

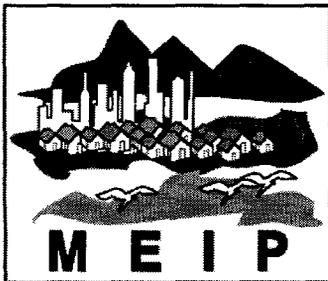
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MEIP City Working Paper Series

Environmental Monitoring in Beijing

Beijing Municipal Environmental Protection Bureau

June 1994



Metropolitan
Environmental
Improvement
Program

ENVIRONMENTAL MONITORING IN BEIJING

Beijing Municipal Environmental Protection Bureau

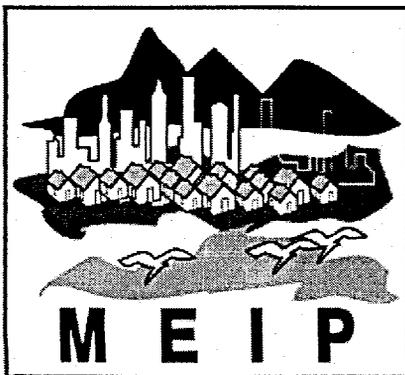
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ABBREVIATIONS

| | |
|----------------|--|
| BMEMC | Beijing Municipal Environmental Monitoring Center |
| BMEPB | Beijing Municipal Environmental Protection Bureau |
| BMEPC | Beijing Municipal Environmental Protection Commission |
| BMG | Beijing Municipal Government |
| | |
| CNEMC | China National Environmental Monitoring Center |
| | |
| EIA | Environmental Impact Assessment |
| EPB | Environmental Protection Bureau |
| | |
| NEMMRAR | <u>National Environmental Monitoring Management Rules And Regulations</u> |
| NEPA | National Environmental Protection Bureau |
| | |
| QA | Quality Assurance |
| QC | Quality Control |
| | |
| SD | Standard Distribution |
| SRM | Standard Research Material |
| | |
| TSP | Total Suspended Particles |
| | |
| WHO | World Health Organization |
| | |
| Y | Chinese yuan (1990) |

Y5.4 ≈ US\$1

INTRODUCTION

Environmental monitoring is the supervision and measurement of environmental quality and its influence on mankind and other organisms. Monitoring primarily measures three aspects:

Measurement of Physical Indices Levels of noise, vibrations, electromagnetic waves, temperature and radioactivity.

Measurement of Chemical Indices The presence of various chemicals in air, water, soil and organisms.

Monitoring of the Ecosystem Ecological changes attributable to human activities, such as soil erosion and desertification resulting from deforestation and livestock grazing; changes in biological quality and community caused by pollutants in the food chain; temperature changes and destruction of the ozone layer by excess CO₂ and CFC emissions.

The principles of monitoring are a defined purpose, a thorough and rational monitoring plan, dependable monitoring methods and quality assurance measures, and scientific methods to analyse and assess the collected data.

Environmental monitoring breaks down into subcategories including routine monitoring, pollution source monitoring, accident monitoring, arbitration monitoring and research monitoring. Monitoring is the foundation of environmental management and science.

China's history of environmental protection, beginning in 1974, falls into 3 stages:

Declaring a national environmental policy, founded on the simultaneous planning, implementation and development of economic, developmental and environmental policy and practice.

Introducing this system and its guiding principles (prevention first, "polluter pays", and the establishment of a governmental authority).

Establishing a set of management measures:

- responsibility for environmental protection objectives;
- periodic assessment of the urban environment;
- mandatory environmental impact assessments (EIAs) for construction projects;
- the San Tong Shi system (measures to mitigate pollution and other public hazards are to be designed, built and implemented simultaneously with the primary project);
- licenses to discharge a limited amount of pollution and fines for exceeding this;

- pollution abatement deadlines;
- emission control measures; and
- environmental protection by enterprises as a condition for promotion and designation as "Advanced" units.

As environmental management capabilities have strengthened, environmental monitoring has been continuously enhanced. From 1974 to 1988, monitoring served as "ears and eyes," only providing basic environmental management information. As environmental management became more important, it was shown that simple supervision did not adequately reflect the importance of monitoring to environmental management.

At the Second National Anti-Water Pollution Meeting in 1989, it was proposed that environmental monitoring should be not just ears and eyes, but also a "ruler" against which environmental protection trends and the level of management are measured. In 1990, environmental monitoring was identified as a primary management and enforcement measure. The 4th National Monitoring Work Conference that same year further emphasized these conclusions. The centrality of monitoring is affirmed in Article 11 of The Environmental Protection Law Of The People's Republic Of China (1989).

Practice over the years confirms the importance of environmental monitoring. The two are dependent on and inseparable from each other. If monitoring is separated from serving environmental management, it is functionless; if environmental management does not rely on monitoring, it loses its scientific basis and becomes blind. This would lead to errors in planning and decision-making.

After the 3rd National Environmental Protection Work Conference (1989), methods characteristic to China were developed. The country was faced with three transformations: transformation of qualitative management into quantitative; transformation of individual abatement into comprehensive; and transformation of concentration control into total emissions control. Monitoring supports and guides these targets.

According to the National Environmental Monitoring Management Rules And Regulations (NEMMRAR) (1983), environmental management comprises six facets: management of monitoring systems; monitoring enterprises; monitoring techniques and technologies; monitoring data and its management; monitoring personnel; and monitoring logistics (conditional assurance). The monitoring system is the link between the six components.

NEMMRAR and The Environmental Protection Law (1989) are the foundation of monitoring system management. The monitoring management branches of the environmental protection bureaus (EPBs) and affiliated organizations are divided into four levels: primary (China National Environmental Monitoring Center), secondary (provincial stations), tertiary (municipal stations), and quaternary (district and county stations).

Monitoring agency functions vary from level to level. Generally, environmental monitoring departments manage monitoring systems, establish a monitoring network, and supervise relations between components. The state and provincial EPBs emphasize program management, while

municipal, district and county stations emphasize objective plan management. Stations at lower administrative levels emphasize developing implementation plans and organizing the enforcement under the instructions of different programs and objectives. In addition, they organize implementation of relevant technical criteria and standards.

The duties of the China National Environmental Monitoring Center (CNEMC) are:

1. To help develop monitoring programs and annual plans for the entire country;
2. To instruct and supervise secondary monitoring stations; to coordinate the national monitoring network; to train and professionally certify monitoring personnel at lower levels;
3. To research statistical and analytical approaches to environmental monitoring data; to collect, store, and analyze national environmental monitoring data; to compile the national environmental yearbooks and draw environmental pollution charts; to assess national environmental quality and present periodic reports to the National Environmental Protection Agency (NEPA);
4. To supervise quality assurance (QA) for national environmental monitoring; to study new techniques, technologies and methods; to organize the development, preparation and dissemination of standard research methods; to select instruments for national environmental monitoring;
5. To undertake comprehensive environmental investigations at the national level and investigate major pollution incidents; to arbitrate major pollution incidents and international environmental disputes;
6. To help develop and revise national environmental standards and technical specifications;
7. As entrusted by NEPA, to review EIAs for major state construction, renovation and expansion projects, and help monitor the environmental benefits of abatement projects.

The main duties of the provincial EPBs are:

1. To help develop programs and annual plans for regional environmental monitoring work;
2. To collect, sort and store regional environmental monitoring data, and supply NEPA with data for various monitoring reports; to compile and submit to NEPA regional environmental yearbooks;
3. To give professional and technical instructions to the tertiary and quaternary environmental monitoring stations; to supervise and coordinate the regional environmental monitoring networks; to train and professionally certify lower-level monitoring personnel;

4. QA for regional environmental monitoring;
5. Within the region, to investigate and arbitrate pollution disputes;
6. To develop and modify local and national environmental criteria and technical specifications; testing and verifying work, and providing basic materials;
7. To undertake environmental QA and research on monitoring techniques and technologies within the region; to help compile the regional environmental report books;
8. As entrusted by NEPA and CNEMC, to investigate pollution incidents, review construction project EIAs, and monitor the environmental benefits of abatement projects;

The duties of the municipal EPBs are:

1. To carry out routine monitoring and analysis of various environmental parameters such as air, water, soil, biology, noise and radioactivity; to collect, store and sort environmental monitoring data and periodically present technical reports on environmental quality and pollution trends in their cities to the environmental protection authorities at their level and secondary monitoring stations;
2. To monitor pollution discharges from city enterprises; to establish pollution source archives and provide monitoring data for strengthening pollution source management and the collection of discharge fees. (Discharge fee management units do not set up their own measurement organs.)
3. To help draft municipal environmental monitoring programs and plans; to accomplish various monitoring tasks as needed by the authorities;
4. To be in charge of environmental quality assessment for their city, to help compile municipal environmental report books and yearbooks;
5. To supervise the environmental monitoring network within their city and organize technical exchanges and training for monitoring personnel;
6. To study problems in important technical links, such as field work, sampling, monitoring point allocation, sample transportation, storage, analysis and measurement to improve monitoring techniques and technologies;
7. To test and verify national and local environmental criteria and technical specifications; to help develop and revise local environmental criteria;
8. To investigate pollution incidents in their city and supervise technical arbitration of pollution disputes.

The duties of the provincial and urban district environmental monitoring stations are:

1. To draw up monitoring plans and regularly measure various parameters; to present monitoring data reports periodically to higher-level stations; to compile and submit to higher levels the provincial environmental quality report books;
2. To monitor provincial pollutant discharge units; to establish pollution source archives; to manage enforcement of applicable environmental rules, regulations, criteria and standards; and to provide monitoring data for the environmental management, including discharge fees;
3. To accomplish various monitoring tasks needed by the environmental protection authorities;
4. To investigate pollution incidents in the province; to provide monitoring data for the arbitration of environmental pollution disputes; to organize a local monitoring network;
5. To propagate general and specific environmental protection policies; to mobilize support and enlist the public in environmental supervision.

The size and function of the enterprise monitoring stations are decided by enterprise management. These stations contribute to the environmental monitoring networks at various levels and are supervised by the corresponding environmental protection authority. Their main duties are:

1. To develop environmental monitoring programs and their own organizational system;
2. To participate in the local environmental monitoring network; to monitor sectoral and regional environmental status in accordance with general plans and requirements; to be responsible for organizing environmental monitoring activities within their own organizational systems or river basins;
3. To help develop and revise the environmental criteria applied to their branch or area; to participate in the discussion and examination of national and local environmental criteria and standards;
4. To investigate major pollution incidents in their organization; to manage implementation of environmental rules, regulations, criteria and standards;
5. To assess new construction, renovation and extension projects of enterprises and institutions in their organization;
6. To collect environmental monitoring data in their organization or river basin; plot charts of pollution trends and set up pollution source archives;
7. The monitoring stations of the enterprises and institutions monitor their own units' pollutant discharge and should be aware of changing trends;

8. Reporting monitoring data and information to the relevant authority and to the local environmental monitoring network;
9. To organize research on monitoring techniques and technology appropriate to their sectors, trades and professions; to train technical personnel and conduct technical staff exchanges;
10. Environmental monitoring stations in sectors like hygiene, water conservation and the ocean are responsible for environmental monitoring in their organization. Aside from coordinating with local environmental monitoring stations, they help investigate major pollution incidents as called on by environmental protection authorities.

According to "The Environmental Protection Law" the relevant administrative authority for environmental protection, in coordination with the departments concerned organizes the monitoring network. The national environmental monitoring network is subdivided into networks at the state, provincial and municipal levels, managed by the relevant EPB.

The national environmental monitoring network comprises the provincial environmental monitoring stations, the state environmental monitoring stations and the units monitoring important river systems and coasts. A national environmental monitoring network, headed by CNEMC, has been established, including an atmospheric monitoring network of 72 stations, a surface water monitoring network consisting of 109 stations, an acid rain monitoring network made up of 200 stations, a radioactivity monitoring network consisting of 29 stations, and a noise monitoring network consisting of 52 stations.

Attention is increasingly being paid to ecological monitoring. Monitoring stations in grassland, desert and ocean regions are being built by national and local governments. Each province, autonomous region, centrally-governed municipality and provincially-governed city, in accordance with local environmental management requirements, has set up local monitoring networks, supervised by the provincial or municipal monitoring station.

Each department, trade, profession and major river system has its own monitoring network, responsible for coordinating with other monitoring networks, conducting environmental monitoring activities, carrying out pollution abatement and collecting data to be reported to the various government levels.

According to NEMMRAR, environmental monitoring stations at different levels are supervised by the environmental protection authorities at their respective levels, while the stations' professional work is managed by the environmental monitoring stations immediately superior. The Beijing Municipal Environmental Monitoring Center (BMEMC) (Figure I-1) carries out its monitoring work under the supervision of the Beijing Municipal Environmental Protection Bureau (BMEPB) (Figure I-2) and CNEMC.

The Beijing Municipal Government (BMG) established the Beijing Municipal Environmental Protection Commission (BMEPC) to unify environmental protection work within the city. BMEPB is the BMEPC administrative body, responsible for environmental protection planning,

| THE BEIJING MUNICIPAL ENVIRONMENTAL MONITORING CENTER (BMEMC) (230 people) | | | | |
|---|--|--|--|---|
| LABORATORY (104 people) | MANAGEMENT (39 people) | SOCIAL SERVICES SECTION (23 people) | ADMINISTRATIVE AND LOGISTICS DIVISION (48 people) | OTHER ADMINISTRATIVE PERSONNEL (16 people) |
| <p>INSTRUMENTATION ANALYSIS DIVISION (11 people): Large sophisticated instruments used for qualitative & quantitative analysis of multicomponent organic and inorganic material.</p> <p>WATER QUALITY MONITORING LAB (22 people): Routine monitoring of surface water and industrial wastewater; research on analytical methods and monitoring techniques.</p> <p>AIR MONITORING LAB (28 people): Routine atmospheric monitoring; monitoring of air pollution sources; research on analytical methods and monitoring techniques.</p> <p>AUTOMATIC AMBIENT AIR QUALITY MONITORING SYSTEM DIVISION (22 people): Continuous year-round real-time monitoring at 1 central station & 8 sub-stations.</p> <p>PHYSICAL TESTING LAB (9 people): Monitoring of noise, vibrations and electromagnetic radiation.</p> <p>SOLID WASTE & BIOLOGY LAB (12 people): Monitoring & investigation of pollution caused by domestic and industrial refuse; monitoring crops; testing fish and water toxicity; monitoring indexed organisms.</p> | <p>MONITORING NETWORK & QUALITY CONTROL DIVISION (5 people): Drawing up the network's annual work plan; management of personnel, training and measurement; standardizing measurement methods, criteria and standards and management of QA system.</p> <p>DATA COLLECTION & ASSESSMENT DIVISION (6 people): Responsible for optimum distribution of monitoring stations and data collection and analysis.</p> <p>TECHNICAL MANAGEMENT DIVISION (5 people): Plans BMEMC's professional work; establishes technical work procedures; manages technical work.</p> <p>EQUIPMENT & MATERIALS DIVISION (7 people): Purchases and maintains BMEMC equipment, supplies and facilities.</p> <p>PERSONNEL AND EDUCATION DIVISION (4 people): Responsible for personnel recruitment, deployment, certification, promotion and compensation.</p> <p>TECHNICAL INFORMATION DIVISION (7 people): Collection & dissemination of foreign & domestic technical information; acquire & maintain books & periodicals.</p> <p>FINANCE SECTION (5 people): Supervise funding, annual budget & accounts.</p> | <p>TECHNICAL DEVELOPMENT DIVISION (10 people): Supervise technical developments and service.</p> <p>ANTI-POLLUTION DIVISION (6 people): Supervise the technical & technological design of small-scale pollution control projects.</p> <p>TECHNICAL SERVICE SECTION (7 people): Provide monitoring equipment & technical expertise to the broader society.</p> | <p>BMEMC OFFICE (5 people): Management of administrative archives and secretarial services.</p> <p>LOGISTICS SECTION (43 people): Supervises logistical matters, utilities and BMEMC vehicles.</p> | <p>Supervises personnel abroad for significant lengths of time.</p> |

FIGURE I-1

determining objectives, and conducting supervision and coordination. The EPBs in each district and county, under district or county leadership, are in charge of environmental management, supervision and coordination. There are full-time environmental protectors in each residential district, and villages and towns in the counties. Thus, a 3-level environmental management and supervision system has been established. Based on years of experience, Beijing's environmental quality system has been set up so that management, quality control and environmental

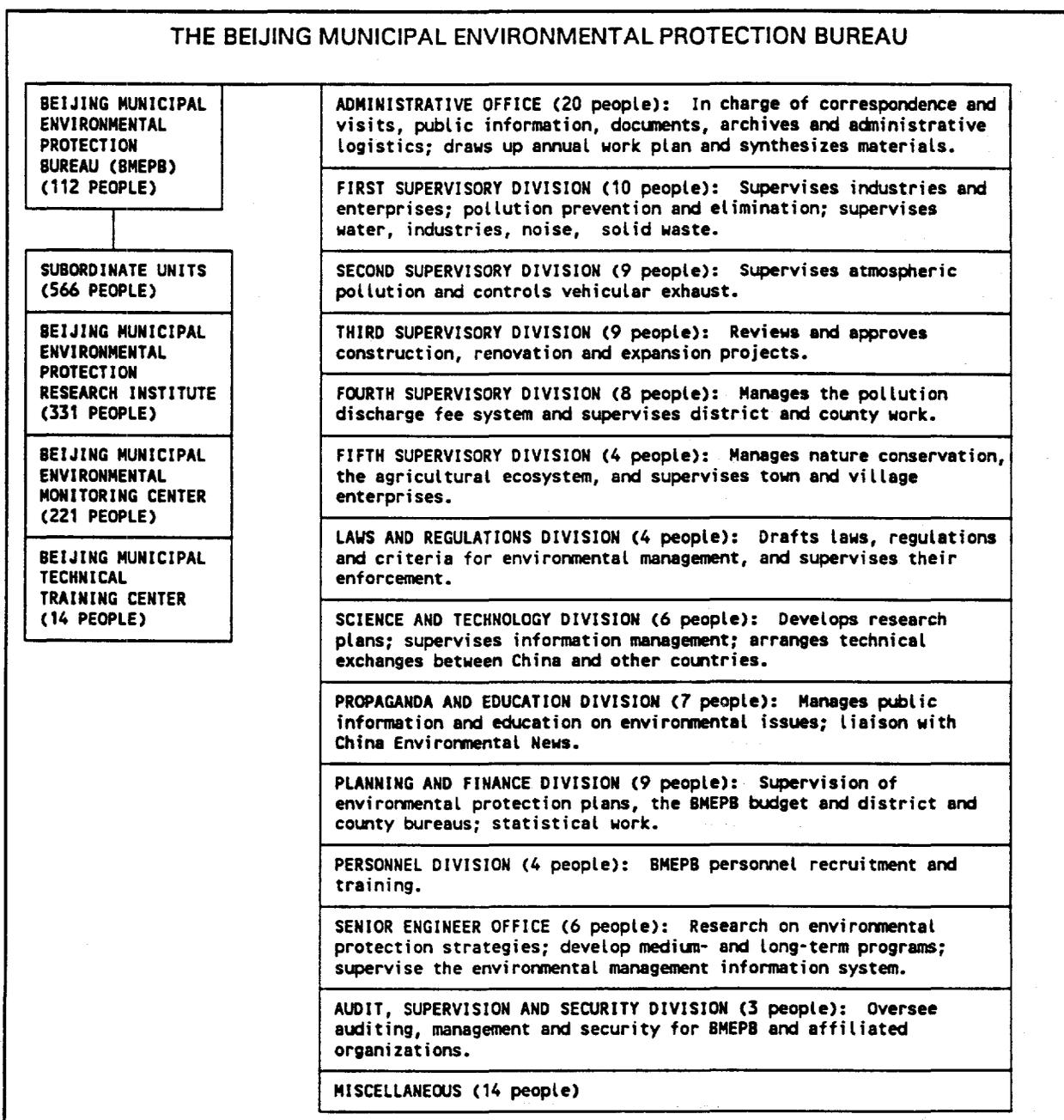


FIGURE I-2

monitoring are the three main component parts (Figure I-3).

Since opening the Three Wastes Control Office in 1971, BMG has developed its monitoring capabilities to include an environmental protection system, an industry and communications system, and water conservation, sanitation and epidemic prevention, and geology departments, all conducting environmental monitoring, sharing results and coordinating with one another.

In 1977 BMEPB was established and began operations. From 1976 to 1985, Beijing's districts and counties established EPBs. Most departments, trades and professions had already

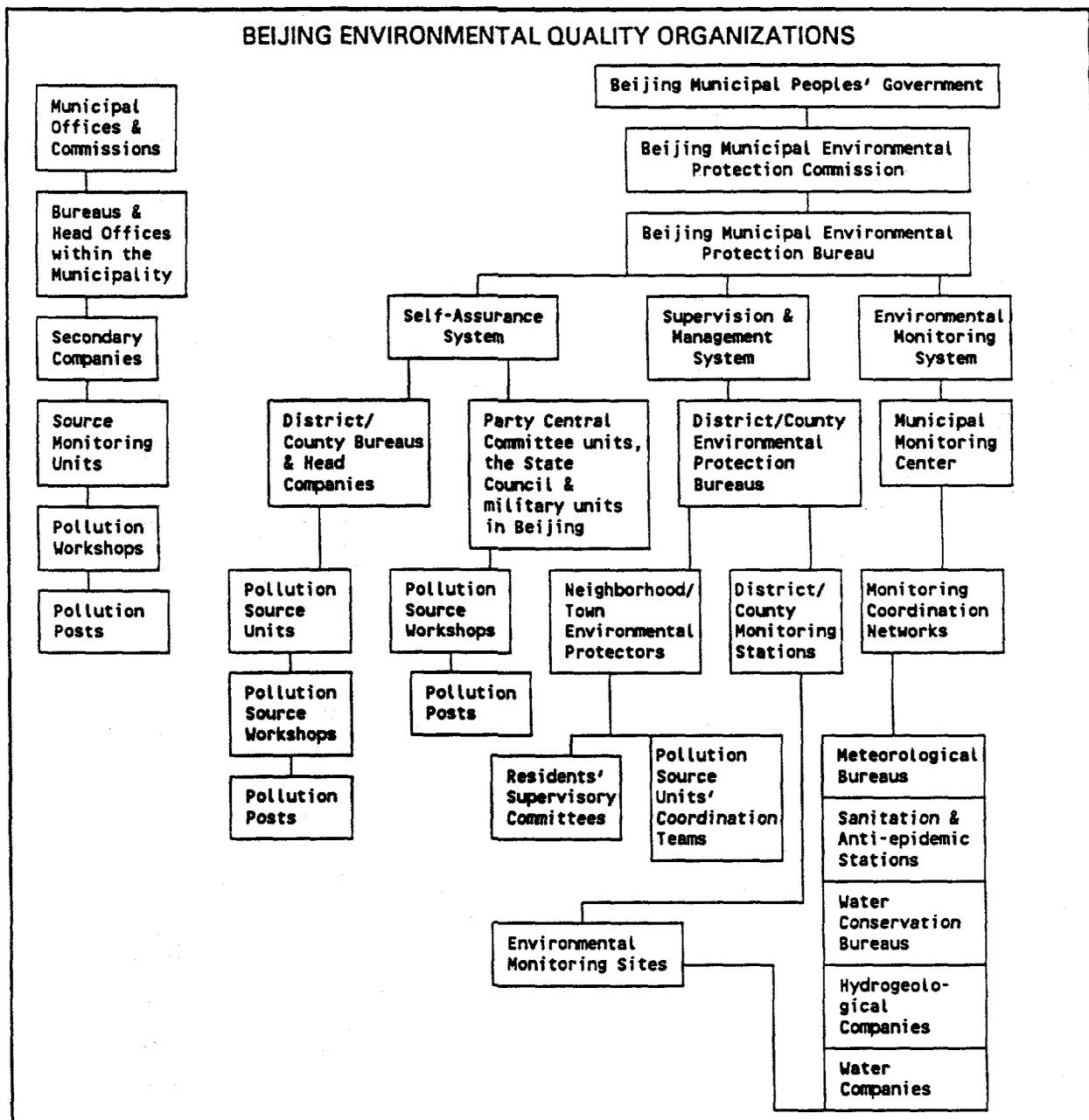


FIGURE I-3

established monitoring offices. Rules, regulations, technical specifications, criteria, methods, quality assurance, pollution source monitoring, data reporting and network management were introduced and modified during this time. Beijing thus developed an environmental monitoring system suited to both environmental protection and Chinese circumstances.

In the last five years, BMEPB has developed optimal monitoring point distribution and improved management; improved technology, networked monitoring stations, standardized site allocation, sampling and analytical methods, computerization of data processing and program-controlled quality assurance have been introduced; and technical procedures appropriate for China have been developed. Beijing's environmental management and monitoring have become increasingly

scientific and its managerial system has served as a model for other cities.

THE SIX COMPONENTS OF ENVIRONMENTAL MONITORING

| Name | Main Contents | Main Basis |
|---|---|---|
| 1. Management of monitoring system | Establishment of networks, definition and adjustment of functions and duties; establishment of relations between the bureau and stations at the same level; relations between higher- and lower-level stations and the relations of business and technology; personnel, funding and materials for monitoring organizations and their subordinate relations. | Management rules for environmental monitoring, state or local network rules and regulations. |
| 2. Management of monitoring business | Development and adjustment of monitoring programs; development, assignment, evaluation and assessment of monitoring work plans; setup and refinement of working procedures, appropriate programs and plans for environmental protection. | "National Environmental Monitoring Management Rules and Regulations" (NEMMRAR) |
| 3. Management of monitoring techniques and technology | Choice of monitoring methods, criteria and procedures; setup and adjustment of QA system; organization and coordination of the monitoring of technical progress; examination and assessment of technical results. | "Technical Specifications", NEMMRAR, state or local criteria, various technical rules and regulations |
| 4. Management of monitoring information | Processing, analysis, assessment, interpretation, handling and storage of monitoring data; standard formats and transmission of reports and technical results; determination of collection scope, degree of processing and general storage of environmental information; management of technical archives. | NEMMRAR, various rules and regulations, "Technical Specifications" |
| 5. Management of monitoring talent | Monitoring staff selection and skills mix; enhancement of ideological quality; technical training and updating; cultivation and guidance of professional awareness; enhancing organizational efficiency and the embodiment of self-value of the staff members. | NEMMRAR, relevant policies, laws and regulations; personnel management; various rules and regulations |
| 6. Management of monitoring logistics | Management of equipment, communications and transport; equipment installation and adjustment; maintenance of instrumental facilities; management of safety, health, welfare and funding. | NEMMRAR, various rules and regulations |

TABLE I-1

THE BEIJING MUNICIPAL ENVIRONMENTAL MONITORING SYSTEM

Beijing's environmental monitoring system is a network supervising the environment. According to "National Environmental Monitoring Management Rules and Regulations" (NEMMRAR), the Beijing Municipal Environmental Monitoring Center (BMEMC), a division of the Beijing Municipal Environmental Protection Bureau (BMEPB) is responsible for organizing Beijing's 18 district and county environmental monitoring bureaus (EPBs), setting up an environmental monitoring network and coordinating the monitoring units of associated bureaus and companies, including the sanitation and antiepidemic bureau, the hydrogeologic bureau, the meteorologic bureau, the agricultural bureau, the head companies of the chemical and textile industries, the Capital Iron and Steel Company and the Yan Shan petrochemistry Head Company. These monitoring units share responsibility for environmental monitoring work in Beijing (Figure 1-1).

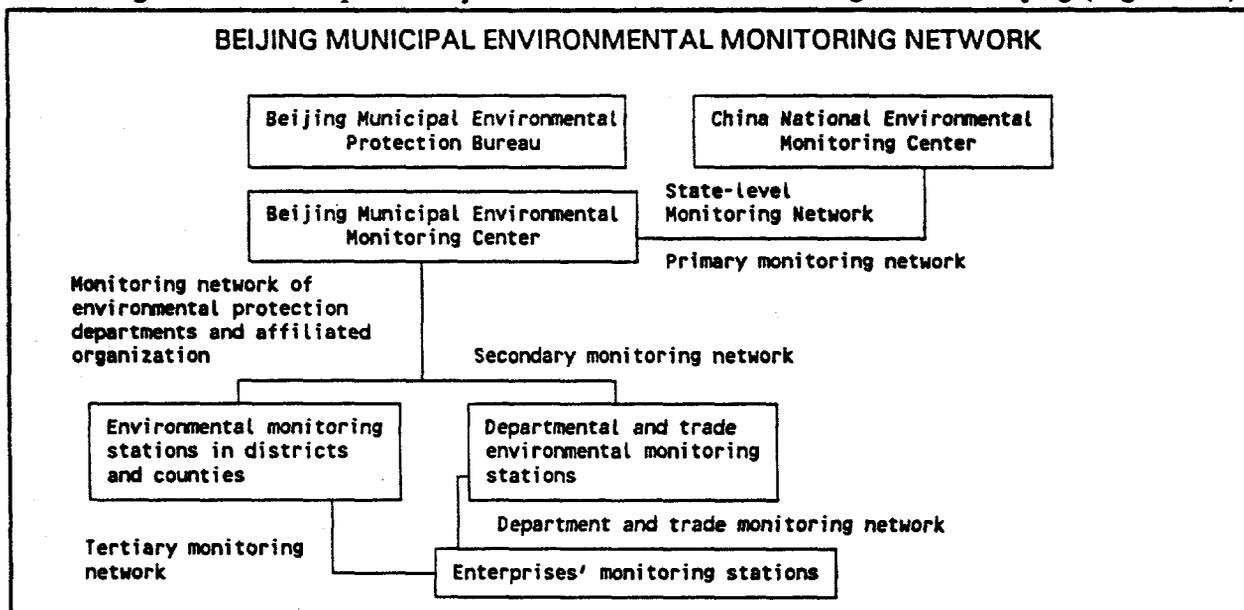


FIGURE 1-1

Construction of BMEPB facilities started in March 1974, and the present quarters were completed and put into service in October 1977. BMEPB is a provincial level environmental monitoring agency, one of the first in China. 230 staff work in the Center, 163 of whom are technical personnel. BMEPB possesses fixed assets valued originally at Y18.62 million. Facilities total an area of 20,000 square metres, presently holding 18 large instrumental facilities and equipment, including an ICP, a GC/MS, an AAS, a GC, an LC, a U.V spectrophotometer, a fluorescent spectrophotometer, a dust β radio-detector, and a mobile automatic air quality monitoring station.

In 1983, in cooperation with Thermal Election Corporation (TECO), an Automatic Air Quality Monitoring System was introduced. This System, which has been running for 7 years, consists of 8 substations (7 in the urban and inner-suburb districts, and 1 in the outer suburbs) and a central station. The data capture rate is over 85 percent. BMEMC is divided into 18 divisions and labs (Table 1-1). This includes a water lab, an air lab, a solid waste lab, a biology lab, a physical testing lab, an instrumentation analysis division, an automatic air monitoring system division, a monitoring network and quality assurance (QA) division, a technical management division, a data collection and assessment division, a technical information division, and a division for supplying equipment and materials. BMEMC has evolved as a technical and organization model as well as a source of data for environmental monitoring work in Beijing.

In accordance with monitoring agency tasks stipulated in NEMMRAR, BMEMC functions as both a provincial and a municipal station, supplying BMG with data needed for environmental management work. BMEMC duties include:

1. Drafting medium- and long-term programs and annual plans for supervision and monitoring of key pollution sources;
2. Organizing and supervising a municipal environmental monitoring network assessing air quality, water, soil, noise and other parameters; organizing technical exchanges, training and certification of monitoring personnel;
3. Managing district and country EPBs;
4. QA work in various monitoring media;
5. Collecting, analyzing, and storing environmental monitoring data; preparing municipal environmental quality assessments and compiling the annual environmental quality report;
6. Various other monitoring tasks as needed by administrative authorities;
7. Developing, revising and verifying state and local environmental standards, technical specifications and criteria; research on environmental management and monitoring; and
8. Investigating pollution incidents in Beijing; arbitration of environmental disputes.

During its years of experience, BMEMC has evolved some characteristics of its own. These include:

1. As well as relying on the network units, BMEMC directly reviews the most important components of the work. BMEMC has accumulated considerable experience in network siting, sampling, analysis, quality assurance, data collection and processing, and large-scale monitoring organizations.
2. As various industries are located in Beijing, and emergencies occur periodically, BMEMC has practical experience in monitoring pollution sources and accidents.

3. BMEMC has for some time monitored and analyzed trace elements, teratogens, carcinogens and mutagens, as it possesses sophisticated instruments and facilities.
4. Through study and research on the Automatic Air Quality Monitoring System, System software has been improved. This System, under strict quality control, has been running for 7 years and its annual data capture is still over 75 percent.
5. Through investigation of pollution sources and data analysis, BMEMC has developed various pollution dispersion models and assessment methods, laying a foundation for air pollution modelling in Beijing's urban areas and inner suburbs.

Following the establishment of BMEMC, between 1976 to 1985 the 18 district and county EPBs established monitoring stations, supplementing Beijing's environmental monitoring network (Table 1-1), the front line of environmental quality measurement and monitoring. At present, 216 staff members work at these monitoring stations.

DISTRICT AND COUNTY ENVIRONMENTAL PROTECTION BUREAUS IN BEIJING

| ENVIRONMENTAL PROTECTION BUREAU | PERSONNEL | TECHNICAL PERSONNEL | | AREA MONITORED (m ²) | VALUE OF INSTRUMENTAL FACILITIES (US\$, 000) |
|---------------------------------|------------|---------------------|------------------|----------------------------------|--|
| | | ENGINEERS | SENIOR ENGINEERS | | |
| Dongcheng District | 10 | 1 | 2 | 400 | 200 |
| Xicheng District | 7 | | 2 | 400 | 300 |
| Xuanwu District | 7 | | 3 | 300 | 200 |
| Chongwen District | 11 | 1 | 7 | 900 | 200 |
| Chaoyang District | 27 | | 3 | 346 | 382 |
| Haidian District | 17 | | 4 | 409 | 150 |
| Fengtai District | 18 | 1 | 4 | 1000 | 300 |
| Shijingshan District | 15 | | 2 | 530 | 300 |
| Mentougou District | 9 | | 1 | 230 | 300 |
| Fangshan District | 16 | | 2 | 1000 | 200 |
| Daxing County | 10 | | 1 | 530 | 200 |
| Tongxian County | 12 | | 2 | 1000 | 200 |
| Shunyi County | 10 | | 1 | 700 | 200 |
| Pinggu County | 9 | | 2 | 500 | 200 |
| Miyun County | 12 | | 1 | 300 | 300 |
| Changping County | 9 | | 3 | 540 | 209 |
| Yanqing County | 8 | | 1 | 400 | 134 |
| Huairou County | 9 | | | 450 | 200 |
| TOTAL | 216 | 3 | 41 | 9935 | 4,175 |

TABLE 1-1

According to each administrative district's characteristics (population, physical geography, industrial layout and structure) the monitoring stations emphasize different primary tasks. For example, the Miyun and Huairou county monitoring stations in the outer suburbs emphasize safe

drinking water; the Chaoyang, Fengtai and Shijingshan monitoring stations in the inner suburbs place more emphasis on the control of industrial pollution; the four urban monitoring stations pay particular attention to environmental and traffic noise, smoke and dust control.

The district and county monitoring stations provide technical support for the implementation of environmental management rules, regulations and measures. They do much work in environmental quality measurement and supervisory monitoring of key pollution sources, and provide a scientific foundation for collecting excess pollution discharge fees. The district and county monitoring stations are the environmental management laws' main enforcers.

These stations' personnel distribution, staff quality, monitoring facilities and station work areas do not fill the entire city's environmental protection requirements. Therefore, it is necessary that they make a greater effort to strengthen and improve their monitoring capability. According to NEMMRAR, Beijing's monitoring stations are classified as quaternary stations (district and county EPBs, provinces, municipalities directly under the central government or big cities). Yet, measured by population and industry density the Chaoyang, Haidian, Fengtai and Shijingshan monitoring stations in Beijing's inner suburbs, have concurrently the functions of a tertiary station (municipal district monitoring stations). This is different from district monitoring stations in other big cities.

Beijing's district and county monitoring stations primarily undertake these tasks:

1. Routine environmental quality measurements in their own districts in accordance with BMEPB and BMEMC monitoring plans; regularly reporting monitoring data to BMEMC; environmental quality assessments in their own districts or counties; and compiling annual environmental quality reports for their district or county;
2. Monitoring pollution sources in their area and using this data to assess excess pollution discharge fees.
3. Other monitoring tasks as needed by the environmental protection authorities;
4. Investigating pollution incidents in the district or county, to provide data for arbitration of pollution disputes;
5. Management of the professional organization and coordination of monitoring networks in their own districts (only certain district monitoring stations are subject to this).

In addition to Beijing's district and county monitoring stations, 19 bureaus or head companies and more than 100 enterprises or institutions located in Beijing have their own monitoring stations or offices, forming an environmental monitoring network covering Beijing. In general, the trade monitoring stations possess more highly qualified staff members and more advanced monitoring methods.

The main functions of the departmental and trade monitoring agencies are:

1. Developing environmental monitoring programs for their organizations;
2. Contributing to the state or local environmental monitoring network and undertaking monitoring work according to network plans and requirements; organizing environmental monitoring network activities within their own organizations;
3. Developing and revising the environmental standards to which the organization will be held responsible; helping evaluate state or local environmental standards and criteria;
4. Cooperating with pollution investigations within their organizations;
5. If certified, helping assess construction, renovation and expansion projects within their subordinate organizations;
6. Collecting environmental monitoring data in their field and making it publicly available;
7. Organizing monitoring research in their field and training technical personnel. These institutional monitoring stations are primarily responsible for monitoring pollutant discharges within their own units to track pollution discharges and changing trends. The monitoring stations report their findings to the local EPBs, participating in the local environmental monitoring network.

BASIC TASKS AND PROGRAMS OF ENVIRONMENTAL MONITORING

Environmental monitoring is the foundation of environmental protection and of laws addressing environmental management. NEMMRAR stipulates that environmental monitoring must:

- regularly monitor significant environmental parameters to track and assess environmental quality status and emerging trends;
- monitor pollutant discharges from regional sources;
- provide the government with accurate and reliable monitoring data in order to implement laws and regulations, enforce standards and and carry out environmental management work;
- support research on environmental measurement to develop new and improved monitoring techniques.

The tasks of the monitoring stations at the various levels are:

- Environmental quality measurements in their region;
- Supervision of pollution sources in their area;
- Research in their area; and
- Supervision and management in accordance with the government's environmental action plan.

ENVIRONMENTAL QUALITY MONITORING

Atmospheric Monitoring

Air pollution in Beijing is primarily smoke, in great varieties and quantities, from burning coal and fly ash. Automobile emissions along major roads and industry in certain sectors also contribute pollution. The main pollutants measured are SO₂, dust, NO_x and CO.

Allocation of Monitoring Points The present distribution of atmospheric monitoring stations throughout Beijing was determined in accordance with the distribution of pollutant sources, district functions, population density and spread of pollution from the source. To improve the distribution and account for changing demographics, the distribution has been adjusted three times, in 1980, 1985 and 1991.

SO₂ is monitored at 71 points in Beijing (Table 2-1). BMEMC operates 8 automatic continuous air quality monitoring stations, while manual sampling is done at the other locations. District

and county EPBs manage 41 monitoring stations; the sanitation and antiepidemic station manages a monitoring station in each of Beijing's 4 WHO districts; the Yan Shan Petrochemistry Head Company monitoring station operates 6 stations near its facilities; and the Iron and Steel Company monitoring station operates 12 sites near its facilities.

SO₂ Monitoring in Beijing

| POLLUTANT | | URBAN AND INNER SUBURBAN AREAS | | | OUTER SUBURBS, DISTRICT AND COUNTY |
|---|----------------------------------|--------------------------------|----------------|-------|------------------------------------|
| | | URBAN | INNER SUBURBAN | TOTAL | |
| SO ₂ (Automatic Monitoring System) | Number Of Monitoring Substations | 3 | 4 | 7 | 1 |
| | Number Of Valid Daily Averages | 821 | 1120 | 1941 | 285 |
| | Capture Rate per Year (%) | 75.0 | 76.7 | 76.0 | 78.1 |
| SO ₂ (Manual Sampling, 5 Days/Quarter) | Number Of Monitoring Points | | | | 41 |
| | Number Of Valid Daily Averages | | | | 752 |
| | Daily Capture Rate (%) | | | | 97.7 |
| SO ₂ (Stations in WHO Districts) | Number Of Monitoring Point | 2 | 2 | 4 | |
| | Number Of Valid Daily Averages | 336 | 335 | 671 | |
| | Daily Capture Rate (%) | 46.0 | 45.9 | 46.0 | |
| Sulphation Rate | Number Of Monitoring Points | 14 | 13 | 27 | 51 |
| | Number Of Valid Monthly Averages | 160 | 152 | 314 | 588 |

TABLE 2-1

Sulphation rates are observed at 91 points in Beijing (Table 2-1). The district and county monitoring stations manage 78 of these (14 in urban areas, 13 in inner suburbs, 51 in outer suburbs or counties); the Capital Iron and Steel Company monitoring station manages 13 sites.

There are 86 monitoring points for NO_x in Beijing (Table 2-2). Automatic continuous monitoring is carried out at 8 BMEMC stations, and manual sampling at the other points. 26 of the manual sampling stations are in urban districts or inner suburbs, 40 in outer suburbs, districts or counties and 12 operated by the Capital Iron and Steel Company monitoring station.

CO is monitored at 34 points across the city (Table 2-3), 8 automatic continuous monitoring points and 26 manual sampling points. Of the manual sampling stations, 22 are set up within the third-ring road (10 within the second-ring road, 12 between the second-ring road and the third-ring road); 4 between the third-ring road and the planned fourth-ring road.

O₃ and IP are monitored at BMEMC's 8 automatic continuous substations.

The Yan Shan Petrochemistry Head Company monitoring station monitors H₂S at 6 locations near its facilities.

There are 96 dust-fall monitoring points in Beijing. 84 are district and county monitoring

NO_x Monitoring In Beijing (1988)

| AUTOMATIC MONITORING | | | MANUAL SAMPLING | | | | |
|------------------------------------|-------------|------------------------------------|--|-------------------|---------------------------------------|---------------|------------------------------------|
| | SUBSTATIONS | VALID DAILY AVERAGE CONCENTRATIONS | | MONITORING POINTS | NUMBER OF MONITORING DAYS | VALID SAMPLES | VALID DAILY AVERAGE CONCENTRATIONS |
| Urban Areas & Inner Suburbs | 7 | 1881 | Traffic Within The Planned 4th-Ring Road | 26 | 1st 5 days of each quarter (20 total) | 2040 | 510 |
| Urban Area | 3 | 779 | | | | | |
| Inner Suburbs | 4 | 1102 | Within Third-Ring Road | 22 | June 7-11 | 1728 | 432 |
| | | | Within 2nd-Ring Road | 10 | Sept. 6-10 | 784 | 196 |
| Outer Suburbs, Districts, Counties | | | 2nd-Ring Road To 3rd-Ring Road | 12 | Dec. 6-10 | 944 | 236 |
| Ding Tomb (clean Point) | 1 | 262 | 3rd To The Planned 4th-Ring Road | 4 | | 312 | 78 |
| | | | Outer Suburbs, Districts, Counties | 10 | | 3144 | 786 |
| | | | Mentougou | 3 | | 240 | 60 |
| | | | Daxing | 1 | | 304 | 76 |
| | | | Changning | 3 | | 240 | 60 |
| | | | Tong Xian | 4 | | 320 | 80 |
| | | | Fangshan | 6 | | 480 | 120 |
| | | | Shunyi | 4 | | 320 | 80 |
| | | | Miyun | 3 | | 240 | 60 |
| | | | Pinggu | 4 | | 300 | 75 |
| | | | Yangqing | 4 | | 300 | 75 |
| | | | Ding Tomb (Clean Point) | 1 | | 80 | 20 |
| | | | Huairou | 4 | | 320 | 80 |
| TOTAL | 8 | 2143 | TOTAL | 66 | | 5484 | 1296 |

TABLE 2-2

stations; the Capital Iron and Steel Company monitoring station manages another 12.

There are 4 TSP monitoring points in Beijing's four WHO districts (industrial, commercial, residential and sanitation), managed by the municipal sanitation and antiepidemic station.

There are 2 monitoring points for atmospheric rainfall; one is on the premises of BMEMC and the other in Daxing county.

CO Monitoring In Beijing (1988)

| AUTOMATIC MONITORING | | | MANUAL SAMPLING | | | | |
|------------------------------------|-------------|------------------------------------|--|------------------|---------------------------------------|--------------|-----------------------------------|
| | SUBSTATIONS | VALID DAILY AVERAGE CONCENTRATIONS | | MONITORING POINT | MONITORING DAYS | VALID SAMPLE | VALID DAILY AVERAGE CONCENTRATION |
| Urban Area And Inner Suburbs | 7 | 1854 | Traffic Environment Within The Planned 4th-Ring Road | 26 | 1st 5 days of each quarter (20 total) | 1530 | 510 |
| Urban Area | 3 | 832 | | | | | |
| Inner Suburbs | 4 | 1022 | In 3rd-Ring Road | 22 | Quarterly | 1290 | 430 |
| | | | In 2nd-Ring Road | 10 | June 7 | 582 | 194 |
| Inner Suburbs, Districts, Counties | | | 2nd-Ring Road To 3rd-Ring Road | 12 | to June 11 | 708 | 236 |
| | | | 3rd-Ring Road To | | Sept. 6-10 | | |
| Ting Tomb | 1 | 246 | The Planned 4th-Ring Road | 4 | Dec. 6-10 | 240 | 80 |
| TOTAL | 8 | 2100 | TOTAL | 26 | | 1530 | 510 |

TABLE 2-3

Monitoring Methods and Sampling Frequency Except for the 8 automatic air quality monitoring substations, monitoring at the manual sampling points is carried out by scheduled sampling and evaluating collected samples at the lab. Sampling frequency is determined by analysis of data gathered from the automatic monitoring instruments, compared to the manual sampling results. The combination of manual and automatic continuous monitoring increases the area covered, providing a reasonably accurate evaluation while saving a significant amount in capital construction, maintenance and operation costs.

Data Transmission And Analysis Data from the automatic substations is transmitted to the central station through a dedicated radio communications network and input into the mainframe as tables. After the data is examined and analyzed, BMEPB and other departments issue monthly, quarterly and annual reports.

Vehicle Exhaust In addition to the routine air pollution monitoring system, BMEPB and the district and county monitoring stations monitor automobile emissions; BMEPB also monitors 200 experimental vehicles equipped with exhaust purification equipment.

Manual sampling frequency:

- SO₂, NO_x and CO: 4 times a year (March, June, September and December, for 5 days at

the beginning of the month; 24-hour continuous sampling every other day at the WHO monitoring sites).

- Sulphation rate: measured by the alkalization method once a month.
- H₂S: continuous monthly sampling for 3 days at the beginning of the month;
- Dust: once a month, sampling for a whole month;
- IP: continuous sampling each month for 10 days; Pb and Bap in IP are analyzed at the same time;
- TSP: 24-hour continuous sampling every other day;
- Rainfall: tested for pH, conductivity and chemical components after every rain or snow.

Ambient Water Quality Monitoring

Beijing is located in the valley of the Haihe River. The city receives less rain than the eastern half of the country. Some 60 rivers or streams flow within the city. Since 1949, 84 large, medium-sized and small reservoirs have been built, with a total storage capacity of 71.86 hundred million m³. 70 percent of Beijing's urban and inner-suburb groundwater is in the western and south-west suburbs. This has been heavily tapped for many years and water quality is poor; the water table has descended and pollutants in untreated industrial and domestic wastewater seep into the aquifer through rivers, canals, ditches, sewers, seepage pits and irrigation, hardening the water and increasing the nitrate content. Protecting water quality, especially drinking water, is the focus of water monitoring.

Surface Water Monitoring Points 64.8 percent (10,400 k₂) of Beijing's surface water is in the mountainous areas and 35.2 percent in the plains (6,400 k₂). BMEMC surveyed hydrologic characteristics of the rivers, lakes and reservoirs, the distribution of pollution sources in Beijing, and factors such as controllability, representivity, comparability with historic data, regional status, self-purification capacity and dispersion, then identified spots for monitoring points.

There are 204 surface water monitoring points in Beijing. 50 are in Miyun county, upstream from Beijing's main water sources, Huairou, Yangqing and Pinggu counties and the water source conservation areas of the Haidian and Mentougou districts; 23 are in the tourist zones in Haidian and Xicheng Districts; 54 are in industrial areas and downstream of the city's industrial and domestic wastewater sources (Shijingshan, Fengtai, Chaoyang, Daxing and Tongxian Counties).

Surface water monitoring is managed jointly by BMEMC and the 18 district and county EPBs. In 1990 82 rivers or river sections, totalling 2100 k² (77.8 percent of Beijing's total), were monitored.

18 reservoirs, with a storage capacity of 70.60 hundred million m³, or 98.4 percent of Beijing's total storage capacity, are monitored. 19 lakes, with a capacity is 10.375 million m³, some 90.9 percent of total capacity, are also monitored.

Monitoring Techniques And Frequency Samples are manually gathered and sent to the labs for analysis. Regular monitoring is done 4 times a year, in the dry season (April and May) and rainy season (July and August).

Parameters Measured More than 20 parameters are measured, on various schedules. These include: water temperature, color, odor, PH, SS, COD, hardness, DO, BOD(5), ammonia nitrogen, nitrate nitrogen, volatile phenol, cyanide, heavy metal, oils, total phosphorus, total nitrogen, conductivity and turbidity. Surface water phenol, cyanogen, mercury chromium and arsenic are monitored only at certain locations, once in the dry season and once in the rainy season.

Biological Monitoring The biological status of a water body directly reflects environmental quality, and therefore BMEMC monitors certain water bodies. Stationary monitoring points have been established up and biological samples are collected in certain seasons. Through identification and analysis of species present and their changing circumstances, water quality can be assessed. Work completed includes investigations of eutrophication in lakes, reservoir hygiene indexes and investigations finding that there are no large biological belts in certain rivers.

Groundwater Monitoring Beijing contains rich, if polluted, groundwater resources. Groundwater monitoring is jointly done by the Beijing Hydrogeology Company, the Beijing Sanitation and Antiepidemic Station and the Beijing Running Water Company. Since 1973, a network of groundwater monitoring points has been created, surveying regional water quality. Extra monitoring stations are located near drinking water sources and significant pollution sources. At present there are 562 groundwater monitoring wells, 306 in urban areas and inner suburbs and 256 in the outer suburbs and counties, collecting samples in dry and rainy seasons. More than 20 parameters are measured, including hardness, nitrate, sulfate, chloride, and heavy metals. The monitoring data and materials are reported to BMEMC annually and incorporated into the annual environmental quality yearbooks.

Noise Monitoring Beijing residents increasingly are complaining about noise pollution—50 percent of their letters and calls of complaint address this. BMEMC has established a noise monitoring system consisting of:

- Monitoring points across the city (287 monitoring stations, 95 in urban areas and 192 in the inner suburbs), assessing the average amount of noise in Beijing and the different districts. The monitoring work is carried out jointly by BMEMC and the 8 district monitoring substations. Noise monitoring is conducted from October to November each year.
- Traffic noise monitoring stations in urban areas or inner suburbs (469 monitoring stations, 129 in urban areas, 167 in inner suburbs, 173 in the outer suburbs and counties). Traffic is monitored for 9 days between October and November of each year.

BMEMC and some district monitoring stations also do some noise monitoring as part of the city's environmental master plan. For the last three years they have monitored noise from firework displays on the eve of the Spring Festival. 6 monitoring points were established in the affected residential districts, 4 in urban areas and 2 in the near suburbs.

POLLUTION SOURCE MONITORING

Beijing's industrial development has greatly impacted urban construction and development and environmental quality. In Beijing, there are 9000 industrial enterprises, of all sizes, representing various trades and professions. These include 179 large enterprises, 307 medium-sized ones and 1643 municipal or state enterprises. According to NEPA's "3000 Major Pollution-Causing Enterprises In China", Beijing contains 45 major sources of industrial wastewater and 55 major sources of industrial waste gases. Industrial pollution source monitoring in Beijing is presently done by enterprise, industry, and district and county monitoring facilities. BMEMC irregularly monitors a small number of outstanding industrial pollution sources, and manages arbitration monitoring.

Enterprise monitoring stations report their data monthly to their administering EPB, which also monitors key pollution sources within its district. In 1990, the 18 district and county EPBs monitored 1818 significant industrial pollution sources (404 in urban areas, 886 in the inner suburbs and 528 in the outer suburbs or counties). In addition, 550 kilns were monitored (110 in urban areas, 103 in inner suburbs and 337 in the outer suburbs or counties).

TECHNICAL SUPPORT FOR ENVIRONMENTAL MANAGEMENT

China's environmental management is based on monitoring and measurement. The Beijing environmental monitoring system provides technical support and service through the following features:

Environmental Responsibilities

BMEMC and the district and county EPBs survey environmental quality in their district through analysis of monitoring data, helping enforce existing environmental laws. They then provide the appropriate governmental departments with information needed to draft new environmental protection objectives and revise the municipal work plan.

Reducing Industrial Pollution at the Source and Pollution Licensing

Monitoring stations at the various levels must verify reports on discharges from pollution sources, so that a permissible pollution load, within the local environment's carrying capacity can be distributed between a region's industries. After experiments beginning in 1988, BMEPB has begun issuing licenses to industries, entitling them to discharge a limited amount of emissions.

Under BMEPB supervision, in 1988 the First Light Industrial Corporation, the Chemical Industrial Corporation and the Textile Industrial Corporation experimented with controlling at the factory level COD discharges in industrial wastewater. By 1990, between the three enterprises total industrial output value increased by 1.9 percent, while average COD discharges reduced by 8.16 percent, proving that pollution could be reduced without decreasing production.

The participating enterprises paid close attention to the research, development and application of sampling and measuring instruments, conducted research on wastewater discharge laws and optimum monitoring frequency, and established a integrated monitoring management system, measurably controlling emissions. Since 1991, these enterprises have been experimenting with total control of gaseous emissions.

In 1989, BMEPB began to issue regular pollution control permits to other Beijing enterprises. The Yongding River is Beijing's most important source of drinking water. BMEMC and Mentougou EPB monitoring suggests that in the two years since these permits were issued 370 tons of COD discharge and 220 tons of SSI discharge have been kept out of the river, protecting water quality and helping BMEMC to control other emissions and clean up other river basins.

Pollution Abatement Deadlines

The monitoring stations at the various levels help enterprises develop pollution abatement plans and ensure that they are completed on schedule. BMEMC also supervises the San Tong Shi (measures to prevent and mitigate pollution must be designed and implemented simultaneously with the main project) system, and monitors state-approved construction projects, while the district and county EPBs in turn clear projects approved by the district or county government.

Environmental Impact Assessments

BMEMC and the district and county EPBs supervise the assessment of present environmental status and potential environmental impacts surrounding construction project, quality assurance, and certify the environmental impact report forms that the enterprises must submit.

Excess Pollution Discharges Fees

The district and county EPBs and the department, trade and profession monitoring stations monitor pollution sources on which pollutant discharge fees are imposed, assessing the production process, measuring effluents, their concentrations, the amount the facility is permitted to discharge and the results of abatement procedures and equipment.

ENVIRONMENTAL MONITORING RESEARCH

Scientific research is the foundation of environmental monitoring. To do the most effective job possible, BMEMC must pay attention to both scientific research and monitoring. Research strengthens a monitoring organization's technical reserves and makes the monitoring work more comprehensive.

For the past several years, in addition to research for NEPA, the Beijing Municipal Science And Technology Commission and the Beijing Municipal Administration Commission, BMEMC has conducted research projects of its own, allotting 30 percent to 40 percent of its research budget and 5 percent to 10 percent of its operating expenses for this. Since 1974 BMEMC has completed almost 100 scientific research projects, of which 2 won national prizes and 22 won

ministry or municipal prizes.

This research has led to improved monitoring quality, by producing greater amounts of reliable data, bolstering environmental management and strategic planning and improving service quality. New and improved monitoring methods have been developed, intellectual resources strengthened by the rapidly expanding scope of work, and a contingent of skilled managerial, technical and research personnel has been garnered.

Improving Monitoring Quality

An integrated environmental monitoring system has yet not been established in China, and many urgent monitoring problems must first be solved. Further research on monitoring quality is needed as soon as possible.

Standardization Of Monitoring Methods In the 1970s, NEPA entrusted BMEMC and the Environmental Chemistry Institute (Chinese Academy Of Sciences) with the standardization of monitoring and analytical methods. BMEMC developed a standardized program, subsequently published as "Environmental Monitoring Analytical Methods", collecting the work of hundreds of analysts from monitoring and research units, colleges and universities. This research filled a substantial gap in standardized monitoring and analytical methods.

Research And Testing of Analytical Methods BMEMC organized testing of wastewater and waste gases criteria by EPBs, industry monitoring sections and other Beijing environmental protection offices. The resulting standardized methods became the foundation for pollution source monitoring, the pollution discharge fee system and arbitration standards. BMEMC is presently researching quality assurance techniques and improved pollution source monitoring.

Improved Techniques and Technology BMEMC organized and participated in infrared remote sensing and color photography monitoring of the Guanting Reservoir, the Miyun reservoir, and Beijing's urban areas and inner suburbs, to map the distribution of garbage and smokestacks.

Since the early 1980s, a GC/MS has been used to analyze organic components in groundwater, surface water, pollution sources, flyash and other media, to identify their composition and potential harm.

Improvement of the Automatic Air Quality Monitoring System Since the establishment of Beijing's Automatic Air Quality Monitoring System, continuous research has improved its instruments, software and quality control. The System has been operating for over 7 years, but its annual data capture rate is still over 75 percent. System data is comparable to international standards. BMEMC has compiled a quality assurance manual for a system of this nature, and helped design, install and adjust a municipal automatic air monitoring system for Zhengzhou, adjusted instruments for the city of Anshan, designed and adjusted a mobile automatic air quality monitoring station for the Qing Dao pottery works, and trained technical staff in quality control and maintenance of such a system in Shanghai, Suzhou, Harebin, Shenyang and Macao.

The Dispersion Model Of Atmospheric Pollutants

Environmental monitoring is only the first stage of environmental protection, because raw monitoring data does not provide very much insight. The monitoring data must be thoroughly studied to show where environmental management is needed and what will work best. BMEMC research on pollution prediction and forecasting led to the creation of three models, used to forecast SO₂ concentrations, assess the distribution of various pollutants across the city, and forecast changes in pollution sources and trends under different control scenarios.

As part of work of total pollution emissions control BMEMC researched the total control of pollutants in the canyon section of the Yongding river, and the total control of atmospheric pollutants in Shijingshan County. BMEMC has also studied management measures to control emissions, particularly pollution discharge licenses and fees, and changing pollution control theory from simple concentration control to total emissions control.

To more effectively protect drinking water sources, BMEMC studied the Miyun Reservoir and tourism's effects on its water quality, the effects of aquaculture on drinking water sources, and the environmental impacts of an important iron mine in Miyun County. The effects of the last had been long disputed between the ministries concerned, but BMEMC research led to effective strategies.

Development Of New Environmental Monitoring Realms

Creating a Solid Waste Monitoring System BMEMC has studied for several years the status and sources of hazardous solid waste in Beijing, its toxicity and other environmental effects, suitable sampling and monitoring methods and feasible control measures. A solid waste monitoring system is being established based on these studies.

Listing Priority Water Pollutants In association with other organizations, including China National Environmental Monitoring Center, BMEMC has developed a national list of priority water pollutants, to be used to draft new legislation and a code of preferred monitoring techniques and control measures.

Researching Environmental Criteria BMEMC has conducted research on odor measurement methods and associated environmental criteria, developing one more category for pollution prevention and elimination required by environmental impact assessments of construction projects.

Listing Priority Hazardous Chemicals In association with NEPA, BMEMC studied industrial chemicals used in Beijing, and monitoring procedures for the more hazardous. BMEMC has since issued an inventory of priority hazardous chemicals used in Beijing.

Additionally BMEMC has undertaken research in standard materials, simple on-location monitoring methods and the development of instrumental facilities.

EMERGENCY MONITORING

BMEMC helps investigate pollutant incidents in Beijing, and arbitrates pollution disputes. The monitoring stations in the area of the incident provide the arbitration with data and participate in the investigation.

ESTABLISHMENT OF THE ENVIRONMENTAL MONITORING LABS

TASKS AND DEVELOPMENT OF THE ENVIRONMENTAL MONITORING LABS

Basic Capability in Environmental Monitoring

The basic procedures of monitoring environmental pollutants are monitoring, and analysis of collected field samples.

Field Monitoring Pollutants in ambient air and water vary strongly with time and space. Direct field monitoring is crucial to timely evaluation of the ambient environment. Though pollution parameters measured directly in the field are limited, in the last decade many field monitoring techniques and equipment have been developed, rapidly reporting data from the field. Examples include the portable water quality monitor, which measures pH, humidity, dissolved oxygen (DO), reduction oxidation potential and turbidity; the portable water quality chemical examination case, which also measures these parameters, as well as halogen, nitrate, sulfate and some metal ions; the portable flue gas measuring meter, which measures SO₂, CO, NO and darkness in stack effluents; the portable auto-exhaust measuring meter, which measures CO, HC, and particles in auto emissions; and the portable gas detector tube, which measures hazardous gases in factory smoke.

The portable field monitors are particularly suitable for unstable parameters like DO or turbidity. The simpler portable meters are generally used, but their findings are often less than accurate and are not legally binding. These meters generally are used in preliminary pollution investigations, immediate investigations of pollution incidents and supplements to routine monitoring.

Continuous monitoring by the Automatic Monitoring Systems The Automatic Monitoring System consists of stationary field monitoring stations (including sampling systems and continuous monitoring instruments) and a computerized communication system. The Automatic Ambient Air Quality Monitoring System continuously measures ambient SO₂, NO_x, CO and O₃ and rapidly reports real-time data findings. The automatic water quality monitoring system continuously measures pH, temperature, conductivity, reduction-oxidation potential, dissolved oxygen, turbidity, COD, ammonia, nitrogen, nitrate and chloride in rivers from sewage treatment plant effluent, and rapidly reports real-time water quality data. Automatic monitoring systems are preferred because they offer better time and space resolution, and the data reported are far more accurate and reliable. However, investment and operating costs are high and the parameters which can be measured limited. Where it is possible to establish such a system, it is generally used to measure certain strategic parameters.

Remote monitoring Remote monitoring and sensing samples do not need to be manually

collected, as the device directly collects pollution data from the water surface or atmosphere over an extensive region. Atmospheric smoke, fog, CO, NO₂, SO₂ and O₃, aquatic thermal and petroleum pollution, vegetation changes, and salification, alkalization, erosion and desertification are measured by remote monitoring. The status of a sizable region can be quickly assessed.

However, these techniques are limited: they only determine the relative concentrations of pollutants, not absolute concentrations; their sensitivity and the parameters that can be measured are limited; the collected data must be extensively analyzed. There is no indication that remote monitoring will completely replace manual sampling. Still, the broad range, high speed and low cost of these techniques make them very useful when surveying relative pollution levels across an extensive region and tracking the dispersion of emissions.

Analysis of field samples Pollution parameters that can be directly measured in the field are limited, and automatic screening does not totally fill environmental monitoring requirements. For example, in 1977, USEPA identified 129 priority water pollutants, falling into 65 categories and stemming from 21 types of industrial point pollution sources. Of these, 114 were organic pollutants, 13 were inorganic metals and 2 were other inorganic substances.

In the 1980s China issued "The Comprehensive Discharge Standard Of Sewage", establishing criteria for 31 pollutants, "The Environmental Quality Standard Of Surface Water", outlining criteria for 30 pollutants, "The Hygienic Standard Of Domestic Drinking Water", marking 38 pollution indices, and "The Water Quality Standard Of Farm Irrigation", establishing 22 indexes.

With advances in industry and agriculture, explosive growth in new varieties of chemicals, increasingly thorough study in epidemiology and improved monitoring techniques, parameters monitored are increasing continuously. Laboratories with the skills and equipment to monitor these are crucial to monitoring and environmental impact assessment.

The Environmental Monitoring Labs

The main task of a regional environmental monitoring center is routine monitoring of ambient air, water, soil, solid wastes, pollutants from various sources, noise and electromagnetic radiation. The laboratory should be comprehensive and multifunctional, including an analytical chemistry lab, a biology lab, a physics lab and an electronics lab. Of these, the chemistry lab is the most important and should be able to quantitatively and qualitatively analyze different inorganic and organic matters, collect samples, pretreat these for storage, and undertake quality assurance.

BMEMC is responsible for organization, technology and data acquisition, training, assessment, and quality control of the monitoring network, district and county monitoring stations, and industrial monitoring units, as well as routine and emergency monitoring. BMEMC plays a leading role in developing technical competence in environmental monitoring. The environmental monitoring labs should therefore be sized and skilled as appropriate to their mission.

BMEMC constituent labs include a water quality monitoring lab, an air monitoring lab, an

automatic ambient air quality monitoring lab (the System), an automobile exhaust monitoring lab, a solid waste monitoring lab, an instrumentation analysis division (a central lab containing large and sophisticated analytical instruments, which are shared with other labs and several other organizations), a biological monitoring lab, a noise, vibration and electromagnetic radiation monitoring lab, a quality control and monitoring network division, and a data collection and assessment division.

Development Of The Environmental Monitoring Labs

In 1974, there were no laws or regulations on environmental monitoring, technical specifications or standardized monitoring analytical methods. BMEMC was not established with a specific agenda, but evolved, falling into three stages:

1974-1980: The Establishment of BMEMC.

Pollution status was unknown, and therefore the primary monitoring tasks were to determine the environmental status quo, initiate routine monitoring and monitor the most serious pollutants (atmospheric SO₂ and TSP; aquatic BOD, COD, phenol, cyanogen, arsenic, mercury and chromium) in Beijing.

BMEMC rented lab space and began investigations, developing their work plan, facilities, equipment and processes. The primary monitoring technique was in-lab chemical analysis of field samples. Investment emphasized civil engineering and the most basic water and air monitoring facilities, such as different kinds of samplers, glassware for chemical analysis, reagents, balance, colorimeter and acid analyses. Basic analytical instruments, such as a spectrophotometer, a gas chromatograph and an atomic absorption spectrophotometer were eventually acquired.

This helped Beijing and China develop standard water and air monitoring analytical methods and technical specifications for monitoring point allocation, and sampling periods and frequency.

1980-1985 Creation of the Monitoring Network

Based on the original BMEMC laboratory and the establishment of monitoring methods and technical specifications, the monitoring network was strengthened. District, county, department and enterprise monitoring stations were established, extending monitoring over a greater region.

BMEMC improved its quality assurance and quality control work, and provided technical instruction, training, exams and assessments to the district and county monitoring stations. Parameters monitored continuously increased. In addition to air and water monitoring, soil, solid waste, biological and noise monitoring were added to BMEMC's responsibilities, and the appropriate labs created.

With the increasing list of parameters monitored, more analytical instruments were needed. To avoid duplication of certain basic facilities, a central laboratory equipped with large and sophisticated analytical instruments was established, to be used for water quality, atmosphere,

soil and solid waste monitoring. An automatic air quality monitoring system enhanced monitoring technology and further increase measured parameters. Investment focussed on the establishment of district and county monitoring station labs and acquiring additional basic facilities for BMEMC labs.

1985- Becoming a Research Center

After a monitoring network of 18 district and county monitoring stations in and near Beijing was completed, and eight automatic ambient air quality monitoring substations were established, air and water was routinely monitored by this system.

BMEMC's direct monitoring work was greatly reduced. Emphasis shifted to improving monitoring, tightened monitoring of emissions and increased awareness that environmental monitoring should serve environmental management. Additional monitoring facilities, including an emissions source monitoring group, an automobile emissions monitoring lab and a noise, vibration and electromagnetic radiation monitoring lab were created. The central lab acquired more sophisticated analytical instruments, additional facilities for spectral analysis of organic and inorganic matters, and, in the biological monitoring lab, toxicity test facilities. Investment focussed on acquiring additional basic facilities and lab devices, facilities and devices for pollution source monitoring and sophisticated analytical instruments (GC/MS, ICP etc).

Investment in environmental monitoring research projects was also increased. BMEMC played a central role in developing technical skills in the Beijing environmental monitoring network.

The Environmental Monitoring Labs' Tasks

The Water Quality Monitoring Lab This lab carries out routine and emergency monitoring of surface water, groundwater, drinking water and industrial wastewater. More than 40 parameters in surface water are monitored, especially pH, conductivity, DO, SS, color, COD, BOD, TOC, trichloride, phenol, CN, AS, HG, Cr, phosphorus, heavy metal, and oils; groundwater is monitored for some 40 parameters, particularly hardness, heavy metals, AS, HG, phenol, pesticides, benzene, nitrobenzene, aminobenzene, developer, formaldehyde, and caprolactam. This lab conducts research on analytical methods for pollutants which are not presently monitored, on the laws of transport and transformation of pollutants and on total emissions control. It also prepares ambient water quality assessment and assesses the effect of control measures. This lab also carries out technical training and consultation for district and county monitoring stations.

The Atmospheric Air Monitoring Lab More than 30 pollutants are monitored by this lab, including SO₂, NO_x, CO, F, H₂S, CS₂, HCN, HCL, NH₃, sulfurous smog, phenol, benzene, formaldehyde, THC, non-methane hydrocarbons, BAP, TSP, dust, flue dust, fly ash, AS, Cr, Pb, Cd, Mn, Fe, Ni and Be. Rain is routinely monitored by this lab, for pH, conductivity, SO₄, NO₃, CL, NH₄, K⁺, Na⁺ and Ca⁺². This lab also conducts research on analytical methods and monitoring technology, total emissions control and emission dispersion. Assessment of ambient air quality assessment and the effects of control measures are prepared here. Technical training

and consultation for the district and county monitoring stations are also managed here.

The Automatic Ambient Air Quality Monitoring Lab This lab carries out continuous real-time monitoring year round through the central station and the 8 substations. The automatic monitoring system measures 11 parameters, including atmospheric SO₂, NO_x, CO, O₃, IP₁₀, and meteorologic factors like humidity, temperature and wind direction and speed. This lab also researches pollution models and forecasting and develops monitoring instruments.

The Automobile Exhaust Monitoring Lab This lab measures CO, HC, smoke, dust and Pb in motor vehicle exhaust, makes some highway examinations, and assesses auto emission reduction measures.

The Soil And Solid Waste Monitoring Lab This lab monitors crops and investigates pollution caused by domestic refuse and industrial wastes. More than 10 parameters are measured, particularly soil pH, heavy metals in soil and pesticide residues. At the same time, research is conducted here on the background level of soil and grains, and on the environmental consequences of landfilling wastes. This lab also assesses the effect of waste disposal control measures.

The Central Lab This lab, housing the more sophisticated instruments, provides technical support for monitoring water, particles, soil and wastes. It makes qualitative and quantitative analysis of multi-component organic and inorganic pollutants, and conducts research on analytical methods and monitoring technologies. Research tasks needing sophisticated analytical instruments are done here, as well as technical training and consultation for the district and county monitoring stations.

The Biological Monitoring Lab This lab routinely monitors bacteria and colibocillus, investigates fish poisonings for water pollution and monitors organisms whose status reflects water quality.

The Noise, Vibration And Electromagnetic Radiation Monitoring Lab This lab investigates and monitors ambient traffic noise, industrial noise, vibrations and certain types of electromagnetic radiation. Research on noise monitoring technology, the effects of noise and technical training and consultation for district and county monitoring stations are also conducted here.

THE ENVIRONMENTAL MONITORING LABS' EQUIPMENT

Principles for Selecting Lab Equipment

The instrumental facilities selected for an environmental pollution analysis lab should provide a good level of productive use for the smallest reasonable investment. This is technically complicated, but the following principles help the process:

- Determine the nature and scope of the lab's function: the parameters to be measured;

monitoring frequency and volume, including parameters mandated by national environmental standards; priority area pollutants; parameters not covered by national environmental standards but will be measured for another reason .

- Analytical instruments selected should meet national, district or departmental analytical and reference standards.
- Be aware of the present situation and emerging trends in analytical instruments, domestic and foreign, so that unobsolescent and reliable instruments can be selected. Reliability is the most important factor.
- The lab's master plan should provide for buying the most basic instrumental facilities first, then increasing investment as the work plan develops.
- New instruments must be compatible with older equipment to keep monitoring operations continuous; the instruments should also be compatible with national and international technical specifications.
- Instruments should be considered in terms of their application to both routine monitoring and scientific research, to make full use their capabilities.
- More sophisticated instruments should be purchased only once monitoring has been ongoing for some time, so that the amount of work needed from the instrument can be estimated (if this is not large, partners able to share the instrument should be identified).
- The actual uses of the instrument are paramount. Perfection and complete modernity are unrealistic, although manufacturers are increasingly able to provide customized products.
- Particular attention should be paid to what technical service manufacturer provides, to enhance its operational life. A reasonable number of spare parts should be kept on hand in case technical service cannot be gotten rapidly.
- Careful consideration must be given to the instrumental purchasing schedule. At present, the rate of development and renewal of instruments is very fast; if instruments are purchased too early and cannot be put into operation immediately, capital lies idle and the instruments will become obsolescent before their useful life is over.

Basic Laboratory Facilities And Devices

In addition to the basic facilities and devices (Table 3-1), an atomic spectrometer (atomic absorption spectrophotometer, atomic emission spectrometer), a spectrophotometer (visible and ultra-violet spectrophotometer) and a chromatograph (gas chromatograph, liquid chromatograph and ion chromatograph) may be regarded as an environmental monitoring analytical lab's fundamental needs. With this equipment most pollutants can be measured.

Investment In Lab Facilities

Since BMEMC began operations in 1974, Y8.26 million has^{NO.} been invested in equipment, of which¹⁻¹ Y3.22 million paid¹⁻² for highly¹⁻⁴ sophisticated¹⁻⁵ analytical instruments,¹⁻⁶ and Y5.04 million¹⁻⁷ bought other special-²⁻¹ purpose instruments,²⁻² universal instruments² and other devices.³⁻¹ The large and³⁻² sophisticated³⁻³ instruments are³⁻⁴ mainly used for³⁻⁵ scientific research,³⁻⁶ but also used for³⁻⁷ some of the³⁻⁸ monitoring work,³⁻⁹ especially monitoring³⁻¹⁰ pollution emergencies.³⁻¹¹ The GC/MC (gas⁵⁻¹ chromatograph/mass⁵⁻² spectroscopy) in the⁵⁻³ central lab is mainly⁵⁻⁴ used for the⁵⁻⁵ separation and⁶⁻¹ qualitative and⁶⁻² quantitative analyses⁶⁻³ of unknown organic⁶⁻⁴ pollutants. The⁶⁻⁵ GC/MS can also⁶⁻⁶ detect some 1500⁷⁻¹ water-borne organic⁷⁻² pollutants, and 40⁷⁻³ kinds of poly-aromatic hydrocarbons in suspended particulate matter. This instrument was used for research on organic pollutants, and management of toxic and hazardous chemicals, which could not be done on other instruments.

Basic Facilities And Devices Of The Environmental Monitoring Labs

| Name | Quantity |
|--|----------|
| UNIVERSAL ANALYTICAL INSTRUMENTS | |
| atomic absorption spectrophotometer (AAS) | 4 |
| gas chromatograph (GC) | 8 |
| liquid chromatograph (LC) | 1 |
| ion chromatograph (IC) | 2 |
| ultra-violet spectrophotometer (UV) | 4 |
| fluorescence spectrophotometer (FR) | 2 |
| infrared spectrophotometer (IR) | 1 |
| visible spectrophotometer (VIS) | 6 |
| HIGH-TECHNOLOGY INSTRUMENTS | |
| plasma-induced emission spectrometer (ICP) | 1 |
| gas chromatograph-mass spectroscopy (GC-MS) | 1 |
| SPECIAL-PURPOSE ANALYTICAL INSTRUMENTS | |
| water pollution meter for comprehensive parameters | 1 |
| turbidimeter | 1 |
| dissolved oxygen meter | 3 |
| BOD meter | 2 |
| oil concentration analyzer | 3 |
| mercury meter | 2 |
| TOC analyzer | 1 |
| SO ₂ analyzer (detector) | 1 |
| NO analyzer (detector) | 1 |
| CO analyzer (detector) | 2 |
| fly ash monitor | 2 |
| auto-exhaust analyzer | 5 |
| smoke density meter | 5 |
| BASIC LAB EQUIPMENT AND FACILITIES | |
| balance, thermostat, refrigerator, vibrator | several |
| TESTING METERS | |
| noise meter | 4 |
| and vibration meter | 1 |
| noise frequency analyzer | 1 |
| electromagnetic radiation meter | 1 |
| electronics meter | several |
| SAMPLING DEVICES | |
| water sampler | several |
| soil sampler | several |
| biology sampler | several |
| air sampler | several |
| particle sampler | several |
| gas sampler | several |
| flue dust sampler | several |
| DATA PROCESSING EQUIPMENT | |
| personal computer (PC) | 9 |
| chart recorder | several |
| duplicator | 2 |

TABLE 3-1

The high-frequency ion emission spectral analyzer (ICP) is mainly used for the detection and quantitative analysis of unknown inorganic metal elements. 60 elements can be simultaneously determined. This instrument was used for research on the soil background level of Beijing, and

particle content, source and distribution analysis, which could not be done using other instruments. ICPs are noted for fast and simultaneous detection. When there is a great amount of routine monitoring work, an ICP can do some of the detection work done by an atomic absorption spectrophotometer. The proportion of investment by the labs varies according to the tasks and conditions for which an ICP is needed.

It was not necessary to make a large investment in such sophisticated instruments like a GC-FIR or a fluorescent x-ray spectrometer, because other organizations in Beijing with whom BMEMC cooperates have these instruments. On occasion, BMEMC has rented a GC-FIR to detect organic pollutants, and a fluorescent x-ray spectrometer, a scanning electron microscope and an ion probe to examine the constituents of aerosol particles.

Instrument depreciation maintenance expenses are not included in the total investment previously mentioned. Analytical instruments' useful life averages 15 years. About Y100,000 a year is also put into reagents, glassware and other disposable lab equipment, and Y300,000 a year is spent on the renewal of instrument spare parts and components.

STANDARD ANALYTICAL METHODS

"Careful analysis of false data" was the sarcastic comment common in Chinese environmental monitoring circles during the early 1970s. Monitoring data had been shown to be inaccurate, incomparable, and questionable. The major reasons were the lack of reliable national monitoring and analytical methods and no established quality assurance procedure. To solve this problem, NEPA commissioned BMEMC and the Environmental Chemistry Institute of Academia Sinica to develop standard monitoring and analytical methods.

The Organization

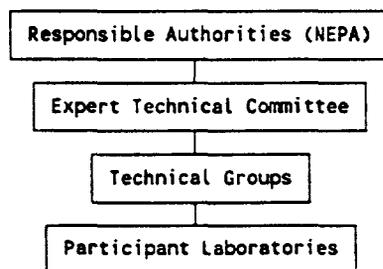


TABLE 3-3

- **Management:** Assign tasks, review and approve methods.
- **Technical Committee:** Evaluate analytical methods and determine the criteria for their accuracy, precision and detecting limits. Review the verification results, validate the methods and report to NEPA.
- **Technical Groups:** Assigned by the Expert Committee to each task. The group leader supervises the test plan design, the preparation of detailed testing procedures, the

preparation and distribution of the testing samples and reference materials, the collection of the measurement results from the participant labs, the calculation and processing of the data, and the determination of the accuracy, precision and detecting limit of the method.

- **Participating labs:** Selected by the Technical Groups. Usually, 6-10 labs are involved in each task. The labs should be familiar with Technical Group test procedures, carry out the measurements accordingly, and report the results to the Technical Group.

Standardization Procedures For Analytical Methods

The standardization procedure for an analytical method involves five stages:

- 1) Identification of a new parameter to be monitored;
- 2) Identification and investigation of a promising monitoring method;
- 3) Testing and verification of the method by multiple laboratories;
- 4) Review and acceptance as a standard analytical method
- 5) Fine-tuning of the procedure as the science develops.

Analytical Method Optimization The basic principles for the selection of analytical methods are as follows:

1. The method should be a) accurate and precise; b) free of interference, or interference, when present, should be balanced by an effective masking agent or pre-separation procedure; c) stable, to ensure reproducibility and accuracy.
2. The method should be sensitive enough to detect the pollutant at concentrations less than 1/3-1/10 of the legal standard under real-world conditions, to ascertain whether standards have been violated.
3. Equipment and reagents required by the method should be readily available to local labs throughout China. Each pollutant should be detectable by more than one technique providing comparable findings, to meet the different requirements of different labs.
4. New techniques and methods, foreign and domestic, should be promoted where possible to popularize them throughout China and raise monitoring technical levels.

A set of analytical methods, some of which had been developed in foreign countries, some in China, were selected, based on these principles.

Inter-lab Coordinated Tests Inter-lab testing is intended to determine the accuracy, precision and allowable error limits of a proposed analytical method, providing the basis for method selection, QC, and arbitration of analytical results. The test should be carried out in a representative sample of labs, using standard samples and procedures.

1. **Test design:**

Test parameters are selected and their qualitative and quantitative requirements are defined based on factors affecting the method's precision, accuracy and statistical requirements, so

that the test results reflect the best representativity and applicability.

- **Labs:** The participating labs should be randomly sampled according to statistical requirements. The Technical Group considers participating labs' regional and technical representivity. At least five labs should participate.
- **Types And Concentrations Of Samples:** The standard samples should be homogeneous and stable throughout the testing period. Usually, three concentrations, low, medium and high, are prepared, as precision often depends on the sample concentration. At least five different concentrations of the sample should be analyzed if the relationship between precision and concentration is to be established.
- **Analysts:** The lab should assign to the test analysts with moderate technical skills and practical experience in the method being used.
- **Analytical Apparatus:** Each lab should use, as far as possible, equivalent apparatus. Equipment (excluding special instruments) should not be shared between two participating analysts.
- **Analysis Frequency:** Each analyst should analyze the same sample at least twice on two different occasions.
- **Determination Times:** At least two parallel samples should not be analyzed during one parallel determination. For each lab, at least six determinations should be carried out for each sample concentration.

Based on these requirements, a method verification procedure was designed, standard samples were distributed, and coordinated tests carried out by participating labs.

2. QC Of The Coordinated Test

- **Calibration of apparatus and measuring devices**
The analysts first plots a QC chart, then analyzes the sample and two parallel QC samples. The results are examined against the QC chart.
- The Technical Group distributes a standard sample of a specific concentration to the participating labs. The labs analyze this, checking the detected concentration against that reported by the Technical Group.
- The Technical Group may, if possible, distribute a reference material to the participant labs so as to find their shortages and fill up them accordingly.

Handling of data obtained through the coordinated test The Technical Group arranges variance uniformity and average uniformity tests based on data collected from the participating labs. In-lab single-value uniformity tests should be carried out by the outliers. Precision, accuracy, detection limits, and permissible errors are calculated from this processed data.

Evaluation Of The Analytical Method The Technical Committee reviews and evaluates the verification results against the established criteria, decides whether to validate this method, and report this to the responsible agency for review and approval. The review cycle normally takes about two years.

Achievements

Analytical methods verified through these procedures were compiled into a book, Analytical Methods For Environmental Monitoring (1983). The 127 formal methods measuring 72 parameters and 27 tentative methods for 24 parameters included in this book have been endorsed by NEPA as national standardized environmental monitoring analytical methods. Since 1983, most of the water quality monitoring methods have been updated as technological and other advances have enhanced monitoring methods.

There are three important steps in standardizing an analytical method: a) the choice of a sound analytical method, b) well-organized QC procedures at all stages and c) scientific assessment of the analytical method.

Methods verified through standardized procedures play an important role in environmental monitoring and analysis in China. Their specific functions are:

1. Obtaining reliable and comparable monitoring data throughout the country.
2. Identifying a method's accuracies, precisions, allowable errors and detection limits, so that monitoring and QC are trustworthy.
3. Providing authoritative data, capable of supporting a court case.

Pollution Source Monitoring Methods: Analytical Methods For Environmental Monitoring is suitable for environmental monitoring, but Unified Analytical Methods For Source Monitoring, compiled by NEPA, is more appropriate for emissions and effluents with high pollutant concentrations and multiple interferences. Source monitoring methods are hard to verify through the standard procedure, due to the unavailability of stable standard samples representing various industrial effluents. However, within one region, such as BMG, industrial wastewater can be considered standard samples during the brief period when it is stable. NEPA, the district and county EPBs and the industrial agency labs selected several representative enterprises from various industrial sectors in the Beijing region and organized coordinated tests. The analytical methods developed through these tests are suitable for monitoring industrial wastewater in the Beijing region.

Analytical methods for new pollutants should be developed simultaneously with growing scientific knowledge of the pollutant's environmental effects. Analytical methods already established should be continuously improved to improve its sensitivity, low detection limits, high selectivity and rapid detection. A revised edition of standardized methods is published every 3-5 years. Monitoring And Analytical Methods For Water And Wastewater and Monitoring And

Analytical Methods For Air And Emissions have been issued in third editions.

QA AND QC

Monitoring data support environmental protection. Wrong data can lead to misjudgments and wrong conclusions; there is a common saying, "Wrong data are worse than none at all". A complete quality assessment (QA) system has been established to ensure that monitoring data are representative, complete, accurate, precise, comparable, and can bolster a court case.

QA Organizations And Their Responsibilities

QA management activities in China are handled at three levels: the national QA group under NEPA, the secondary QA groups at the provincial, municipal or autonomous region level, and the tertiary QA groups at the city level. In addition, special QA offices and labs have been established as part of monitoring stations.

The BMG QA Management Group comprises the BMEPB Deputy Director for Monitoring, the BMEMC Director, BMEMC QA experts and technicians, and representatives from district, county and enterprise monitoring stations. Monitoring network QA is managed by BMEMC. Daily management of QA activities is supervised by the QC & Network Office, operating out of a lab in BMEMC. In addition, other professional labs under BMEMC and monitoring stations under district, county and enterprise monitoring stations often undertake QA and QC activities in their fields.

The responsibilities of the QA Management Group are:

- Reviewing and approving QA regulations and work plans;
- Developing QC procedures; requirements;
- Compiling technical documents (monitoring specifications, manuals, guidelines);
- Supervise the development of reference material and QC samples;
- Manage technical support and personnel training for network monitoring stations;
- Certify the network and its laboratory personnel;
- Evaluate network labs; and
- Supervise arbitration of monitoring data quality disputes.

Responsibilities of the BMEMC professional labs' and district, county and enterprise monitoring stations' QA offices include:

- Manage QA activities within their fields, review QA technical plans and organize their implementation, and review QC data;
- Develop QA work plans and regulations and organize their implementation, and regularly report on QA activities to station management and the next level of monitoring stations;
- Provide QA guidance to lower-level monitoring stations and organize technical training and quality examinations; and
- Organize certification and lab evaluation.

Working Contents Under QA And QC

QA refers to the total quality management of all environmental monitoring activities, ensuring correct and reliable monitoring data. QC refers to the control of the quality of analytical operations at the labs, an important component of the QA system (Figure 3-1).

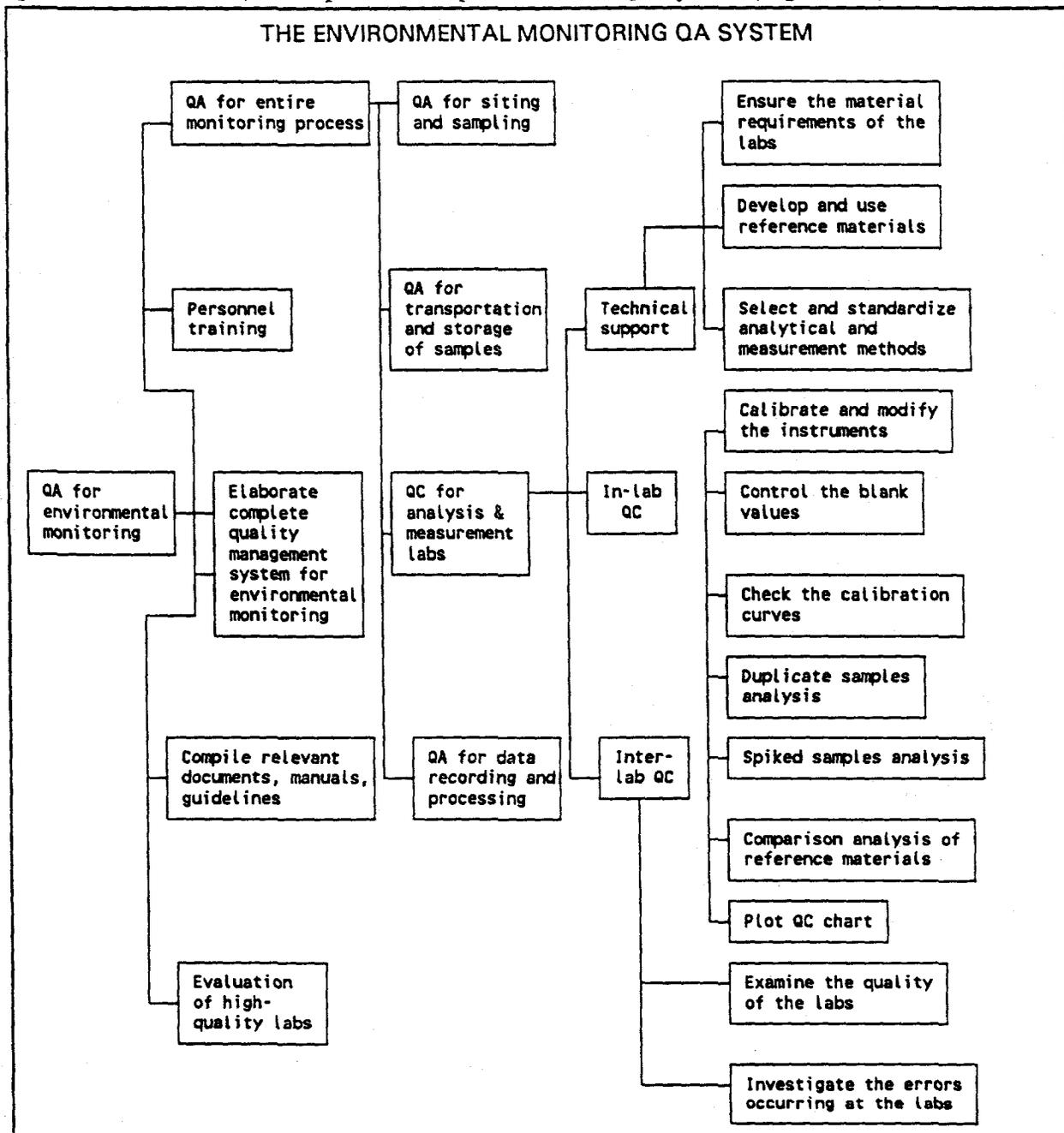


FIGURE 3-1

QA For The Whole Monitoring Process Environmental monitoring is a complex process including many factors, such as location of sampling sites, sampling frequency, transportation and preservation of samples, laboratory analysis, and the processing and recording of data.

Failure at any stage can contaminate the findings. The QA process was developed to ensure monitoring quality.

1. Sampling Sites And Samples Preservation

Monitoring data quality depends on its representivity. Monitoring site location, sampling frequency, time during which samples are collected, and methods are determined based on the monitoring objective, parameters to be monitored, pollutant properties and analytical methods as stipulated by "Technical Norms For Environmental Monitoring" and "Technical Provisions For Source Monitoring". The temporal and spatial distribution of the sampling sites should reasonably reflect the concentration levels, variation ranges and patterns of the pollutants.

The regular maintenance and calibration of sampling devices and instruments and the choice and maintenance of sample containers should be carried out according to technical provisions.

Sampling personnel should closely adhere to operating rules, fill out the sampling records, and preserve and transport the samples according to technical provisions. A specific procedure should be established for each stage.

A blank test should be made at the sampling site to identify any errors in collecting, preserving, storing or transporting samples. A random control check on the sampling procedure should be done to ensure that field personnel have followed all sample collecting provisions. Any deviations should be promptly corrected.

2. In-lab QC

The purpose of in-lab QC is to ensure that monitoring and analysis errors are controlled within allowable limits and that results achieved are reasonably precise and accurate. In-lab QC includes the standardization and calibration of instruments and equipment, blank tests and testing of the process, the plotting and review of the calibration curves, and the identification and review of the reference samples, to confirm the accuracy of analytical results. Blank test values, precision, and accuracy can also be controlled using the QC charts. These measures should enable the analysts to control analytical errors within a predictable range.

3. Inter-lab QC

The purposes of inter-lab QC are to investigate systematic errors among the labs and find their source, to improve their monitoring and analysis levels.

- All labs in the monitoring network should use national analytical methods to reduce systematic errors and ensure that the data obtained are comparable. Non-standard methods may be used if they have been tested and approved. All labs should monitor and review their analytical quality against the standard detection limits and accuracies.
- Standard samples and QC samples prepared by each lab should be tested against institutional reference samples, to confirm the value of a quantity.

- All labs in the monitoring network should participate in BMEMC's annual examinations and analysis of unknown samples. Certificates will be given to qualifying analysts and uncertified analysts will be barred from monitoring, analysis or reporting data.
- Systematic errors between labs should be promptly investigated.

4. Calculation And Processing Of The Monitoring Data

The monitoring data should be calculated and processed according to "The Technical Norms For Environmental Monitoring" and environmental monitoring QA manuals.

All labs should submit corresponding QC data to the QC managers simultaneously with reporting analytical data. The analytical data are validated only when the QC data pass.

In addition to these QA measures, other QA activities include:

Development of a complete quality management system. "The Quality Management System For Environmental Monitoring In Beijing Municipality", outlines the role of QA in the monitoring network and specifies standards for analysts, sampling, the preservation and transportation of samples, the management of labs, monitoring and analysis methods, the quantity and value transmission system for QA, the examination of labs' analytical quality, QC for regular monitoring and analysis, the review and management of regular analysis data, and reporting on QA. In addition, some individual labs have drafted their own standards for personnel, instrument management, lab safety, QA procedures, data review and reporting and sample maintenance. QA standards and monitoring have been enhanced by the development of these systems.

Development Of Reference Materials Reference materials are materials whose values, characteristics and composition are known and can be directly used as reference standards to calibrate instruments and evaluate measurement methods; this helps labs to gather comparable and consistent data from different regions, industrial sectors, and labs.

BMEMC has developed reference manuals for water quality, soil, crops and organisms, some of which have been adopted as national standards. In addition, BMEMC prepares QC samples for regular air and water quality monitoring.

The basic prerequisites for national primary reference materials:

- **Certification** Several labs test the material using the certified measurement method (or additional methods, if approved);
- Consistent results should be reported from all labs.;
- The material should be stable for at least one year;
- Homogeneity should be within a specific range;
- The material should be nationally certified and catalogued; and
- The material should be composed according to national provisions.

Certified reference materials can be used in instrument calibration, comparison analysis, and lab evaluations. BMEMC supplies lower level labs with national primary and secondary reference materials and QC samples.

QA Manuals The publication of QA manuals and guidelines has helped implement of QA in environmental monitoring. BMEMC participated in the publication of a number of books:

- **Books on monitoring and analytical methods**

Analytical Methods For Environmental Monitoring (1983), including monitoring and analytical methods for water, air, soil, plants, and noise pollution. The book was a collaboration between 66 organizations.

"Unified Analytical Methods For Source Monitoring: Wastewater", 1983.

"Unified Analytical Methods For Source Monitoring: Waste Gases", 1982.

"Analytical Methods For Water And Wastewater Monitoring", 1989.

"Analytical Methods For Ambient Air And Waste Gases Monitoring", 1990.

"Guidelines For Analytical Methods For Water And Wastewater Monitoring", 1990.

- **QA Manuals**

"QA Manual For Ambient Water Quality Monitoring", 1989.

"QA Manual For Ambient Air Quality Monitoring", 1989.

- **"Technical Codes For Environmental Monitoring Surface Water And Wastewater" (Vol. 1), 1986.**

"Ambient Air And Waste Gases", (Vol. 2), 1986.

"Noise", (Vol. 3), 1986

"Biological Monitoring (Water Quality)", (Vol. 4), 1986.

"Strengthening The Technical Training of Monitoring Personnel"

Rewarding High-quality Labs Labs may be judged high-quality in order to encourage and reward outstanding labs, share experiences, raise monitoring personnel quality and improve labs' monitoring quality and management. These labs are selected based on the results of quantitative examinations and assessments made by an expert examination panel, judging them on personnel quality, physical conditions, management, QA activities, and professional achievement.

THE AUTOMATIC AIR QUALITY MONITORING SYSTEM

Coal is Beijing's major industrial and domestic energy source; as much as 24 million tons of raw coal is consumed annually. This is a significant source of air pollution, especially SO₂ and TSP. Beijing's annual SO₂ average is twice as high as WHO guidelines (60 µg/m³) and in winter may reach as high as 700 µg/m³. The annual TSP average is three times higher than WHO guidelines (90 µg/m³) and during winter has been as high as 1000 µg/m³. There are 490,000 motor vehicles in Beijing; NO_x and CO pollution near major roads is significant. The daily NO₂ average is approaching the WHO guideline of 150 µg/m³. From May to October, there are 194 hours a year during which the hourly O₃ average is higher than standard, with a peak value of 290 µg/m³. There is serious potential for photochemical smog pollution.

Beijing is developing rapidly and air pollution is already very serious. Before the 1980s, only periodic manual sampling and laboratory chemical analysis of SO₂ and TSP was done in Beijing. About one hundred persons were needed to carry out a city-wide air quality survey. This survey could be done only twice a year (once in winter, once in summer); during each survey period samples were only taken for four hours a day for five days, totalling 40 hours a year. Samples taken over such a limited period are temporally unrepresentative, and do not reflect maximum pollution levels or distribution patterns. Chemical analysis of the samples usually took two or three days, so pollution status was not promptly reflected and pollution control measures' effectiveness could not be assessed.

These measures did not provide the timely, complete, accurate, or city-wide pollution monitoring crucial to environmental management and the implementation of environment protection regulations. In 1982 NEPA decided to study the feasibility of an automatic air quality monitoring system, and named Beijing the demonstration city.

DESIGNING AN AUTOMATIC AIR QUALITY MONITORING SYSTEM FOR BEIJING

Objectives

The requisite guidelines for an automatic air quality monitoring system are:

- Evaluation of the city's air quality and comparison of this against national environmental quality standards;
- Observation of long-term variations in the city's air quality;
- Assessment of impacts caused by air pollution;
- Evaluation of pollution control measures' effectiveness;
- Application of this information to city planning; and
- Development of pollution diffusion and forecasting models.

In order to realize these goals, a system that would accurately monitor the crucial parameters and achieve representative time and space resolution, for the least cost possible, was needed.

Requirements

Parameters Monitored Beijing's air pollution is characterized by coal burning and vehicle exhaust, so the most important parameters are:

- SO₂, TSP, NO_x, CO, O₃, and meteorological factors such as wind direction and speed, temperature, and relative humidity.
- Time Resolution
Five minutes is the standard time resolution for a continuous real-time monitoring system. The hourly average is derived from twelve five-minute values, and the valid annual data capture rate should not be less than 75 percent of the theoretical annual number of data.
- Space Resolution
BMG total land area is 16807.8 km², of which the city covers 87.1 km². Beijing's population is 10.668 million, of which 2.616 million live within city limits. This large an area calls for a great many monitoring sites for comprehensive space resolution, but the enormous investment needed makes this unrealistic. It was decided that eight sites would suffice for the core Beijing Municipal Air Quality Monitoring System (System), based on guidelines for number of sites and correction factors in WHO/GEMS Air Quality Monitoring in Urban And Industrial Areas". Monitoring locations were chosen from data obtained from the 84 manual sampling monitoring sites of Beijing's 1970s monitoring network, and eight representative locations were statistically identified.

Features

The System, which began operations in 1984, was designed with the following features:

- The System is a network of 8 stationary monitoring substations (three in permanent buildings, five in movable shelters) with standard monitoring parameters and instruments (Table 4-1).
- It is a real-time monitoring system; the mainframe collects data from the substations every five minutes. The central station is informed of air quality status at any given time.
- The System is operated continuously, year-round. Large amounts of monitoring data are obtained, long-term pollution patterns displayed and areas or times of the most serious air pollution problems are noted.
- A radio/computer network controls the substations and immediately transmits data. Data is collected and processed continuously and various reports, tables, plots or other formats can be readily generated and used by administrative personnel.
- A quality assurance (QA) and technical support lab helps the System to operate dependably. The substation microprocessors automatically calibrate and correct the monitoring instruments, ensuring that the data obtained are accurate, reliable, comparable, and trackable.

- It is an automatic and unattended System needing minimal maintenance, saving large amounts of manpower.

LOCATIONS AND FEATURES OF SUBSTATIONS

| LOCATION | DISTRICT | FEATURES | SUBSTATION TYPE |
|--|----------------------------------|---|---------------------|
| 1. Ming Tombs | Scenic and historic area | Upwind of clean area; background site. | Movable shelter |
| 2. Near BMEC, No. 4, West Chegongzhuang road | Boundary of Haidian-Xicheng Dis. | Includes traffic from Xicheng & Haidian Districts; convenient for comparing data from various instruments & making studies. | Movable shelter |
| 3. Qianmen Dongdajie | Dongcheng Dis. | City center; near main roads; commercially active; dense population | Movable shelter |
| 4. Dongcheng Dis.; Dongsi Liutiao | Dongcheng Dis. | Commercially active; densely populated; many small heaters; downwind area with serious air pollution | Stationary building |
| 5. Tiantan Park (Temple of Heaven) | Chongwen Dis. | Downwind area; median & small factories; densely populated; many small winter heating stoves; serious air pollution. | Movable shelter |
| 6. Agricultural Exhibition Hall | Chaoyang Dis. | Northeast suburb; large & medium factories; many new residential blocks with central/district heating; residents will increase; | Movable shelter |
| 7. Haidian District, Huangzhuang | Haidian Dis. | Northwest suburb; many cultural, educational & scientific research institutions; population rapidly increasing; | Stationary building |
| 8. Shijingshan District, Gucheng | Shijingshan Dis. | Western suburb close to Capital Iron & Steel Corp., emitting coal-burning fumes and other gases | Stationary building |

TABLE 4-1

System Enhancement

Data collected from 1984 to 1988 was used to revise each substation's representativity, using such techniques as space correlation analysis and cluster analysis. Upon completion of the study, sites will be adjusted to achieve optimal System layout.

A mobile monitoring van was added to the System in 1990, to be used as a backup substation should a substation fail, as an additional substation if Beijing changes enough to make System layout suboptimal, or as a temporary substation in response to pollution concerns. This van played an important role during the 11th Asian Games in 1990.

Industrial enterprises have been encouraged, through Governmental subsidies, to establish monitoring substations in their plant. The data obtained by these substations are shared, through on-line communication or exchange of data diskettes, with the System's mainframe computers. By 1990, substations had been established at the Yanshan Petrochemical Corporation, the Capital Iron & Steel Corporation, and the Beijing Coking & Chemicals Plant, giving the System three

additional off-line substations.

CONFIGURATION AND INVESTMENT OF THE SYSTEM

Configuration

The System consists of three parts: local substations, the central station and a QA and technical support lab.

Substations

In each substation, air is continuously pumped through the sampling system manifold into the reaction chambers, where it is continuously monitored. Ten times every second the microprocessor at each substation collects the real-time data from each instrument and holds this data in temporary storage. Every five minutes the central station queries each substation, which sequentially transmits back the five-minute averages generated by the monitoring instruments and related information such as temperature and winds at the substation.

If needed by the central station, the substation can transmit current real-time data, retransmit past data, and perform zero and span corrections, within a specified range, on the instruments.

In addition to passively operating under central station control, if the central station or communication links fail the substation microprocessors can store the five-minute averages for 16 hours or more and transmit these to the central station with no data loss when communication links are restored.

The Central Station

The central station is equipped with a PDP-11/44 minicomputer, running application software MONSYS under the multi-user real-time operating system RSX-11M.

Real-time control: MONSYS, timed by RADIO and based on parameter IAST, signals to each substation, which, in turn transmit the first set of five-minute averages to the central station. The central station signals the substation if these data are received without trouble. The substation then deletes the successfully transmitted data set and transmits the next set of data. This process continues until the substation is emptied of five-minute data. All the data are flagged during transmission, indicating whether they are normal data, invalid data, zero-calibration data, span-calibration data or higher-than-standard data. The operator can control the substation through DIAG, read data from the substation, transmit the central station time to the substation, revise central station parameters, revise substation parameters and transmit these to the substation, transmit substation parameters back to the central station, and issue corrections and substation start and stop orders.

RADIO, via LOGGER, can also display on the console status messages transmitted back from the substations, such as power, calibration or communication failure, or data storage full. There

is a healthy transparency between the central station and the substations.

Data Reports and Tables: Two data files are constructed when MONSYS is started. One is the five-minute data file, storing the five-minute averages of all parameters monitored at the 8 substations for 32 days. The other is the hourly data file, which stores the hourly averages of all parameters monitored for 367 days. REPORT produces various reports based on these files. The System regularly provides one hourly report, the three daily reports, seven monthly reports, five figures, and five retrievals. The reports and retrievals can be called up and displayed on the CRT terminal or printed. As the five-minute data are stored by the month and the hourly data by the year, last month's five-minute data and last year's hourly data of last year are transferred from disk to tape storage as the new month or year begins and the new files are opened. The files on tape can still be read and reports and retrievals still produced, through REPORT using the data on DL3 even if DL1 is being used by MONSYS for real-time data collection.

Quality Assurance And Technical Support Lab

The quality assurance and technical support lab (QA lab) is an important part of the System. A complete QA procedure for all components is of vital importance to the System's proper operation, especially technical support, preventative maintenance, rapid diagnosis and debugging, and an appropriate stock of spare parts.

The QA lab is equipped with various primary standard gases (SRMs), working standard gases, flow rate calibration devices (including high-volume, medium-volume and low-volume), special monitoring instruments used for standard transfer, calibration devices for meteorological instruments, portable calibration devices for performance audits, electronic measurement and test apparatus, tools for special and general purpose, and spare parts.

The main tasks of the QA lab are:

- To minimize data loss from instrument failure or interference;
- To establish a complete QA procedure to ensure that data obtained by the System are valid, accurate, comparable and trackable.

Equipment

Continuous air monitoring instruments are the backbone of the System. There are various commercially available monitoring instruments which such a System might use. The right choice of instrument is the key to the System's normal operation. Instruments selected should meet the following requirements:

- Instrument design should be equivalent to internationally recognized standards as approved by authoritative organizations.
- The instruments should operate continuously, automatically, and with minimal attendance for a long time.
- The instruments should generate accurate and reliable data and be able to be checked and

calibrated for zero and span at pre-determined intervals.

- Instrument measurement ranges and other specifications should meet national air quality standards.
- Instruments should need minimal maintenance and replacement, and make problem diagnosis as easy as possible.
- The instruments' long-term and continuous operation should meet national safety regulations.

The most important feature is instrument reliability over long-term unsupervised operation.

A careful survey, drawing on experience at home and abroad was carried out during the design of the System. Monitoring instruments using dry methods and approved by the USEPA were finally selected. The major equipment used in the System is listed in Table 4-2.

A PDP-11/44 minicomputer, produced by DEC, was originally selected as the System's central mainframe. It has since become possible to use less expensive microcomputers to replace the minicomputer.

Investment

Capital Investment The System comprises 8 substations, a central station, a communications network, and a QA and technical support lab. Investment in System hardware (excluding land acquisition and civil works) was US\$1.3 million (1983).

Operation of the System during 1984-1991 suggests that these figures are reasonable. Investment corresponds to the total number of substations; investment in other components will increase as the number of substations decreases.

Investment in the QA and technical support lab is vital to the collection of reliable data. Beijing experience suggests a minimal QA procedure should account for 10 percent to 20 percent of total investment.

When stocked spare parts account for 10 percent to 15 percent of the total investment, the long-term reliability of the System is ensured and the annual valid data capture rate should not be less than 75 percent. If prompt technical service from the instruments' manufacturers is available, investment in stocked spare parts may be safely reduced below this.

As computer technology is developing rapidly investment in a mainframe and data communication system may be reduced to as little as 10 percent.

Operation Costs These include replacement costs for spare parts and the costs of power, traffic, and other consumables (not including instrument depreciation and labor costs) (Table 4-2).

SYSTEM OPERATION

The System, put into operation in early 1984, has been continuously operated, 24 hours a day,

SYSTEM OPERATIONAL COSTS (1984-1993)

| Cost | Accumulated Investment (US\$X1000) | Accumulated Cost (US\$X1000) | Annual Cost (US\$X1000) |
|--|------------------------------------|------------------------------|-------------------------|
| Cost of spare parts consumed | 470 | 380 | 38 |
| Cost of power, traffic and other consumables | 110 | 110 | 11 |
| Total | 580 | 490 | 49 |

TABLE 4-2

365 days a year for 8 years. Zero and span calibrations are automatically carried out at each substation at predetermined times every day (the first three years) or every other day (the subsequent five years). Every day, the QA technicians print out the substations' calibration and status reports and submit them to the System manager.

- The System manager orders scheduled adjustment or maintenance, based on the "Control Limits And Corresponding Activities Table".
- Monthly preventive maintenance is done out at each substation and a report filed.
- Each substation is cleaned and inspected annually, usually in autumn.
- The instruments' standard transmissions (working standard gases and gas flows) and multi-point linear calibrations are inspected annually, usually at the same time as the substation cleaning.
- A performance audit of each substation is done every other year.
- Once a month experienced technicians review the validity of the collected data.
- Each month's data is analyzed at the beginning of the next month and this is reported to BMEPB.
- An analysis of the previous year's data is completed in January of the next year and an annual monitoring report submitted.

All of these records are maintained in a complete technical archives.

Valid Data Capture Rate

The rate of valid data collected by the System is the major assessment of its reliability. Except for the off-line data obtained by IP₁₀ particulate monitors, System data is collected on-line. Each substation reports every five minutes on ten parameters. 2880 five-minute data should be reported from each substation every day, 1,051,200 five-minute data in a year, and 8,409,600 data should be obtained from the 8 substations per year.

$$\text{Annual Valid Data} = \frac{(\text{8409600} - \text{Permissible Lost Data}) - (\text{Lost Data})}{\text{8409600} - \text{Permissible Lost Data}}$$

Permissible lost data is data lost during daily substation zero and span calibrations, scheduled System maintenance, multi-point linear calibrations and performance audits, and a certain

percentage of data unavoidably lost.

Lost data is data lost during instrument failures, unexpected instrument maintenance, repair or adjustment, and invalid data caused by calibration failures. Valid data capture rates for 1984-1990 are shown in Table 4-3.

Real-time Data Capture Rate (%)
(1984-1990, 8 Substations)

| Month | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Annual Mean |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|-------------|
| Year | | | | | | | | | | | | | |
| 1984 | -- | -- | 97.0 | 96.7 | 93.0 | 91.0 | 91.3 | 88.1 | 94.6 | 93.6 | 94.5 | 87.3 | 92.7 |
| 1985 | 96.3 | 94.3 | 96.4 | 89.6 | 92.6 | 91.8 | 87.2 | 82.5 | 94.7 | 92.8 | 91.8 | 87.0 | 91.4 |
| 1986 | 87.3 | 87.0 | 90.0 | 91.5 | 95.4 | 94.7 | 93.6 | 90.9 | 80.9 | 87.5 | 87.7 | 93.6 | 90.8 |
| 1987 | 95.7 | 91.3 | 83.9 | 85.6 | 94.5 | 89.1 | 89.5 | 81.7 | 94.9 | 90.0 | 89.9 | 89.9 | 89.9 |
| 1988 | 91.8 | 75.8 | 84.7 | 73.3 | 87.0 | 86.0 | 70.9 | 81.7 | 75.9 | 71.6 | 85.4 | 85.5 | 80.8 |
| 1989 | 71.4 | 89.9 | 90.4 | 86.0 | 85.2 | 85.1 | 69.3 | 78.7 | 85.5 | 58.8 | 74.8 | 74.7 | 79.2 |
| 1990 | 64.3 | 85.8 | 88.3 | 69.0 | 68.1 | 63.5 | 69.6 | 83.5 | 88.7 | 85.9 | 73.3 | 85.0 | 77.1 |

TABLE 4-3

Data capture rates during 1984-1987 were higher than 90 percent and fairly stable, but have dropped to 80 percent since 1988. The monitoring instruments failure rates were relatively stable during this time. The computers failed less often than the monitoring instruments, but computer failure causes serious data loss. Only one parameter would be lost if a substation instrument failed, but ten parameters would be lost in a microprocessor failure. In recent years, due to rapid change in computers it can be difficult or even impossible to get replacement parts for computer models originally purchased. Reduced data capture rates since 1988 can be attributed to this.

System experience indicates that if the System is equipped with well-chosen instruments and maintained by capable technicians, data capture rates reflect the supply of spare parts and the timely replacement of equipment. A large investment is needed to ensure this. Nevertheless, simpler means of improving the data capture rate should be sought out. In general, regional ambient air quality status is reflected reasonably accurately when the annual data capture rate is no less than 75 percent. This rate can be achieved with annual operation costs equivalent to 4 percent to 5 percent of the total capital investment.

Instrument Failure Frequency

Another reflection of System reliability is the average time between instrument failures (MTBF) during operation.

$$M \quad T \quad B \quad F \quad \left(\quad H \quad o \quad u \quad r \quad s \quad \right) \quad =$$

Average Failure Times (Times/Instrument*Year)

80 System instruments (not including those in the central station and the QA lab) are used daily. These failed 1067 times between 1984 and 1990, averaging 153 breakdowns per year or 1.9 times per instrument per year. On average a continuously instrument would operate for 4610 hours, or 192 days before it would break down.

Statistical analysis of instrument failure and MTBF for major instruments over 1984-1990 are shown in Tables 4-4 and 4-5.

Instrument Failure (1984-1990, 8 Substations)

| | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total |
|---------|------|------|------|------|------|------|------|------|------|------|------|------|-------|
| Year | | | | | | | | | | | | | |
| 1984 | 11 | 8 | 7 | 15 | 14 | 9 | 16 | 9 | 29 | 16 | 15 | 11 | 160 |
| 1985 | 13 | 14 | 12 | 9 | 16 | 16 | 15 | 13 | 11 | 10 | 13 | 13 | 155 |
| 1986 | 14 | 13 | 10 | 14 | 5 | 7 | 11 | 8 | 12 | 19 | 15 | 14 | 142 |
| 1987 | 12 | 6 | 14 | 7 | 12 | 11 | 18 | 13 | 5 | 9 | 16 | 8 | 131 |
| 1988 | 11 | 22 | 12 | 24 | 14 | 12 | 9 | 10 | 8 | 11 | 10 | 10 | 153 |
| 1989 | 17 | 8 | 9 | 10 | 15 | 16 | 20 | 16 | 11 | 7 | 11 | 17 | 157 |
| 1990 | 11 | 13 | 16 | 12 | 9 | 12 | 25 | 10 | 24 | 11 | 16 | 11 | 170 |
| Average | 13 | 12 | 12 | 13 | 12 | 12 | 16 | 11 | 14 | 12 | 14 | 12 | 153 |

TABLE 4-4

INSTRUMENT FAILURE FREQUENCY AND MTBF (1984-1990)

| Failure Times | TECO Model 43 SO ₂ Monitor (8 Sites) | Model 14B/E NO _x Monitor (8 Sites) | TECO Model 48 CO Monitor (8 Sites) | TECO Model 49 O ₃ Monitor (8 Sites) |
|--------------------------------|---|---|--|--|
| 1984 | | 21.00 | 21.00 | 16.00 |
| 1985 | | 26.00 | 16.00 | 13.00 |
| 1986 | | 13.00 | 20.00 | 25.00 |
| 1987 | | 17.00 | 15.00 | 13.00 |
| 1988 | | 13.00 | 15.00 | 14.00 |
| 1989 | | 15.00 | 23.00 | 16.00 |
| 1990 | | 17.00 | 21.00 | 18.00 |
| Annual Mean | | 17.40 | 18.70 | 16.40 |
| Failure Times (Times/Ins.Y) | | 2.18 | 2.33 | 2.05 |
| MTBT (hs) | | 4018.00 | 3760.00 | 4273.00 |
| | | | | 4358.00 |

TABLE 4-5

Zero and span drifts in the instruments are caused by changes in electronic circuits and gas lines over the long-term operation of these instruments. According to QA control limits, the microprocessor will not automatically correct the drifts if they are greater than ± 3 percent for

zero drift or ± 15 percent for span drift, and must be manually adjusted. Between 1984 and 1990 40 instruments were adjusted 817 times, or 2.9 times per year; an instrument could be operated for 3020 hours or 126 days before adjustment was needed (Table 4-6). Instrument repair or adjustment averaged 4.8 times per instrument per year; this reliability and maintenance level was found acceptable.

INSTRUMENT ADJUSTMENT FREQUENCY 1984 TO 1990 (8 SUBSTATIONS)

| Year | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total |
|---------|------|------|------|------|-----|------|------|------|------|------|------|------|-------|
| 1984 | 10 | 15 | 11 | 15 | 5 | 15 | 9 | 9 | 12 | 3 | 11 | 13 | 128 |
| 1985 | 17 | 8 | 14 | 27 | 6 | 5 | 7 | 16 | 15 | 23 | 17 | 18 | 173 |
| 1986 | 9 | 6 | 3 | 5 | 6 | 6 | 7 | 9 | 18 | 9 | 8 | 6 | 92 |
| 1987 | 17 | 4 | 3 | 11 | 7 | 11 | 8 | 15 | 3 | 13 | 8 | 7 | 107 |
| 1988 | 14 | 17 | 10 | 11 | 7 | 7 | 13 | 13 | 9 | 7 | 5 | 9 | 122 |
| 1989 | 17 | 4 | 3 | 11 | 7 | 11 | 8 | 15 | 3 | 13 | 8 | 7 | 100 |
| 1990 | 9 | 4 | 8 | 5 | 5 | 10 | 11 | 8 | 11 | 5 | 7 | 12 | 95 |
| Average | 13 | 8 | 8 | 11 | 6 | 9 | 9 | 13 | 11 | 10 | 9 | 10 | 117 |

TABLE 4-6

QA AND EQUIPMENT MAINTENANCE

QA

The System comprises many components, including the gas sampling system, continuous monitoring instruments, radio communication links and computer control systems. Problems caused by any one component can harm or even cripple the entire System. Instrument drift or failure due to changes in electronic circuitry, optical paths or gas lines during operations, fluctuations in regional power supply, weather changes or staff technical skills directly affect data accuracy. The System was designed to operate unsupervised and the time between substation inspection and maintenance tours is long. Great amounts of invalid data might be taken for valid if substation problems are not promptly identified. An effective quality assurance routine is therefore very important.

Major procedures of Beijing's QA program, as based on the USEPA QA Manual, are:

- **Standard Transmission**
These include standard gas flow transmission and standard gas concentrations transmission.
- **Gas flow standard transmission**
The flowmeters used in the substations' multi-gas dynamic calibrator are calibrated at the QA lab through the following steps. First, the volume flows of the primary standard flowmeters (soapfilm and wet flowmeters) are calibrated using National Institute of Standards and Technology (U.S.) standard barometers, thermometers, and stop watches. Then the transmission standard-the mass flowmeter is calibrated using the primary standard flowmeter. Finally, the two working standards-the mass flow controllers (0-10 L/min and

100mg/min) used in the substation's multi-gas dynamic calibrator are calibrated with the transmission standard.

QA lab transmission standards are recalibrated every six months and substation working standards are calibrated once a year. The acceptance indexes for flow calibration are very strict—the correlation coefficient of the calibration curve must be > 0.9999 , the slope between 0.99-1.01, and the intercept < 1 percent of full scale.

- **Standard gas concentrations**

The QA lab is equipped with primary standard cylinders containing CO and NO (SRM). The primary standard gases concentration values are transmitted, using a set of special analyzers, into the QA lab transmission standard cylinders. Then the transmission standards are transmitted, using special analyzers, into the working cylinders for daily calibration at the substations. The errors of the calibrated concentrations should be within ± 2 percent.

SO₂ is transmitted using SO₂ permeation tubes. The permeation rate of a tube selected from a batch of commercially available products is determined at the QA lab. This permeation rate is then used as the transmission standard, against which the substation permeation tubes are measured.

The substation O₃ analyzer concentration values are directly calibrated against the QA lab's primary O₃ UV photometer (TE49PS).

- **Instrument Calibration**

Instrument calibrations include multi-point (5-7 points) and single-point calibrations. The former are done while inspecting new machines that have not yet been used, or while examining instruments that have been repaired or had major parts replaced. Under normal circumstances, a multi-point calibration is done once a year. Single-point calibrations are done every one to three days, generally to correct zero drifts and span drifts. The calibration point for span is set at 75 percent of full scale.

The QA lab transmission standard cylinders (CO and NO) and permeation tubes (SO₂) are used for multi-point linear calibrations of the substations' monitoring instruments. Linear correlation coefficients are used as the major basis for acceptance of the instruments calibrated. For SO₂ and NO analyzers, the coefficients should be higher than 0.999; for O₃ and CO analyzers, they should be higher than 0.9999.

- **Data Corrections**

In addition to data collection, the substation microprocessors also correct data. After regular zero and span calibrations, the instruments, within specified control limits ($\leq \pm 3$ percent for zero drift and $\leq \pm 15$ percent for span drift) for each channel, calibration parameter and correction mark, instrument drift may be automatically corrected by the microprocessors. Beyond these limits the correction function is disabled, and the data is flagged for calibration failure. The operators must then visit the substation and examine and correct the failed instrument. The instrument should be overhauled if its zero drift is

greater than ± 5 percent or its span drift ± 25 percent, and should not be used again until the failure is located and repaired and a complete multi-point linear calibration done (Figure 4-1).

- Performance Audits

In addition to the regular zero, span, and multi-point linear calibrations of substation

instruments, FIGURE 4-1

independent performance audits should be done periodically in order to establish System self-assessment guidelines so that the auditor can assess effectiveness during substation and QA operations, further verifying and improving the accuracy of the System.

A set of portable gas calibrators and cylinders containing SO_2 , NO and CO mixtures are used for the audits. Audit concentration points and other criteria are taken from the USEPA QA manual. Assessment results are usually considered satisfactory if the correlation coefficient is within the range of 0.9950-0.9999, and unsatisfactory if it is less than 0.9950. Monitoring and calibration instruments and standard transmissions returning unsatisfactory results should be carefully examined in order to identify the problem.

A System of this type needs a thorough and stringent set of QA procedures, in order to insure the precision and accuracy of the monitoring instruments and to control and improve the quality of the data collected.

Equipment Maintenance

High quality instruments should be chosen for the System in order to improve its reliability. Maintenance and management is very important. System management emphasizes:

- Training, supervision and experience exchanges for maintenance personnel, who should be able to rapidly diagnose and correct instrument failure.
- Strict implementation of preventive maintenance procedures. This is especially important during the windy and dusty days between winter and spring and humid and rainy days in summer. A detailed preventative maintenance program, including maintenance items, cycles, and requirements, is described in Table 4-7.

Control Limits For Zero And Span Drifts And Recommended Measures

| | | | |
|-----------------------------------|-----------|--|------------------------------------|
| Zero Drift (% Full Scale) 0 | $\pm 5\%$ | Data invalid; maintenance & instrument recalibration required | $\pm 25\%$ |
| | $\pm 3\%$ | Instruments must be manually readjusted | $\pm 15\%$ |
| | 0 | System automatically corrects itself | Span Drift (% Full Scale) 0 |

BENEFITS OF THE SYSTEM

The System has become an effective monitor of Beijing's ambient air quality. In the eight years

since its implementation, its major objectives have been fulfilled and measurable environmental benefits have been achieved.

Comprehensive Assessment of Ambient Air Quality

The System is a real-time, continuously operated monitoring system. Present and past air quality status, such as the ambient levels of SO₂, CO, NO_x, O₃, TSP and related meteorological conditions in any Beijing district can be accessed by the control center at any time. The System collects great quantities of accurate and internationally comparable data; an "Annual Report On Beijing's Environmental Quality" is produced based on this information. These data provide a scientific basis for the analysis of Beijing's air quality and reflect the effectiveness of control measures and the development of Beijing's environmental management program. The System has become an important tool of Beijing's environmental management agencies.

Air Quality Problems And Trends

Beijing has gained a deeper understanding of its key air quality problems, such as the effects of SO₂ and TSP pollution from coal-burning. In the urban districts, annual SO₂ averages are twice as high as the National Secondary Standard and WHO guidelines of 60μg/m³ (during winter daily SO₂ averages top the annual average by 26.5 percent, and peak values have reached as high as 700μg/m³ when meteorological conditions have prevented dispersion; annual SO₂ averages are therefore determined by winter pollution levels). Daily SO₂ patterns reveal peaks in the morning and the evening, corresponding to patterns in heating and household cooking. The EPBs have therefore taken measures to control SO₂ emissions from municipal furnaces and domestic stoves.

Efforts have been made in recent years to change the energy structure. Fuel gases (coal gas, liquified natural gas) are being promoted; 165,000 families use these for heating and 85 percent of Beijing households use them for cooking. 19.3 percent, or 32.14 million m₂ of the City of Beijing has been fitted with municipal heat. An improved coal briquette is being promoted for domestic use and heating boilers have been refitted accordingly. SO₂ emissions have been controlled somewhat. The annual SO₂ average over the past ten years has stabilized and slightly decreased, in spite of continuous growth in industry, population and energy consumption during the same period. Nonetheless, it will be difficult to meet the National Standard and WHO guidelines without large investments.

The System found a gradual increase in NO_x, from 93μg/m³ in 1986 to 109μg/m³ in 1990.

In downwind suburban areas from late spring to early autumn, O₃ peaks reached as high as 290μg/m₃; during 1991 194 hours found O₃ concentrations higher than standard. This forecasts potential photochemical smog pollution; BMG has strengthened traffic pollution control measures accordingly.

Research Applications

The System has excellent time and space resolution, and the data obtained can be used in various scientific studies. The following studies have been carried out during the System's eight years'

operation.

- "Predicting and Forecasting Air Pollution In Urban And Suburban Areas In Beijing". A study forecasting air pollution used data collected by the System, emission inventories obtained during the source survey, and background information on atmospheric physics from 1986-1988. Four sets of models were established:
 1. "Forecast Model For Air Pollution Potential", forecasting wintertime SO₂ pollutions and summertime O₃ concentrations;
 2. "Atmospheric Dispersion Model: SO₂ Disk Model", which, in combination with the first model, forecasts daily and winter SO₂ and O₃ averages and their various sources;
 3. "Atmospheric Model: Practical Model For Air Quality Assessment", assessing pollution status and contributions from various sources and forecasting the effectiveness of various control measures; and
 4. "Patterns Of Photochemical Smog Pollution And Simulation Of The Pollutants' Behavior", providing a basis for further study of photochemical smog pollution.

Based on these results, a study entitled "Long-term Least-Cost Environmental Management Strategic Planning", supported by the World Bank, is underway.

- "Contributions From Various Particulate Sources And Their Control". Monitoring data indicates that TSP, a serious problem in Beijing, in winter is only 20 percent to 30 percent higher than that in summer. Other studies estimate that 60 percent of TSP comes from natural sources and 40 percent from coal-burning. Contributions from various sources have been studied since 1990, using System data, samples collected specifically for this study and the receptor model-chemical mass balance model combined with the dispersion model, to trace the contributions from various TSP sources and provide a basis for EPB decision-making.
- "Air Quality Monitoring Siting And Monitoring Frequency Optimization". Representative monitoring of a region's environmental quality using the fewest possible monitoring sites is very important. Monitoring sites should be continuously adjusted to reflect industrial, population and traffic pattern changes. The present locations have been optimized through cluster analysis of System data. Areas outside System coverage are monitored using a mobile unit. Optimization options and a development program will be drafted based on the results of these activities.

Due to Beijing's large area, manual sampling is still necessary in remote areas not covered by the System. Statistical analysis of historic data obtained by the System have found optimal frequencies for manual sampling. Study of SO₂ sampling frequencies revealed that the relative errors were:

| | |
|---|------------|
| 8 times per day (30 minutes at a time) == > | 6 percent |
| 6 times per day == > | 11 percent |
| 4 times per day == > | 14 percent |
| 4 times per day (daytime only) == > | 20 percent |

A study of sampling cycles, showed that relative errors were:

| | |
|--------------------------------|------------|
| sampling every other week == > | 20 percent |
| five days per month == > | 20 percent |
| five days per quarter == > | 35 percent |

These results were used to determine the optimal frequencies and cycles for manual sampling.

- "System Design Optimization". The System has been frequently reviewed and modified since its establishment. System hardware and software have been improved and operational experience accumulated. BMEMC supervised the design, installation, testing and operation of automatic air quality monitoring systems and personnel training for Zhengzhou City, Lanzhou City, and Anshan Iron & Steel Corp, and supervised the design, installation, and trial operation of air quality mobile monitoring units for Qingdao City and Beijing Municipality, as well as training technical teams capable of designing, installing, testing, operating, maintaining and managing these systems.

About 20 research and assessment projects have been carried out with the help of the System, and its environmental benefits will be more apparent if more application and research projects are done using the large amount of data collected by the System.

EVALUATION OF THE SYSTEM

During the 1960s, automatic air quality monitoring systems were established in many developed countries around the world, and these technologies matured during the 1970s. Long-term experience has proven these systems' effectiveness, but their cost/benefit ratio and how to obtain acceptable time and space resolution for the least possible investment are still being examined by environmental agencies around the world.

Beijing's Automatic Air Quality Monitoring System has operated effectively for eight years, but is not the one critical measure for ambient air quality monitoring. The investment in such a system is large, but the cost/benefit ratio should be measured by whether monitoring objectives have been met and useful data are collected. If these data are then applied to a sound pollution control program, the cost of a computerized system would not necessarily be more than that of manual sampling methods. Beijing's System cost an initial capital investment of US\$1.3 million and annual operating costs are US\$49,000. Average annual costs will be US\$135,000 if the System is operated for 15 years. The System generates not less than 525,600 hourly data and 6,307,200 five-minute data each year; each hourly data costs US\$0.25 and each five-minute data only US\$0.02.

An air quality monitoring system could be broadly defined as any systematic program providing air quality data. A monitoring system may be relatively simple or very complicated; basic systems are shown in Table 4-8. Various hybrid systems may be composed from these basic systems, according to individual requirements. As Table 4-9 shows, different systems

correspond to different monitoring objectives.

TYPES OF AIR QUALITY MONITORING SYSTEMS

| SYSTEM TYPE | SYSTEM STRUCTURE | TIME RESOLUTION |
|--|---|--|
| A. Manual sampling method Passive sampling method Absorption tube method | Chemical absorption candle + Chemical analysis at lab Chemical reaction film | Continuous, ≥ 30 days Periodic, ≥ 30 minutes Periodic or $\geq 1-24$ hours |
| B. Automatic sampler system | Automatic sampler + Instrumental determination at lab | Continuous |
| C. Off-line continuous monitoring system | Continuous and automatic instruments + Computer (off-line) | Continuous, ≥ 5 minutes |
| D. On-line real-time monitoring system | Continuous and automatic instruments + Data communication Computer (off-line) | Continuous, ≥ 5 minutes |

TABLE 4-8

Type C and D Systems fill a wide range of objectives, but call for a large investment. Type A is simpler and its monitoring parameters are limited, but certain objectives may be achieved through a generous use of manpower. Type B fills many basic objectives, but its monitoring parameters are limited and time resolution is poor. The final selection will be determined by the seriousness of local air pollution, population distribution, progress in pollution control, monitoring tasks and objectives, and the available technical and financial resources. A careful study should be made to define the specific objectives and the usage of the desired monitoring data.

The system's space and time resolution should be determined before the system is designed, as the requirements for each are different. Good space resolution needs sufficient sampling sites, while good time resolution can only be achieved when sampling is done in appropriate intervals over a long period of time. Long-term continuous monitoring at many sites is needed if both good space and time resolutions are wanted. The large investment required makes this difficult, so many environmental protection agencies opt for either good space resolution or good time resolution. The goal of design optimization is to get acceptable time and space resolution for the least possible investment.

Mixed systems (a certain number of continuous automatic substations located in strategic commercial, residential and industrial areas, measuring priority pollutants) may be economically reasonable when monitoring objectives and acceptable time and space resolutions have been determined. The ratio of the cost for single instrument used in different systems is as follows:

Manual Sampler: Automatic Sampler: Continuously Monitoring Instrument = 1:10:100.
The lifetime of the latter is significantly longer than that of the former.

Prior to the 1980s, monitoring relied on manual sampling. Time resolution was very poor due to low sampling frequencies and long intervals between sampling. Manual sampling methods were greatly affected by the operators' skills and many factors could not be controlled through QA procedures. Later, much data proved invalid. It will be more cost-effective if more

ATTAINABLE OBJECTIVES BY DIFFERENT MONITORING SYSTEMS

| Monitoring Objectives | Requirement For Times Resolution | Objectives Attainable By Different Monitoring Systems | | | | |
|---|---|---|---------------------|-----------------------|-----------------------------------|----------------------------------|
| | | A. Manual Sampling | | B. Automatic Sampling | C. Off-line Continuous Monitoring | D. On-line Continuous Monitoring |
| | | Passive Sampling | Absorption Sampling | | | |
| REGULAR MONITORING | | | | | | |
| (1) Observation of long-term trend | Daily mean or monitoring mean | | | | | |
| (2) Judgement of pollution status | Daily mean and concentration from one measurement | | | | | |
| SPECIAL MONITORING | | | | | | |
| (3) Pollution forecast | Hourly mean | | | | | |
| (4) Assessment of health risk | Hourly or daily mean | | | | | |
| (5) Assessment of environmental impacts | Daily or monthly mean | | | | | |
| (6) Supply information for city development | Hourly or daily mean | | | | | |
| (7) Verification of dispersion model | Five-minute data | | | | | |
| (8) Survey of public complaints against pollution | Hourly mean or five-minute data | | | | | |
| (9) EIA | Daily or monthly mean | | | | | |

TABLE 4-9

parameters are included when a continuous and automatic monitoring station is established.

The necessity for a real-time, on-line system has been questioned. Obviously, the requirement for a real-time environmental monitoring system is not as urgent as that of a meteorological, fire-fighting or traffic control system. However, transparency between the control center and the substations helps insure that the substation status and the data quality can be confirmed at any time. If a mixed system must be established, it is important to ensure that the different monitoring techniques and analytical methods chosen will generate reliable data and that standardized QA/QC procedures will be adopted.

Above all, an air quality monitoring system must be designed in accordance with prevailing local conditions.

| No. | Item | Maintenance Cycle (Times/month) | Month | | | | | | | | | | | |
|--|---|------------------------------------|-------|---|---|---|---|---|---|---|---|----|----|----|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | Remove the water from the cold trap at outlet of the air compressor | 1/2--1/1 | | | | | | | | | | | | |
| 3 | Check for any water trapped by the pipelines | 1/2--1/1 | | | | | | | | | | | | |
| 4 | Check the pressure indicated at 111 front panel | 1/1 | | | | | | | | | | | | |
| 5 | Clean 111 fan filter | 1/1 | | | | | | | | | | | | |
| 6 | Remove the dust inside 111 | 1/6 | | | | | | | | | | | | |
| 7 | Check the temperature indicated at 146 front panel | 1/1 | | | | | | | | | | | | |
| 8 | Clean 146 fan grid | 1/1 | | | | | | | | | | | | |
| 9 | Remove the dust inside 146 | 1/6 | | | | | | | | | | | | |
| 10 | Check the pressure indicated at the inside pressure gage | 1/1 | | | | | | | | | | | | |
| MONITORING INSTRUMENTS MODEL 43 | | | | | | | | | | | | | | |
| 1 | SO₂ ANALYZER Check flow and pressure, clean the capillary if necessary | 1/1 | | | | | | | | | | | | |
| 2 | Check zero and full scale | 1/3 | | | | | | | | | | | | |
| 3 | Clean 5 VDC output | 1/3 | | | | | | | | | | | | |
| 4 | Clean fan filter | 1/1 | | | | | | | | | | | | |
| 5 | Clean fluorescent chamber | 1/12 | | | | | | | | | | | | |
| 6 | Remove the dust inside 43 | 1/12 | | | | | | | | | | | | |
| 7 | Replace aromatics cutter | 1/18 | | | | | | | | | | | | |
| 8 | In humid season remove water trapped in the pipelines | July--Sep. | | | | | | | | | | | | |
| 14 B/E NO_x ANALYZER | | | | | | | | | | | | | | |
| 1 | Replace the dessicator | 1/1 | | | | | | | | | | | | |
| 2 | Check the pressure in the reaction chamber and clean the capillary and film as necessary | 1/1 | | | | | | | | | | | | |
| 3 | Check zero and full scale | 1/3 | | | | | | | | | | | | |
| 4 | Check 5 VDC output | 1/3 | | | | | | | | | | | | |
| 5 | Clean fan filter | 1/1 | | | | | | | | | | | | |
| 6 | Clean cooler fan | 1/2 | | | | | | | | | | | | |

| No. | Item | Maintenance Cycle (Times/month) | Month | | | | | | | | | | | |
|--|---|---|-------|---|---|---|---|---|---|---|---|----|----|----|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 7 | Clean the dust inside 14B | 1/6 | | | | | | | | | | | | |
| 8 | Check and replace the converter | ef < 96% | | | | | | | | | | | | |
| 9 | Clean the reaction chamber and PMT | 1/12 | | | | | | | | | | | | |
| 10 | Replace O ₂ remover | 1/24 | | | | | | | | | | | | |
| MODEL 48 CO ANALYZER | | | | | | | | | | | | | | |
| 1 | Check flow and clean the capillary if necessary | 1/1 | | | | | | | | | | | | |
| 2 | Check zero and full scale | 1/3 | | | | | | | | | | | | |
| 3 | Check 5 VDC output | 1/3 | | | | | | | | | | | | |
| 4 | Check detector Intensity 1 (KH ₂) Intensity 2 (") AGC1 (") AGC2 (") T (°C) P (mmHg) | 1/1 | | | | | | | | | | | | |
| 5 | Clean fan filter | 1/1 | | | | | | | | | | | | |
| 6 | Clean the dust inside 48 | 1/6 | | | | | | | | | | | | |
| 7 | Clean optical path chamber | INT < 15 KH ₂ | | | | | | | | | | | | |
| 8 | Check correlation coefficients | 1.14-1.18 | | | | | | | | | | | | |
| MODEL 49 O₂ ANALYZER | | | | | | | | | | | | | | |
| 1 | Check flow and clean the capillary if necessary | 1/1 | | | | | | | | | | | | |
| 2 | Check zero and full scale | 11/3 | | | | | | | | | | | | |
| 3 | Check 5 VDC output | 1/3 | | | | | | | | | | | | |
| 4 | Check the detectors Detector A (KH ₂) " B (") Noise A (") " B (") T P | 1/3 | | | | | | | | | | | | |
| 5 | Clean fan filter | 1/1 | | | | | | | | | | | | |
| 6 | Clean the dust inside 49 | 1/6 | | | | | | | | | | | | |
| 7 | Clean the optical chamber | f < 70 KH ₂ | | | | | | | | | | | | |
| 8 | Replace the converter of O ₂ , remove | A,B balance < ±3% | | | | | | | | | | | | |

| No. | Item | Maintenance Cycle (Times/month) | Month | | | | | | | | | | | |
|-----------------------------------|---|---|-------|---|---|---|---|---|---|---|---|----|----|----|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| METEOROLOGICAL INSTRUMENTS | | | | | | | | | | | | | | |
| 1 | Check zero, full and semi-full scales | 1/3 | | | | | | | | | | | | |
| 2 | Check and clean the transducer | 1/12 | | | | | | | | | | | | |
| 3 | Clean or replace the bearing WS | 1/24 | | | | | | | | | | | | |
| WS | | | | | | | | | | | | | | |
| 1 | Check zero, full and semi-full scales | 1/3 | | | | | | | | | | | | |
| 2 | Check and clean the transducer | 1/12 | | | | | | | | | | | | |
| 3 | Clean or replace the bearing | 1/12 | | | | | | | | | | | | |
| Hum/T | | | | | | | | | | | | | | |
| 1 | Check zero, full and semi-full scale | 1/3 | | | | | | | | | | | | |
| 2 | Check and clean the transducer | 1/12 | | | | | | | | | | | | |
| 3 | Check and clean the fan | 1/12 | | | | | | | | | | | | |
| GENERAL FACILITIES | | | | | | | | | | | | | | |
| 1 | Clean the shelter | 1/1-3 | | | | | | | | | | | | |
| 2 | Clean the air conditioner filter | 1/1 | | | | | | | | | | | | |
| 3 | Clean the lobby fan | | | | | | | | | | | | | |
| 4 | Check and clean exhaust outlets | 1/6 | | | | | | | | | | | | |
| 5 | Check the temperature and power controls | 1/1 | | | | | | | | | | | | |
| 6 | Add oil to air conditioner and instrument pumps | 1/6 | | | | | | | | | | | | |

Signature of the operator _____
Date (Day/Month) _____

MANAGEMENT AND USE OF MONITORING DATA

The achievements of environmental monitoring are reflected in the collected data. Conversely, the validity of monitoring data is the foundation of environmental management. BMEMC assembles data on water, air, noise, soil and biology gathered by the municipal, district and county monitoring stations, some of the enterprise monitoring units, such as the Capital Iron & Steel Corporation, the Tap Water Company, and the Hydrological & Geological Company, and results from a survey of the industrial sector and furnaces and kilns located in Beijing. All of these are important raw data.

Foreign monitoring technology was introduced in 1983 and an Automatic Ambient Air Quality Monitoring System established. Since then, Beijing's ambient air quality has been continuously monitored, guiding environmental management and research. Procedures were developed for the analysis, storage and statistical application of this data, evolving alongside environmental monitoring activities.

ANALYSIS AND STORAGE OF MONITORING DATA

Monitoring data obtained from chemical analysis are reported only once they have been checked by the analysts according to quality control (QC) procedures. In addition, designated personnel review raw data collected from these sources. Data outside normal ranges must be rechecked and the reason identified in order to ensure the reliability of the data.

Instrumental data errors from the automatic monitoring system have been virtually eliminated by BMEMC's complete quality assurance (QA) system, and standards ensure the accuracy and comparability of data obtained from different monitoring substations. Nonetheless, certain factors cannot be controlled through QA procedures; in these cases the data are analyzed for validity, processed by special data analyzers and stored for later use.

Validation and Processing Of Automatic Monitoring Data

In addition to comparing real-time data with zero-drift and span-drift control limits during regular corrections, it should be specially analyzed to remove data generated during abnormal operational conditions. This is the last and most important QC procedure.

From the beginning BMEMC emphasized the importance of data analysis and processing, and

designates special technicians for the monthly analysis of all collected data. A computer program has been developed to assist this. The analysts, who are full-time technicians with an appropriate professional background, must have:

- Theoretical and practical experience in environmental monitoring; familiarity with selecting sample sites, sampling methods for various pollutants, knowledge of pollutant sources how they affect sampling, and a quantitative understanding of concentrations and variation patterns of pollutants in different areas.
- Knowledge of the monitoring system's data acquisition methods and QC procedures.
- Some knowledge of basic statistics.
- Attention to equipment status and varying trends.

Checking the raw monitoring data includes:

Diagnosis of Corrections to Zero And Negative Values Under zero drift control limits allow a small amount of drift. Monitors may indicate values dropping slightly below zero when ambient concentrations of the pollutants are extremely low; these values do not reflect actual conditions because it is impossible that the concentrations could be negative. Zero and negative values, therefore, are corrected to half of the monitors' minimum detectable limits (MDLs) during the hourly averages calculation.

Negative values caused by monitor failure are invalid and removed from the hourly averages calculation.

The analysts review the two different results and decide whether the data should be corrected or removed. The diagnosis procedure:

- First, certify the results of zero and span calibration. If these do not qualify, delete data obtained during this period.
- If they qualify, check for possible MDLs based on conditions at the monitoring site; check the data for any variation patterns and compare these to results from similar monitors at the same site or the same monitors at similar sites, to see whether the monitors have failed or reflect actual conditions. The data listed in Table 5-1, though very close to the MDLs, are valid data collected from one substation during high humidity conditions.

Data Obtained During A Failure Correction If the values of zero-drift and span-drift are higher than those allowed by the control limits, the data are invalid and the substation microprocessor will not correct these.

BMEMC analyzes correction failures in order to increase the data capture rate. Failure corrections may also be caused by inadequate supply of standard gases or a decrease in permeability. If this is found to be the case and the monitors are operating normally, the data

will be accepted and, after correction for drift, included in the statistics of valid data.

Sudden-Change Values A sudden-change value occurs when the difference between two consecutive five-minute values is higher than half of the standard scale. Generally, pollution concentrations vary only slightly over time. Abnormal values, such as the sudden occurrence of full-scale or zero values, are usually caused by instrument

POLLUTANT CONCENTRATIONS AT HIGH HUMIDITY (mg/m³)

| SO ₂ | CO | NO _x | HUM |
|-----------------|-----|-----------------|-----|
| 0.005 | 0.5 | 0.013 | 100 |
| 0.005 | 0.4 | 0.012 | 100 |
| 0.005 | 0.4 | 0.010 | 100 |
| 0.005 | 0.4 | 0.010 | 100 |
| 0.005 | 0.5 | 0.012 | 100 |
| 0.005 | 0.5 | 0.011 | 100 |
| 0.005 | 0.4 | 0.011 | 100 |
| 0.005 | 0.4 | 0.011 | 100 |
| 0.005 | 0.4 | 0.012 | 100 |
| 0.005 | 0.4 | 0.012 | 100 |
| 0.005 | 0.5 | 0.013 | 100 |
| 0.005 | 0.5 | 0.014 | 100 |

failure and are invalid. Sudden changes in environmental conditions, such as a change in wind direction or a heavy emission of pollutants, can also lead to drastic value change. These values reflect an actual change in environmental conditions and are valid.

TABLE 5-1

ABNORMAL SUDDEN-CHANGE OF CO (mg/m³)

| SO ₂ | CO | O ₃ | NO _x |
|-----------------|------|----------------|-----------------|
| 0.162 | 3.4 | 0.002 | 0.131 |
| 0.164 | 4.4 | 0.002 | 0.125 |
| 0.161 | 3.2 | 0.002 | 0.118 |
| 0.151 | 12.2 | 0.002 | 0.097 |
| 0.142 | 2.5 | 0.002 | 0.097 |
| 0.148 | 4.5 | 0.002 | 0.138 |
| 0.144 | 4.3 | 0.002 | 0.119 |

Analysts consider the instruments' properties and local environmental characteristics.

TABLE 5-2

Table 5-2 shows a sudden increase in CO but no change in other parameters. This CO value is thus presumed interference and would be deleted. In Table 5-3, there is also a sudden-change value for CO, but at the same time, the SO₂ and NO_x values are also increasing and O₃ values decreasing. This reflects actual ambient concentrations of these pollutants and would be accepted.

NORMAL SUDDEN-CHANGE OF CO (mg/m³)

| SO ₂ | CO | O ₃ | NO _x |
|-----------------|------|----------------|-----------------|
| 0.112 | 3.4 | 0.005 | 0.091 |
| 0.137 | 3.8 | 0.007 | 0.105 |
| 0.147 | 4.7 | 0.008 | 0.128 |
| 0.169 | 4.8 | 0.009 | 0.119 |
| 0.182 | 16.8 | 0.002 | 0.143 |
| 0.175 | 7.1 | 0.007 | 0.121 |
| 0.171 | 6.8 | 0.010 | 0.131 |
| 0.178 | 5.6 | 0.009 | 0.140 |

TABLE 5-3

Power Failures Temporary power failures may occur at substations. The microprocessors and radio sets will resume operations once power is restored, and data will be transmitted to the BMEMC. The monitoring instruments, however, require a warm-up period; data generated during this time are invalid. This period is calculated according to the instrument type and the impact of power failure on its performance.

When the system was implemented, a computer program was written to boost working efficiency and help automate data checks. Key functions of the program are:

An automatic filtration of all five-minute data Negative values are corrected to half of the instruments' MDLs; sudden-change values and fixed values are flagged; starting and ending times of failure corrections are recorded. Data invalidated by power failures and instrument recovery time is deleted. Five-minute data between the starting and ending times as input by data analyzers is deleted. The first two five-minute data for NO_x, NO₂ and NO after the conversion from calibration to monitoring are deleted.

This program was established based on data analysis experience accumulated over the first several years of operations. The data derived are accurate and representative. In addition, problems revealed by data analysis have been used to examine the operating system, enhancing its operational reliability.

For example, data analysis revealed that at one substation the concentration of certain pollutants followed a regular daily variation. Meteorological conditions and instrument calibrations were stable, but concentrations were lower than the base pollution status in the area. An examination of the site revealed a crack on the sampling manifold inside the shelter, blending air inside the shelter with samples pumped into the instruments, and monitoring data did not reflect ambient air quality. The data became valid after the sampling manifold was replaced.

In another example, one substation's hourly O₃ concentrations were higher than standard for several successive days in October 1986, even though instrument calibrations were normal, sunny days were infrequent and the substation was in an area without significant O₃ pollution. Data analysis indicated that these high O₃ values were abnormal. A field survey then found that the ventilation pump had failed, so O₃ emitted from the NO_x monitor did not disperse but accumulated around the shelter, leading to increased O₃ concentrations around the sampling intake. These data, though obtained from a normally operating O₃ monitor, had to be deleted; results stabilized after the ventilation pump was replaced.

It is very difficult for the checking program and QA procedures to identify abnormal cases of this type. These problems often only can be found by experienced technicians applying an understanding of environmental conditions, pollutants' variation patterns and a careful study of the actual circumstances. Data analysis is an important QA procedure to insure normal operation of the System.

Following this review, the remaining five-minute data are correct, valid and can be used for the calculation of hourly averages. These data are stored for use if no errors are found on rechecking.

Modes of Data Storage

Disk and Tape Storage The five-minute averages are stored on the mainframe computer hard disk, as are the hourly averages derived from the average of the five-minute data. The hard disk's storage capacity is just enough for 32 days of five-minute data and one year of hourly averages from each substation, so at the end of each month the five-minute and hourly data are transferred onto tape backup for storage.

The five-minute and hourly data are stored in data files, tagged by pollution code and date. The concentration data (valid and invalid, zero and span adjustment information) obtained through monitoring are stored in sequence, in the designated file. The data over a certain period for a certain pollutant can be called up by specifying time, code and record numbers.

Storage in Report Form Generally, the data are not stored in report form. However, daily averages sometimes are used to analyze environmental quality, or individual daily averages may

be used for research or to compare different monitoring methods. In these cases it is more convenient to use the monthly reports. It is also more practical to print out monthly the daily averages over one month and monthly average for each parameter monitored at each substation. These reports are also an effective mode for data storage. These reports have been printed out monthly since 1984. If the daily averages are required they can be derived from the monthly reports. Otherwise, daily averages should be called after they have been dumped from the tape back onto the disk.

Various reports are issued using the monitoring data. These are produced by data management technicians using specially designed computer programs. However, data stored in the report format are suitable for only limited applications. They are not suitable for sorted statistics and calculation, which find it more convenient to use the data on disks.

Monitoring data obtained through manual sampling are also stored in this format and will be managed by and stored in the computer when the database is completed.

Beijing Surface Water Quality Information Management System

In Beijing there are 204 water quality monitoring sites, located at major waterways, lakes and reservoirs. Water samples are taken manually and analyzed in laboratories. More than 20,000 monitoring data are collected each year. The Beijing Surface Water Quality Information Management System was established using an IBM-PC/AT computer for more efficient use of these data. Data from previous years were also incorporated once they were collated and screened, the measurement units standardized and the monitoring and analytical methods identified.

Water systems have been sequenced, coded, and stored in the computer for inquiry and recall. Water qualities are assessed in accordance with their function (drinking water, agricultural irrigation, etc.) using the Nemorow pollution index.

The water quality database can produce reports, diagrams or tables detailing:

- one-year data;
- multi-year data;
- monitoring methods; and
- high values.

REPORTS AND STATISTICAL ANALYSIS OF THE MONITORING DATA

The System does not belong to WHO/GEMS/Air, so WHO report formats are not used. System reports are instead based on the format established by System software MONSYS. The statistical analysis methods and the diagrams and tables, however, are based on WHO's "Analysis and Interpretation of the GEMS Data".

Major Reports

Hourly, daily and monthly reports, rose plot concentration curves and daily and monthly calibration tables are regularly generated by the System.

Hourly reports: for each parameter twelve five-minute averages each hour and the hourly average are reported from each substation.

Daily reports: Three reports are produced:

- Daily average for each parameter at each substation;
- Hourly averages, maximums, minimums, daily averages and standard deviations (SD) for all parameters at each substation;
- Hourly averages, maximums, minimums and daily averages for one parameter at each substation.

Monthly reports: Seven reports are produced:

- Monthly average of each parameter from each substation;
- Daily averages, maximum and minimum daily averages, monthly averages and standard-violation rates within one month for all parameters at one substation;
- Hourly averages and daily maximums, minimums, averages and SDs within one month and daily hourly maximums, minimums, averages and SDs for one parameter at each substation.
- Statistics on wind direction and speed at each substation;
- Statistics of maximums, averages and their frequencies at various wind directions and speeds for each parameter at each substation;
- Statistics of standard-violation rates within one month for all parameters at each substation;
- Statistics of data capture rates.

Rose plots: These are plotted using the five-minute data over one month at each substation.

Three types are produced:

- Wind roses;
- Pollution roses for one pollutant;
- Pollution index roses for one pollutant.

Concentration curves: These are also plotted using the five-minute data, showing concentration changes each day for each pollutant at each substation.

Daily calibration tables: Calibration time, calibration values for zero and span, and percentage of values higher than standard, for each parameter at each substation.

Monthly calibration tables: Zero and span values during each calibration within one month; values higher than the given calibration values will be flagged for all parameters at each substation.

Retrieval The System automatically retrieves the following figures:

- Five-minute data exceeding the standard, and corresponding meteorological conditions (monthly);
- Maximum five-minute values, and corresponding meteorological conditions (monthly);
- Maximum hourly averages, and corresponding meteorological conditions (annually);

- Daily average values exceeding the standard, and the corresponding day (monthly);
- Daily average values exceeding the standard and the corresponding day (annually);

These tables, reports and retrieval results can be obtained from the database, and displayed on-screen or printed out. Pollutants may be measured in ppm or mg/m₃.

Statistical Processing And Comprehensive Expression Of Monitoring Data

Air pollutant concentrations are characterized by great volumes and variations. Pollutant sources vary considerably during the year and consequently the data plot themselves over a large range. These data should be analyzed by scientific statistical methods before being used to judge pollution levels and changes. Statistical terms and methods used are consistent with WHO provisions and winter and summer data are assessed separately before being incorporated in the monthly and annual statistics. Furthermore, the eight System substation sites are classified based on their locations (urban, near, suburb, urban near-suburb, and rural) and their different environmental circumstances are factored into the analysis.

Calculation Of The Central Tendency And Discrete Index Of The Data Maximums, minimums, averages (including arithmetic averages, geometric averages and medians), standard distributions (including mathematical and geometric SDs), percentiles, and standard violation rates are calculated.

The averages and standard violation rates include monthly and annual averages, winter and summer season averages, urban, inner-suburb and urban near-suburb area averages.

Test Of Data Distribution Data are grouped based on their range. Each datum is grouped, frequency and accumulated frequency distribution tables are plotted, and accumulated frequency percentages are calculated. Data distribution characteristics are determined through making plots on the logarithmic probability papers.

Analysis Based on the above calculations, analyses are made of the pollutants' temporal and spatial distribution characteristics and the relationships between pollution and meteorological conditions and between pollution, geographical environment and pollution sources. The relationship between pollutant concentrations versus time and pollution roses are plotted.

The confidence interval estimations, differential importance tests, and trend analysis are also carried out during the multi-year data statistics.

MONITORING DATA AND ENVIRONMENTAL MANAGEMENT

Much environmental quality information has been provided for environmental management and decision-making since the foundation of BMEMC. The service is provided in several forms:

Monthly Ambient Air Quality Reports

Since 1985, monthly reports (Monthly Report On Ambient Air Quality In Beijing), based on

analysis of the statistical data obtained by the System have been circulated to environmental management and municipal agencies, other monitoring institutions, and large enterprises. These reports include: monthly averages of each pollutant at each substation; maximum daily averages; standard violation rates; comparisons with the previous month and with the same month in previous years; comparisons of pollution levels among the substations; analysis of special pollutant concentrations and a comprehensive assessment of monthly pollution status.

Seasonal Reports On Environmental Quality

A report is issued each quarter. In addition to System data, manual sampling data obtained by district or county level monitoring stations are incorporated into this report, particularly CO, NO_x, TSP, dustfall, SO₂, and sulphation rate data. Headings and agencies copied are same as for the monthly reports.

Bulletins are issued after surface water monitoring during wet and dry periods. Concentrations of various pollutants occurring during these periods, standard violation rates and the reasons for these are counted and analyzed.

Annual Environmental Quality Reports

Annual reports on environmental quality have been issued since 1988, in preparation for the annual national environmental protection meeting. All data obtained through the environmental protection system and a basic statistical analysis are included in these reports.

In addition to the annual reports, environmental quality reports will be compiled every five years. These reports will: review fundamental conditions, urban development patterns, construction and environmental statistics; evaluate environmental quality based on monitoring and statistical data; summarize the current status of pollution sources and emerging trends; and highlight achievements and countermeasures in the field of environmental protection.

The data collected by the environmental protection institutions are inadequate for a comprehensive analysis as required by these reports. Therefore, more data are drawn on to compile these reports, particularly on waste gases, wastewater and solids discharge, treatment and comprehensive usage; modification of furnaces and kilns; discharge of priority toxic substances in industrial wastewater; investment in pollution control, and the implementation of pollution control simultaneously with industrial projects, and meteorological information like visibility, inversions, precipitation, temperature and wind speed and direction.

Provision of Information to Administrative Agencies

The information required by administrative agencies can be rapidly accessed from BMEMC's large store of information, particularly the real-time data generated by the System. Examples include:

Service During the 11th Asian Games BMEPB officials paid close attention to environmental quality and changes and took measures to control pollution sources to ensure the success of the

11th Asian Games, held in Beijing in 1990. BMEMC supplied average concentrations of various pollutants, their variation patterns at representative locations over the past several years, and monitoring data during the games.

Monitoring sites and areas have been expanded since 1990 as Beijing hopes to host a future Olympic Games and wants to ensure the required environmental quality.

This collection of monitoring data enables BMG and environmental protection agencies to strengthen abatement measures, control industrial pollution at the source, and greatly improve environmental quality.

Monitoring During Severe Weather Conditions Beijing's environment deteriorates during the winter due to increased emissions from coal-burning stoves and meteorological inversions. Conversely in spring, windy and dusty days are common. At these times, BMEMC monitors related parameters and provides this data and its analysis to the appropriate agencies.

Other Services Fireworks may cause both safety problems and environmental pollution. Environmental quality data from spring festival periods has been analyzed and ambient noise levels and relevant pollution parameters monitored for the last three years. Reports have been provided to administrative agencies to help them decide whether Beijing should designate special areas for firework displays.

A serious **flashover** accident occurred over the North China Power Network in February 1990. An analysis was carried out, using monitoring data from the time of the accident, and the results are being used to prevent future incidents.

Data was provided to the World Bank mission during their study of China's environmental status.

Environmental Impact Assessments For New Construction Projects According to current laws, an environmental impact assessment (EIA) is required for any new construction project or extensive renovation. A survey of the existing environmental status and an estimate, based on the nature and scale of the work to be done, of potential environmental impacts stemming from the investment must be prepared and submitted to the appropriate administrative agencies to help them decide whether or not to approve the project. Beijing Oriental Chemical Plant and Yanshan Cement Plant were constructed according to these requirements.

Monitoring of Pollution Emergencies Special monitoring is carried out after a significant water or air pollution event. For example, special monitoring was carried out in 1974 when wastewater containing **chloral** was discharged from a pesticide plant, and when SO₂ was emitted from a dye plant.

Complaints about noise pollution have increased in recent years. BMEPB has asked BMEMC to measure noise levels and pressed sources to control their noise by a given deadline. The effectiveness of these measures has been evaluated by BMEPB.

ENVIRONMENTAL FORECASTING

A study, headed by BMEMC, the Environmental Science Center of Beijing University and the Beijing Meteorological Science Institute, entitled "Air Pollution Predictions And Forecasting For Beijing's Urban And Inner-suburb Areas And Its Applications" was carried out during 1986-1989. Many disciplines, particularly environmental monitoring, atmospheric physics, and meteorology were involved in the study, which incorporated much environmental monitoring and meteorological data, such as the temperature of the atmospheric boundary layer and the structure of the wind field.

Major Contents Of The Study

Survey Of Air Pollution Sources In Beijing A survey of pollution sources was a fundamental task of the study. A database of air pollution sources was established based on a survey of Beijing's furnaces, kilns, stoves, traffic patterns and hydrocarbon emissions from gasoline stations throughout the city.

Beijing's Atmosphere The diffusion of atmospheric pollutants is affected by topographical and meteorological conditions. Diffusion factors were determined after analysis of the meteorological background of Beijing's air pollution and observation and analysis of the atmospheric boundary layer and diffusion characteristics over the city. A study of wind field patterns was carried out to determine their effects on pollutant transportation.

Data from the Automatic Ambient Air Quality Monitoring System Monitoring data obtained over the previous four years were analyzed; the results indicated no significant difference in the data obtained in different years. In addition to assessing pollution status and general pollutant patterns, these data were also used to study the distribution of pollutant concentrations, to examine the distribution of monitoring substations, the processing of data, and the calculation of the optimal intervals for monitoring.

Beijing Regional Atmospheric Dispersion Models Simple dispersion and practical dispersion models were developed for different pollutants and application areas.

Study Results A series of air pollution prediction and forecasting models has been established based on the results of this study.

Air Pollution Potential Forecast: Extensive analysis and statistical calculations of atmospheric circulations and major meteorological factors were carried out and equations for quantitative forecasts were established. This analysis and forecast of the weather's affect on serious pollution is extremely useful for preventing sudden pollution events. A short-term (24 hours) forecast system of SO₂ concentrations in urban areas was established using the simple dispersion model combined with the pollution potential forecast.

Practical Dispersion Model: This model is based on the multiple source Gaussian dispersion equation and can be used to assess current status, including the simulation of concentration field and contributions of various sources, such as in the analysis of the current status of and reasons

for SO₂ pollution in Beijing. This model can also be used for total pollutant discharge quantity control. First, the average winter SO₂ concentration from 1990 to 2000 was predicted based on the 1985 pollution sources survey. Then total quantity control targets for SO₂ at various phases and optimal reduction rates for various area sources under different conditions were determined, using methods similar to those used in Japan and information obtained from continuous monitoring.

The database of sources like furnaces, kilns, and stoves has supported the establishment of a complete, dynamic database for environmental management. The analysis and study of continuous monitoring data should help optimize System operations and statistical processing of monitoring data, which may have important practical values for resolving similar problems in air pollution monitoring elsewhere in China.

This study has yielded highly useful measures for managing Beijing's air quality. The study, however, is still in the testing phase and its achievements have not been widely applied. In addition, the survey of pollution sources needs to be expanded and study of the atmospheric boundary layer should be intensified to provide even more accurate and effective air pollution forecasts.

SERVICE TO OTHER RESEARCHERS

Monitoring data are highly valuable to scientific studies, such as the relationship between the environment and human health, or between changing weather patterns and environmental pollution.

Environmental monitoring data obtained by BMEMC have been carefully screened, making them accurate, valid and widely applicable, particularly in environmental management and forecasting. These data, if further developed, might play an even greater role in other fields, particularly in cooperation with other cities or countries.

PERSONNEL TRAINING

BMEMC was China's first environmental monitoring department, established as environmental monitoring was just beginning and there were no personnel specifically trained in the subject. Most of the staff first recruited for BMEMC were technical personnel, experienced in chemistry, biology, physics, geology, geography, meteorology or electronics, as well as a number of grass-roots laboratory technicians. Various professional training was given to the technical staff at different levels.

Early on some highly trained technical staff were drawn into BMEMC. They had university-level and post-graduate training, research aptitude and practical work experience, but needed to adapt their expertise to the demands of environmental science. Their environmental monitoring skills were improved through environmental research, academic exchanges and visits within China and to foreign countries, collecting publications on environmental monitoring (generally not available in China at the time) and other supplementary education to enhance knowledge and skills.

They came to master the overall theory of environmental monitoring and new developments in monitoring science and technology, and defined the domain and direction of the work to be done by their department and within their individual specialities. They gradually took lead in their specialties' academic realm. Later, they often became heads of or advisors to technical offices, in charge of professional work. They developed professional work plans, set the course for scientific research, organized major comprehensive scientific research and instructed postgraduates and personnel in scientific research and technical work.

BMEMC established the post of Graduate Student for young technical fellows possessing strong professional skills and expected to benefit from further studies. Upon finishing postgraduate courses, they research new environmental monitoring topics under the guidance of a tutor. BMEMC has guided 6 Graduate Students through to their masters degree.

Over the past decade, BMEMC sent 23 core staff to America, Japan or Canada to enhance their scope and study advanced technologies, techniques and experiences; on their return most became the technical backbone of BMEMC. Because not all staff came from an environmental monitoring background and some personnel needed to enhance their knowledge, in the early 1980s BMEMC introduced training classes for technical staff at the assistant engineer level and

above. Examples included weekly classes in "Introduction to Environmental Monitoring", which lasted for half a year, in which technical personnel received extensive training, and studies in mathematical statistics. Computer applications and foreign language training were also offered, in order to supplement staff skills.

Laboratory technicians and sample collectors undertake the most direct and routine monitoring tasks, so their technical skills directly influence the quality of the monitoring data. However, most of them do not bring to the monitoring stations a strong professional education. BMEPB, BMEMC and the district and county EPBs prioritize personnel training in their annual working plans. The training is formulated specifically for the district and county monitoring stations. BMEPB annually budgets Y20,000 to Y30,000 for training. Subordinate technical personnel are sent to training and experts are brought to the stations.

Following NEPA regulations on monitoring quality assurance, in 1987 BMEPB developed the "Certificate of Technical Quality" for environmental monitoring staff and analysts, and stipulated that uncertified staff would not be allowed to report monitoring data. The technical proficiency parameters include basic theory, experimental operation skills and analysis of unknown samples. Through training of district and county monitoring staff, nearly 90 percent of samples collected qualify on first check.

PURPOSES AND REQUIREMENTS OF TRAINING

Only a small percentage of staff will enter colleges or universities to pursue formal schooling, which means most staff members will be trained only at their posts. For the laboratory technicians, the following goals are sought through training:

Basic Analytical Chemistry

Through studying basic analytical chemistry, laboratory skills, mathematical statistics, quality control and assurance, analytical principles, and typical analytical experiments, the students develop the ability to think independently and solve problems.

Basic Operational Skills

Through practice in the correct use of glassware and training in volumetric, colorimetric and gravimetric analysis and sampling technology, the students master basic operational monitoring skills.

Use of Special-purpose Instruments

Through use of the large special-purpose instruments, such as the GC, the AAS, the infrared oil detector and the automobile exhaust analyzers, the students learn the methods and principles of instrumental analysis, using the instruments for simple maintenance work.

The purposes of training are:

- Raising the basic theoretical level by asking the students to integrate theory with practice;
- Cultivating a practical work style, a serious attitude towards the sciences and a rigorous scientific approach;
- Increasing the abilities of the technical personnel to carry out scientific experiments independently, analyze and solve problems when they meet with difficulties, and improve environmental monitoring quality within the system.

TRAINING METHODS

These methods are intended to enhance monitoring personnels' professional and technical training.

- Promising young staff are identified and sent to colleges or universities for formal study.
- Once BMEMC and a local university jointly held a two-year environmental monitoring program, equivalent to a technical secondary school. The students from this course since have become core staff at the city's environmental monitoring posts.
- BMEMC provides local monitoring station staff with post-technical training in water, air and noise parameters.
- BMEMC offers short-term training classes 3-4 times each year, inviting experts, professors and engineers to give lectures. This is the most common form of training.
- Instrument manufacturers sometimes provide training.
- BMEMC periodically sponsors competitions in environmental monitoring techniques and technologies.

Training Plan And Content

BMEPB budgets funds each year for training to cultivate technical personnel and enhance their monitoring ability, develop environmental protection capacity and better serve environmental management. Over the past decade BMEMC has held 50 training courses, training over 2000 staff. Personnel from other Beijing organizations and various industrial bureaus, factories, mines and other enterprises are often also admitted to these classes.

Professional and technical training is developed very much in response to the basic skills needed for monitoring and analysis. After identifying the amount of training needed in the coming year and the amount of funds budgeted for training, classes are placed in the work plan. BMEMC conducts classes 3-4 times a year. These courses are normally completed with a written exam or exam plus hands-on test.

Training work already undertaken by the environmental monitoring network system includes:

- **Basic theory:** Principles and experimental operational skill of volumetric, colorimetric and gravimetric analysis; water and air sampling methods and technology.
- **Monitoring methods:** Measurement methods for SO₂, NO_x, CO and sulphation rate in air and BOD₅ and NH₃ in water.
- **Professional management:** The directors of district and county EPBs and monitoring stations visit and study more advanced units and share experiences with them, to heighten awareness of service and enhance their management skills.
- **Special-purpose instruments:** To understand the structural principles of the GC and the AAS infrared oil detector; to practice instrument adjustment; to know how to use analytical instruments; how to do sample analysis and measurement.
- **Quality assurance** to learn quality control technology, to master quality control methods and the stipulations of quality assurance.
- **Pollution source monitoring:** To master the measurement technologies of certain parameters, especially boiler flue dust and gas, auto exhaust, industrial wastewater and waste gas;
- **Computer applications:** To learn BASIC programming language for data processing; to create a database; to use computers for scientific management;

| Class | Date | Length | Study Topic | Number Trained | Rep. Cr. in ILOC Monitoring of Train. |
|-------|----------|---------|--|----------------|--|
| 1 | 3/1/82 | 2 weeks | Operation of Model 590 mercury detector | 24 | |
| 2 | 3/22/82 | 2 weeks | Monitoring SO ₂ , NO _x and dust | 15 | |
| 3 | 8/3/82 | 1 week | Noise measurement methods and technology | 35 | |
| 4 | 10/11/82 | 1 week | Boiler flue dust measurement | 35 | 8 from initial set |
| 5 | 10/18/82 | 1 week | Boiler flue gas measurement | 30 | |
| 6 | 12/24/82 | 2 weeks | Atmospheric SO ₂ measurement by acidity test method | 30 | |
| 7 | 4/23/83 | 1 week | Boiler flue dust measurement (emphasis on field monitoring) | 23 | |
| 8 | 10/10/83 | 4 weeks | GC analysis | 29 | |
| 9 | 10/19/83 | 2 weeks | AAS analysis | 14 | |
| 10 | 5/4/84 | 3 weeks | AAS analysis | 24 | 4 from W. G. B. |
| 11 | 9/10/84 | 1 week | Management (for BEPB and BMEPC managers) | 35 | |
| 12 | 1/22/85 | 1 day | Use of Model 5100 calculator for processing monitoring data | 35 | |
| 13 | 7/29/85 | 2 weeks | Water monitoring QA | 34 | |
| 14 | 9/9/85 | 2 weeks | Basic laboratory principles | 36 | |
| 15 | 4/12/86 | 1 week | Pollution source monitoring methods | 96 | |
| 16 | 9/19/86 | 2 days | Measuring water flow velocity | 80 | |
| 17 | 10/17/86 | 2 weeks | Measuring oil content with OCMA-200 oil detector | 24 | |
| 18 | 10/22/86 | 1 week | S-3001 noise meter | 25 | 3 from dir. points |
| 19 | 11/18/86 | 4 days | Flue gas darkness test | 41 | 3 from dir. points |
| 20 | 3/9/87 | 1 week | Polarographic measurement of atmospheric benzene | 40 | |
| 21 | 6/22/87 | 1 week | Environmental monitoring sampling technology | 50 | |
| 22 | 9/5/87 | 1 week | Water monitoring and quality control technology | 36 | |
| 23 | 9/5/88 | 1 week | Boiler flue dust and gas measurement | 257 | 17 from initial set |

| Class | Date | Length | Study Topic | Number Trained | Ref. Cr. in ECE Mining Safety |
|-------|----------|---------|--------------------------------------|----------------|----------------------------------|
| 24 | 5/18/88 | 2 weeks | Oil detector, DO meter | 40 | |
| 25 | 12/12/88 | 1 week | Comprehensive data analysis | 36 | |
| 26 | 2/22/89 | 1 week | Boiler flue dust and gas measurement | 117 | 5 fm in the sa |
| 27 | 7/3/89 | 1 week | Monitoring server management | 35 | |
| 28 | 8/21/89 | 1 week | Monitoring automobile exhaust | 80 | |
| 29 | 9/11/89 | 1 week | Environmental noise test | 54 | |
| 30 | 11/13/89 | 1 week | Atmospheric monitoring QA | 36 | |
| 31 | 2/22/90 | 1 week | Boiler flue dust measurement | 50 | |
| 32 | 3/19/90 | 1 week | Automobile exhaust management | 60 | |

INTERNATIONAL COOPERATION

BMEMC has carried out environmental monitoring for over 15 years, accumulating significant experience. A contingent of some 150 technical personnel has been established. BMEMC frequently conducts academic activities and technical exchanges with domestic and foreign environmental monitoring organizations and departments. In addition, BMEMC has an extensive history of cooperation with domestic and foreign equipment manufacturers. BMEMC is thus qualified to conduct the following international cooperation activities:

DESIGN AND IMPLEMENTATION OF THE ENVIRONMENTAL MONITORING SYSTEM

Automatic Ambient Air Quality Monitoring System Project

Design and implementation of automatic ambient air quality monitoring systems in urban and rural areas and industrial districts.

- General design of monitoring systems.
- Optimum allocation of monitoring stations.
- Structural design of monitoring substations.
- Selection, installation and adjustment of monitoring facilities and equipment.
- Development of computer application software for monitoring systems.
- Real-time and on-line adjustment and operational testing of monitoring systems.
- Quality assurance and technical support for monitoring systems.
- Technical training of operational personnel and maintenance of monitoring systems.
- Experience in operational management of monitoring systems.

Automatic Stack Emission Source Monitoring System Project

- Design and implementation of continuous sample-extraction and non-sample-extraction monitoring of emission sources.
- Overall design plan of monitoring systems.
- Design of sampling and sample pretreatment.
- Structural design of monitoring sub-stations.
- Selection, installation and adjustment of monitoring facilities and equipment.

- Development of computer application software for monitoring systems.
- Real-time and on-line adjustment and operational test of monitoring systems.
- Quality assurance and technical support of monitoring systems.
- Technical training of operational personnel and maintenance of monitoring systems.
- Experience in operational management of monitoring systems.

Automatic Water Quality Monitoring System Project

Design and implementation of automatic and continuous water quality monitoring systems for surface water, groundwater, industrial wastewater and effluents from sewage treatment plants.

- Overall design plan of monitoring systems.
- Optimum distribution of the monitoring network.
- Structural design of monitoring sub-stations.
- Design of sampling and sample pretreatment.
- Selection, installation and adjustment of monitoring facilities and equipment.
- Development of computer application software for monitoring systems.
- Real-time and on-line adjustment and operational tests of monitoring systems.
- Quality assurance and technical support of monitoring systems.
- Technical training for operational personnel and maintenance of the monitoring systems.

Mobile Environmental Monitoring Stations

Design and implementation of monitoring stations for mobile ambient air quality, stack emission sources and dual-purpose mobile monitoring stations for ambient air quality, emissions, radioactive material and water quality.

- Overall design of mobile monitoring stations.
- Selection of vehicle, instrument and equipment of mobile monitoring stations.
- Retrofitting of monitoring vehicles and installation and adjustment of instruments and facilities.
- Development of computer application software for mobile monitoring stations, separate from or integrated with the monitoring systems.
- Quality assurance for mobile monitoring stations.
- On-line adjustment and operational links of mobile monitoring stations.
- Technical training of operational personnel and maintenance of mobile monitoring stations.
- Management of mobile monitoring stations.

DESIGN AND ESTABLISHMENT OF THE ENVIRONMENTAL MONITORING LABS

Design and establishment of environmental monitoring labs of the environmental monitoring organs at the various levels (state, province, municipality, region, etc.)

- Determining the duties of the environmental monitoring organs.
- Design of environmental monitoring facilities.

- Technological and architectural design of the environmental monitoring laboratories.
- Layout of the various labs, including chemical analysis labs, instrumentation analysis labs, auxiliary labs and computer facilities.
- Selection of instrumental facilities for the environmental monitoring labs.
- Installation and adjustment of the monitoring labs' instrumental facilities.
- Quality assurance plan of the environmental monitoring labs.
- Technical support of the environmental monitoring labs including the supply of standard gases, standard reference materials (samples) and samples for quality control assessment.
- Technical training of environmental monitoring lab personnel.

ESTABLISHMENT OF THE ENVIRONMENTAL MONITORING SPECIALIST CONTINGENT

- Provide various specialists for short-term or long-term international technical cooperation, exchange, discussion and consultation.
- Design of environmental monitoring program
- Design of environmental monitoring network.
- Environmental monitoring technology (sampling, analytical methods, monitoring facilities, data processing).
- Environmental monitoring quality assurance.
- Environmental pollution investigation and assessment (assessment of present status, environmental impact, environmental risk).
- Including air, water, soil, solid waste, biology, noise and vibration.

RESEARCH AND DEVELOPMENT OF ENVIRONMENTAL MONITORING

- Cooperative research projects on regional and global environmental monitoring.
- Research on environmental pollution dispersion and transportation.
- Research on priority pollutants in the local environmental.
- Research on the regional environmental monitoring network.
- Research on critical global environmental projects.

DISCUSSION

STANDARD ANALYTICAL METHODS

Why other countries' methods cannot be adopted directly:

In China, a method can be approved only once it has been optimized according to standard principles. Some native standard analytical methods, internally tested and verified, equal international standards. The adoption of other countries' certain methods cannot invariably be ruled out. However, foreign methods should not be copied indiscriminately, but studied, analyzed, tested and verified, for several reasons:

1. The makeup of a sample is very complicated, and other factors may influence methods. For instance, industrial waste gas or wastewater varies according to different raw materials, production processes and environmental control measures applied. Any analytical process should be carefully examined to identify the method that will yield the most precise results.
2. China's conditions must be taken into consideration while selecting methods. For example, are the appropriate instrumental facilities and reagents available, are the labs qualified, are the methods convenient and feasible? If these factors do not fit China's circumstances, foreign analytical methods will not be used.
3. Methods selected have undergone a standardization procedure, in which representative samples are scientifically studied. Following experiments by an appropriate number of labs, a fairly accurate evaluation of the method and its permissible error range can be determined, which provide standard guidelines for quality control monitoring. The standard analytical method developed thus may be used during arbitration in settling monitoring data disputes, because its reliability is generally recognized.

Experience has shown that some foreign methods cannot be directly used in China:

1. Some pollutants common in China, such as organic chloride, phosphorus pesticides, anilines or nitrobenzines, are not common in other countries, and therefore different analytical methods are necessary.
2. Other countries often have adopted more advanced instruments not yet common in China, such as automatic colorimetric analysis of organic and inorganic molecules. Abroad, the

atomic absorption technique of graphite crucible is commonly used for trace metal analysis and ultra-micro metal analysis; this is not in common use in China. Instead, the flame atomic absorption method and other chemical methods were adopted. The chemical method is still China's primary method of inorganic ion analysis, as ion chromatographs are not commonly available. Often because of the high price or unavailability of certain instruments, detectors, reagents or instrumental carriers, methods more suited to China's circumstances have been developed.

3. Some native analytical methods are better than those of foreign countries, such as the colorimetric measurement of arsenic. While the photometric method of silver diethyldithiocarbamate is commonly used abroad, the new silver salt method (spectrophotometric determination of trace arsenic by using silver nitrate polyvinyl alcohol absorbent solution) was developed in China. Its sensitivity is much higher than that of the former (the detection limit is 0.0004 mg/l, compared to), while reducing secondary pollution from the reagent. This method is now commonly used for background detection in China.

Quality Assurance

In the 1970s, developed countries perfected environmental monitoring quality assurance. It has been suggested that monitoring data from the early 1960s cannot be used because of poor quality assurance.

In the early 1970s, scientific research in environmental quality investigation was carried out in Beijing by EPBs, universities and several research institutes of the Academy of Sciences of China, all of which were technically capable. However, river pollutant monitoring found that pollution source data were contradictory, producing irrational data, because no quality assurance measures were taken. For example, the reported level of mercury varied considerably, in spite of stable discharge patterns and control measures in place. On review it was found that two different analytical methods were used with no quality assurance measures.

Often funds were wasted because of inaccurate monitoring data:

1. Oils and fats were found in the effluent from an oil refinery. The refinery used freon as a solvent to analyze the greases in the effluent and concluded that both the oil and fat exceeded discharge limits. Different types of equipment were designed by the engineers to remove oil and fat from the effluent, but were not satisfactory. After investigating the analytical method, it was found that the substances taken for oil and fat were in fact another organic compound, dissolving both in water and freon. This could be removed by other methods, which meant that costs for de-oiling and de-fatting equipment could be reduced.
2. The initial analysis of suspended solids (SS) in a certain factory's effluent indicated that SS exceeded limits. When compared to effluent from a neighboring sewage treatment plant, the turbidity of the factory effluent was the same as that from the plant, but the SS in the sewage treatment effluent was only half the legal limit. This showed

that the SS in the factory effluent did not exceed the limit. It was later found that they were using two different glass-fibre filters for analysis, both of which were approved by the U.S. Environmental Protection Agency (EPA). After changing the filters, SS in the factory effluent met the quality index, saving US\$90,000 in filter facilities.

3. The concentration of cyanogen ions (CN') in wastewater was 10 times the median lethal concentration for fish, according to ASTM detection methods, but in biological tests the fish thrived. Later, review of the method revealed that SCN' was inadequately screened out and that the wastewater contained much more SCN' than CN'. Because SCN' is less toxic, treatment costs were far less.

Since the 1980s, quality assurance work has been increasingly carried out in China, improving monitoring quality. Assessment of technical proficiency has been made by the state on behalf of the monitoring departments and the provincial and municipal environmental protection research institutes, and the monitoring departments now get even better assessment results than the institutes. This is because they have implemented the principles of environmental monitoring quality assurance management.

1. To be determined by the operator according to the conditions of the instruments.

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