waste rock took up 60 hectares, 90 hectares of land is occupied by more than 200 tons of waste rock in Dabaoshan Multi-metal Mine, Guangdong province. It has been documented that a total area of 66,666.67 hectares land has been taken up by waste rock and tailings in China. In accordance with an annual food yield of 6,000 kg per hectare, output of grain would be decreased by 0.4 million kg.

Meanwhile, much acid and alkaline waste water from yard for waste rock and slags contain many of hazardous heavy metal ions and radioactive elements(like Hg, Cd, As, Cr, Pb and so on). This waste water may pollute water body and soil near the mine, and will be harmful to human and animal health. Moreover, after soil is polluted by heavy metal, microbes in the soil will be killed in large quantity. As a result, soil will lose its capability of decomposition and digestion and its fertility will decrease, so soil desertification and impoverishment will be accelerated fairly. The concentrations of heavy metal in soil and rice nearby Xihuashan Tungsten Mine, Jiangxi Province is indicated in table 3 and 4 as follows(Shown in table 3). It is shown that most of these concentrations are much higher than standard concentration.

Besides, collapse of tailing dam and waste slags yard caused several serious environmental pollution accidents. For instance, the Jinduicheng Molybdenum Mine tailing dam, Shaanxi province was broken in April 1988. Consequently, about 140 million tons of tailings and waste water flowed into Luo River, Shaanxi province, then entered the Yellow River and covered 440 km. All of fish ponds and electric power stations have been damaged by heavy metal and cyanide, and as high as 14 million yuan compensation to farmers had been made.

The General Situation Of Land Reclamation In China

Mining Waste Land

Based on data of the National Land Administration Bureau, accumulated waste land caused by human activity amounts to about 13 million hectares. Among this, waste land caused by such production as mining, brick-and-tile-making, etc. is about 3 million hectares including 1 million hectares destroyed by rural and township enterprises and 2 million hectares by state owned industrial and mining enterprises. Research results show that in the mining industry, land directly used by mining projects accounts for 59%, the peeled-off field of open-pit mines occupies 20%, tailing dam 13%, waste rock and coal rock 5%, together with 3% waste land destructed by mining subsidence. During surface

mining, the area of destroyed land is 2-11 times as much as underground mining. This kind of land destruction transfers fertile cultivated land into waste land or bog, and causes serious pollution like water resource pollution, air pollution, etc.. The conditions of local water and geology deteriorate and ecosystem suffers from serious destruction too.

It has been documented by the National Environmental Protection Bureau that industrial solid waste throughout China amounted to 0.65 billion tons in 1995, 30 million tons more than 0.62 billion tons that in 1994, and gross accumulated amount of industrial solid waste has reached 6.641 billion tons over the past years, which is 0.18 billion tons more than that in 1994 and takes up 55,085 hectares land. Among it, the discharge of coal rock is 0.15 billion tons and gross accumulated output in the past years is 2 billion tons occupying 6000 hectares of land. The annual discharge of coal ash is 50 million tons while gross accumulated waste has taken up 13,000 hectares of land. Non-ferrous metal refinery industry discharges 60 million tons of solid waste annually, and total accumulated amount has amounted to 1 billion tons occupying 60,000 hectares of land.

Besides solid waste above, subsidence caused by mining is also a serious problem. It is reported that the area across China reaches 1700 hectares annually and total accumulated area has reached 140,00 hectares. The degree of land disturbance varies from mine to mine. It is estimated that at present in China waste land caused by coal mining is 20,000 hectares every year and is expected to exceed 33,000 hectares annually at the end of this century.

Land Reclamation Conditions

According to data of the National Land Ministration Bureau, total accumulated area of reclamation land in China is 133,300 hectares by the end of 1991. Considering data in 1987, it is estimated that accumulated total area of destroyed land reach 2 million hectares and reclamation ratio is 6.67%, 3--5 times of that before of 1989, just 1--2%.

In recent years, land reclamation in China has developed rapidly. It is reported by Liu Renying (1995) from the National Land Ministration Bureau that area of various kinds of destroyed land by mining which are now brought back to use totaled 133,300 hectares across China in 1994, which equals the total area in 1992 and 1993. In accordance with this calculation, different kinds of destroyed land with total area of 400,000 hectares have been rehabilitated by 1994 throughout China which is 13.33% of total waste land with area of 3 million hectares in China at present. Namely, the reclamation ratio in China is 10-15% or so. However, reclamation conditions vary from region to region and mine to mine. Table 4 indicates the reclamation ratio in some aluminum mines, and table 5 described the reclamation of derelict strip-mined land in China. Based on the two tables, reclamation ratio in some mines can reach 15% and some as high as 90%. It can be seen from table 9 that average reclamation ratio of waste land in aluminum mines in China ranges from 20% to 45.46%. After reclamation, 80% waste land is transferred into arable land where grain crop grow very well.

It is estimated that annual waste land which is rehabilitated will be over 130,000 hectares in China during the period of "the Ninth Five-year Plan" and reclamation ratio will reach or exceed 20% so that the existing arable land area will be kept stable.

The Strategies On Environmental Management And Pollution Control

To Strengthen Environmental Planning, Accelerate and Perfect Environmental Laws and Related Regulations as Well as Spread the Consciousness of Environmental Protection Energetically

Because that environmental problems have close relationship with people's life and prospects of the country, Chinese central government put an emphasis on environmental management and protection. With the implementance of the strategies on sustainable development, many of concerning environmental laws and regulation were issued in recent years. Several technical policies on environmental protection in non-ferrous metal industry were drawn up in 1983. Till 1985 it was completed and compiled into the Blue Cover Book of State Science and Technology Commission (8th). During the period, on the base of the real situation of non-ferrous metal industry, these policies have been actively put into effect and played a positive role in controlling environmental pollution and ecological damage. Meanwhile, because of technology, economy and society in China have greatly changed in the past ten years. The situation and the task of environmental protection became more formidable and urgent. Some articles of technical policy could not suit the needs of sustainable development strategy of non-ferrous metal industry, it is very necessary to make some significant adjustment and revision of environmental technical policy. Therefore, it should be the first step to investigate and assess the implemented status quo and effect of the technical policy, problems emerging from execution,

adaptability of the policies' content and so on, then on the basis, many local government has made environmental planning, some special environmental laws (or Regulations) start to take effect. Some important environmental engineering project were initiated in recent years, e.g., Huai River Environmental Engineering Project, Dianchi Environmental Engineering Project in Yunan Province and so on. The principle of environmental management is that: The enterprise or individual which polluted the environments must treat the environment or pay environmental treatment.

In recent years, the following treatment technologies and measures have been undertaken in the control of "three waste" in non-ferrous metal industry including industry sanitation standard by means of taking compulsory measures in most of underground mine. For instance, among key enterprises, the environmental protection planning was drawn up and managed to combine with economic management so that it become an important part of economic management. In particular, recently people's eco-environmental consciousness was strengthened to a great degree by means of propaganda.

To Extend Cleaner Production Energetically or Adopt Advanced Technologies in Order to Reduce Environmental Pollution

It is an optimum way to realize the change of resources extensive production to intensive environmental management to popularize cleaner production energetically. Through implementation of cleaner production, the enterprise may initiate a series of critical productive links like product design, raw material selection, innovation of process, technical improvement and productive management and so on. On one hand, industrial pollution will be eliminated in the process of production so as to realize optimum control of industrial pollution, minimize industrial waste, change "end-pipe control" to "whole-process control", and turn passive pollution management to active prevention management; on the other hand, it will be helpful to decrease productive costs of enterprise and enhance economic profit.

If cleaner production is put into operation in the whole system of CNNC, we must set about reforms of primary stages like innovation of technology, adaptation of new techniques, renewal of equipment and execution of environmental planning. Since the 1980s, the level of techniques, installation and management in most of enterprises such as dressing, mining and smelting in CNNC have been raised to large extent. In some enterprises and mines, techniques and installation have already reached international advanced level.

To Turn the End-of-pipe Environmental Management to the Whole-process Control

Since CNNC was set up over ten years ago, the state and CNNC have invested a large amount of capital in the control of industrial pollution, built a lot of facilities controlling pollution and put many environmental protection projections into operation in many mines and factories, which has produced obvious economic, social and environmental benefits. However, the rate of eliminating industrial pollution is quite lower than the development rate of industrial production, the treatment rate of industrial pollution is very low in China. Leaders in different levels, including leaders of industry and enterprise, should be obliged to change their guiding thoughts in the following aspects: the Control of end of the pipe of pollution must be changed into the control of the whole process of industry production step by step in order to strengthen environmental management in mines and enterprises, thus the amounts of generation and discharge of pollution will be reduced through saving energy resource, reducing consumption and the promotion of comprehensive utilization of resource. Through technical innovation, improvements of process, renewal of equipment and implementation of cleaner production for near twenty years, not only the discharges of pollutants were reduced, but also recovery of metals from "three-waste" and comprehensive utilization of solid wastes were undertaken. The capability and technical level of pollution control were enhanced step by step. For instance, some advanced mining technology was employed to reduce the discharge of waste rock. Zhongtiaoshan Non-ferrous Metal Industry Company renovated mining technology from their former mining method to a block caving method so that the loss of ore mineral was reduced from 20 percent to 10 percent, the dilution rate of ore mineral was also reduced to from 20-30 to 10-15 percent. This was a big decrease in discharging ratio of per 10 thousand tons, thus remarkably reduce waste rock in the process of mining. In open-pit mines such as Xiaoyi Aluminum Mine in Shanxi Province, Pingguo Aluminum Mine, etc., the application of the technique of internal removing soil was popularized. Because the operation of internal draining soil was adopted in advance, 60-70 percent strip material was returned to the open-pit mine, thereby reducing the area of occupied land and effectively protecting the eco-environment. In addition, similar to the control of pollutant discharge, the control of concentration will be turned into the control of both

concentration and total quantity. Some key non-ferrous metal enterprises have established environment monitoring stations to monitor the state of enterprises' environment and the contents of key pollutants for a long-term or in succession. Almost all new projections and enterprises must strictly insist on environmental laws and environmental planning, in other words, almost all new construction, reconstruction and expanded projects have to undergo technological transformation, their facilities for preventing pollution or other public hazards should be designed, built and put into operation simultaneously with the main body of the projects. Since 1979, the stipulation of "three simultaneousness" has basically been implemented among large and medium scale newly built and extension projects of CNNC.

To Recovery or Reuse the "Three-wastes" Fully

In view of ecosystems approach, some discharged wastes may be recycled. In recent years, lots of work about comprehensive utilization of tailings have been done. Firstly, tailings may be used as a secondary resource to recover valuable associated elements something like tin and copper from tin tailing, lead, zinc, tungsten, silver from lead & zinc tailings, fluorite concentrate and sulphurous iron concentrate and so on from copper mine tailings. Tailings can also be utilized to manufacture building material to prevent the land from being destroyed and environment pollution. For example, In Xihuashan Tungsten Mine, Jiangxi Province, tailing were used to produce calcareous calcic-brick of high quality, which not only saved money, occupied less land, but also helped to eliminate tailing pollution. Every year 1,700 m^3 of tailings are utilized and 10 million pieces of brick are produced. At the same time, by-product-lime powder may be supplied for building. Additionally, mines also use tailings to produce cement floor bricks, cement beams and so on. On the other hand, a considerable amount of metals can be recovered from waste water. For example, during the period from 1978 to 1984, Shenyang Smelter recovered 1,768 tons of metal from the sewage, the value amounted to 1.06 million RMB. In addition, Dexing Copper Mine mixes the alkaline waste water containing sulphur from dressing process with acidic waste water containing copper from mining to launch a chemical reaction and recover CuS, while eliminating waste pollution. Table 6 depicted the discharge and reuse of SO_2 in Chinese Non-ferrous Metal Industry.

According to statistics data, the annual discharge of tailings in Chinese non-ferrous metal mines amounts to about 60 million tons and take up 11.2 percent of total amount of industrial solid waste, while the amount of strip material from open-pit mine in China reached 260-320 million tons, the amount of waste mineral from underground mine was 170 million tons. Therefore, how to recover "three-waste" effectively still is an urgent problem to be solved. At present, research on the technology for environmental treatment and comprehensive utilization of waste rock from mining, tailing from dressing and all sorts of smelting slag have been strengthened greatly in China.

Conclusions

In China, non-ferrous metal industry is not only an important basic industry of national economy, but also one of the essential sources that cause environmental pollution. Due to discharge of pollutants, atmosphere, water body, soil, crop and people's health are polluted and injured to different extent. In order to keep sustainable development of CNNC, more attention must be paid to strengthen environmental management in mine, control of industrial pollution and "three-wastes". In the regard to the philosophy of controling industrial pollution, "end-pipe control" has to be turned to "the whole process control". Moreover, pollution treatment has to solve some basic problems like environmental planning, establishment of environmental law system, innovation of techniques, improvement of technology, renewal and improvement of equipment, reduction of the discharge of pollutants and popularization of cleaner production. Since 1980s, technical level of treating industrial pollution has been raised, and good economic profit, environmental profit and social profit have been achieved. Land reclamation has also been undertaken extensively in China. So far, 40 million hectares of land is rehabilitated. To promote policies on land reclamation, a series of research and demonstrations pilots on theories, methods and techniques of ecological restoration of waste land have been created.

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Table 1 Discharges of pollutants in Chinese Non-ferrous Metals industry

	Waste Water (million tons / a)	Waste Gas (billion m^3 / a)	Solid Waste (million tons / a)
Total discharge	560	250	59
Percentage	3.5	9.7	10.6

Table 2 The Concentration of heavy-metal ions in waste water from CNNC

	Hg (tons /a)	Cd (tons / a)	As (tons / a)	Pb (tons / a)
Total discharge	5.6	88.0	173.0	226.0
Percentage	16.0	48.8	11.3	20.0

Table 3 Soil pollution By Heavy Metals In A Tungsten Mine, Jiangxi Province (1988)8

	pH value	Cu(ppm)	Pb(ppm)	Zn(ppm)	Be(ppm)	As(ppm)	Fe(%)
Near	2.5	1417	160	180	1.801	22	8.6
mining area	5.4	72	80	80	1.801	22	4.1
Xiaban Irrigation Area	5.0	495	100	150	2.703	15	4.75
Along Tongmu River	5.5	30.8	72	60	1.801	4.0	4.05

Table 4 Reclamation Ratio in Some Aluminum Mines

Mine Name	Total Area	Total Reclamation Area (M m^2)	Reclamation Ratio (%)	Reclamation Depth (m)	The Usage of Reclamation Land
Xiaoguan Bauxite Mine	3.187	1.449	45.46	1.2--1.5	Peeled off field, Agriculture
Yangquan Bauxite Mine	0.948	0.319	33.65	0.5	Peeled off field, Agriculture
Luoyang Bauxite Mine	0.782	0.133	17.04	0.5	Peeled off field, Agriculture
Fengshui Bauxite Mine	5.869	1.699	29.0	0.5	Peeled off field, Agriculture

Table 5 Reclamation of Derelict Strip-mined Land in China

Regions	Mining land area (hectares)	Reclamation area (hectares)	Reclamation ratio (%)
Fushun	400	61.8	15
Xiaomabei	400	146.7	37
Xialongtan	400	150	37.5
Lingbei	800	200	25
Kebao	133.3	120	90

Table 6 Discharge and Reuse of SO_2 in Chinese Non-ferrous Metal Industry

Years	SO_2 discharge in waste gas (10^4 tons)	Smoke-making acid (10^4 tons)	Utilization rate of sulphur (%)
1981	67.80	86.10	45.33
1982	57.62	89.10	50.37
1983	45.73	100.39	58.91
1984	56.05	124.60	59.20
1985	46.41	119.60	53.33
1986	41.27	132.48	54.58
1987	47.52	163.21	64.74
1988	52.72	171.13	63.19
1989	54.47	183.48	64.11
1990	49.00	181.82	63.51
1994	-	223.4	70.86
1995	75.00	276	70