

JIANGSU PROVINCIAL ENVIRONMENTAL MONITORING PROJECT

FEASIBILITY STUDY

Prepared for:
Environmental Protection Department
Jiangsu Provincial Government

Prepared by:



H&J, Inc. U.S.A.



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J. Cooper

**FEASIBILITY STUDY
FOR
JIANGSU PROVINCIAL ENVIRONMENTAL MONITORING
PROJECT (JPEMP)**

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Chapter I

CHAPTER I EXECUTIVE SUMMARY AND INTRODUCTION

1.1 Executive Summary

Jiangsu Province is in the process of building up its automatic environmental quality monitoring and control system. This system consists of two subsystems: an automatic air quality monitoring system, and an on-line automatic water quality system. The two subsystems share similar functions-data collection, transmission, statistical analysis, and distribution.

It is planned that from 2000 to 2005, 70 automatic air quality monitoring substations and three mobile air quality monitoring stations will be established in Jiangsu Province. The automatic air quality monitoring and control system at the provincial level, that monitors Nitrogen Oxides (NO_x), Sulfur Dioxide (SO₂), Total Suspended Particulates (TSP) and Particulate Matter 10 (PM₁₀), will be established to realize the purpose of real-time data acquisition, distant monitoring and real-time transmission. The monitoring of Particulate Matter 2.5 (PM_{2.5}), mobile pollution sources, organic pollutants, and forecast of air pollution will be implemented gradually.

The automatic water quality monitoring will be based on on-line monitoring techniques. It is planned, during the current five-year period (2000 to 2005), to build 38 automatic water quality monitoring stations (will expand further to 50) and three mobile stations in major watersheds, sensitive areas, on the sections of major administrative boundaries, and important urban drinking water resources. The number will be expanded to 50 in the future. The parameters that will be monitored include Chemical Oxygen Demand on Manganese (COD_{Mn}), PH, temperature, conductivity, Dissolved Oxygen (DO), turbidity etc.

In addition to air and water quality monitoring systems, an environmental information processing system will also be developed and implemented. This system includes an environmental information control center and environmental monitoring data transmission mechanism. The control center takes the peer-peer communication means, collects data in set time frame and implements distant monitoring. The control center takes two systems running in operation-backup mode to ensure around-the-clock operation.

In order to successfully implement the proposed project, the Grantee will apply the U.S. Trade and Development Agency (USTDA) Grant for assistance with the following issues:

- The reasonable technology to lay out the monitoring sites according to the different backgrounds of the provincial cities, towns, and villages;
- Determination of the parameters that should be monitored at different sites;
- Selection of the automatic air quality monitoring equipment;
- Selection of the automatic water quality monitoring equipment; and
- The technology for data collection, processing, distant transmission, and real-time data acquisition.

The following tasks will be performed:

- To fully review, evaluate, and understand the Grantee's air and water quality automatic monitoring framework and capabilities.
- To provide technical assistance to Jiangsu Provincial Environmental Monitoring Center (JPEMC) to evaluate the selected air quality monitoring station and point locations; and identify and locate the additional air quality monitoring locations. Determine the parameters that should be monitored at different air quality monitoring locations.
- To provide technical assistance to JPEMC to identify and locate the water quality monitoring location. Determine the parameters that should be monitored at different water quality monitoring location.
- The selection of automatic air quality monitoring equipment.
- The selection of automatic water quality monitoring equipment.
- To provide technical assistance for automatic monitoring data collection, processing, distant transmission and real-time data acquisition.
- To develop the Technical Assistance Report.

A final report that summarizes the results of each of the above tasks will be prepared in both English and Chinese. It will include the overall findings, provide the specific recommendations for project implementation, and provide a list of U.S. supply sources.

1.2 General Information

This *Feasibility Study for Jiangsu Provincial Environmental Monitoring Project* is funded by the USTDA through a cooperative grant agreement (Grant No.: CH2396658). The Consulting Team from the American firms of H&J, Inc. and E&E, Inc. are assisted by local specialists from the Jiangsu Environmental Protection Department (JEPD) and the JPEMC. The report covers the following information:

- A General Introduction;
- Air and Water Quality Monitoring Network Background Information;
- Evaluation of the Existing Air and Water Monitoring Systems;
- Recommendations for Building up New Automatic Air and Water Monitoring Stations;
- Recommendations for Purchasing New Mobile Air and Water Monitoring Vehicles;
- Brief introduction of selection and optimization of AWMS locations using modern remote sensing technology.
- Recommended Manufactures/Vendors/Instruments Evaluation and Analysis; and
- Recommendations Regarding Costs for Purchasing Instruments; Costs for Installation, Assembly, and Civil Works; and Costs for Routine Calibration, Operation, and Maintenance.

In order to accomplish the objectives, the Consulting Team conducted the following tasks with the assistance of the JEPD and the JPEMC.

- Reviewed documents provided by the JEPD and the JPEMC concerning Jiangsu's existing air and water quality monitoring program, the existing and proposed automatic and mobile air and water quality monitoring stations, the Provincial Environmental Annual Report for year 2002 and the Provincial Environmental Bulletin (2000-2002).
- Visited air monitoring stations in Nanjing, Yangzhou, and Xuzhou, as well as industrial sites in the same cities. Visited an automatic water monitoring station at Sanjiangying in Yangzhou municipality at the conveying point for the project of diverting water from the south to the north (Yangtze River).
- Visited the laboratories of the Jiangsu Provincial Environment Monitoring Center (JPEMC), Nanjing Municipal Environment Monitoring Center (NEMC) and Yangzhou Municipal Environment Monitoring Center (YEMC).
- Interviewed and had symposia with the technical staffs and operators for the existing automatic monitoring station and laboratory instruments from JPEMC, NEMC and YEMC.
- Contacted several U.S. manufactures/vendors that manufacture automatic water monitoring instruments and mobile monitoring vehicles to collect information about quotations, specifications and characteristics of the products, as well as new technologies and new products, etc.

1.2.1 Provincial Background

Jiangsu Province, Su for short, is located near the seaside of the eastern coast of China. The longitude of Jiangsu is between 116° 18' and 121° 57' east and the latitude is between 30° 45' and 35° 20' north. The position of Jiangsu is in the lower reaches of the Yangtze River and Huai River, with the Huanghai Sea to the east. Anhui Province is to the west of Jiangsu Province and Shandong Province is to the north; Zhejiang Province and Shanghai are adjacent to Jiangsu to the south. There are no tall mountains, but there are plenty of famous "smaller" mountains as well as large bodies of water. The rivers and ports crisscross throughout the province. The land is comparably higher in the northern and southwest regions in Jiangsu. The other part of Jiangsu is composed of broad expanding plains including the Huanghuai Plain, the Jianghuai Plain, the Binhai Plain, and the Yangtze Delta from north to south.

Jiangsu Province now has 13 key municipalities directly under the province. They are Nanjing, Suzhou, Wuxi, Changzhou, Zhenjiang, Yangzhou, Nantong, Lianyungang, Huaiyin, Taizhou, Xuzhou, Yancheng and Suqian. The capital of the province is Nanjing. Year ending 2002, the province had over 78,900 ha. of garden and greenbelt areas throughout its 13 key municipalities. These same cities have over 240 attractive parks which boasted nearly 49 million visitors in 2002.

Jiangsu Province is situated in the Temperate Zone and Subtropical Zone, with a humid and semi-humid monsoon climate. The Jiangsu section of the Huai River

and the Northern Jiangsu Irrigation Canal is China's dividing belt between the two zones. The annual average temperature is 13°C - 16°C (55°F - 61°F) with the average winter temperature in January being -2°C - 4°C (29°F - 39°F), and the average summer temperature in July being 26°C - 29°C (79°F - 85°F). The highest temperature on record is 40.9°C (106°F), and the lowest temperature on record is -23.1°C (-10°F). The temperature increases from northeast to southwest gradually. The temperature in the western area rises more quickly in spring than in the eastern area. In addition, the temperature in the southern area lowers more slowly in autumn than in the northern area. The annual frost-free period lasts on an average of 220 days. The annual average precipitation is 1,010 mm, half of which comes in summer. The recorded heaviest daily precipitation was 314.3mm. Floods in the summer and typhoons at the end of summer and/or beginning of autumn often hit this province. The region north of the Huai River experiences a longer spring than autumn with the opposite being true for the region south of the Huai River.

The rainfall in the eastern and southern regions is more than in the northern and western regions. Areas around Tai Lake, Yisu, and near the Yangtze River have the greatest amounts of rainfall; being above 1150mm. The region between the Yangtze and Huai Rivers and in the northern area of southern Yangtze is 950 to 1100mm of rainfall; the northern region of the Huai River has rainfall of 700 to 950mm. Summer (June to August) has the greatest rainfall amount, which accounts for up to 60% of the total amount. Rainfall in autumn (September to October) accounts for up to 22% of the total; and spring (March to May) has up to 26%; and winter (December to February) has rainfall of up to 13%. The annual evaporation capacity in Jiangsu is 900-1050mm, which increases from east to west because of the ocean warm and wet vapor stream.

A map of Jiangsu Province, Figure 1-1, follows.

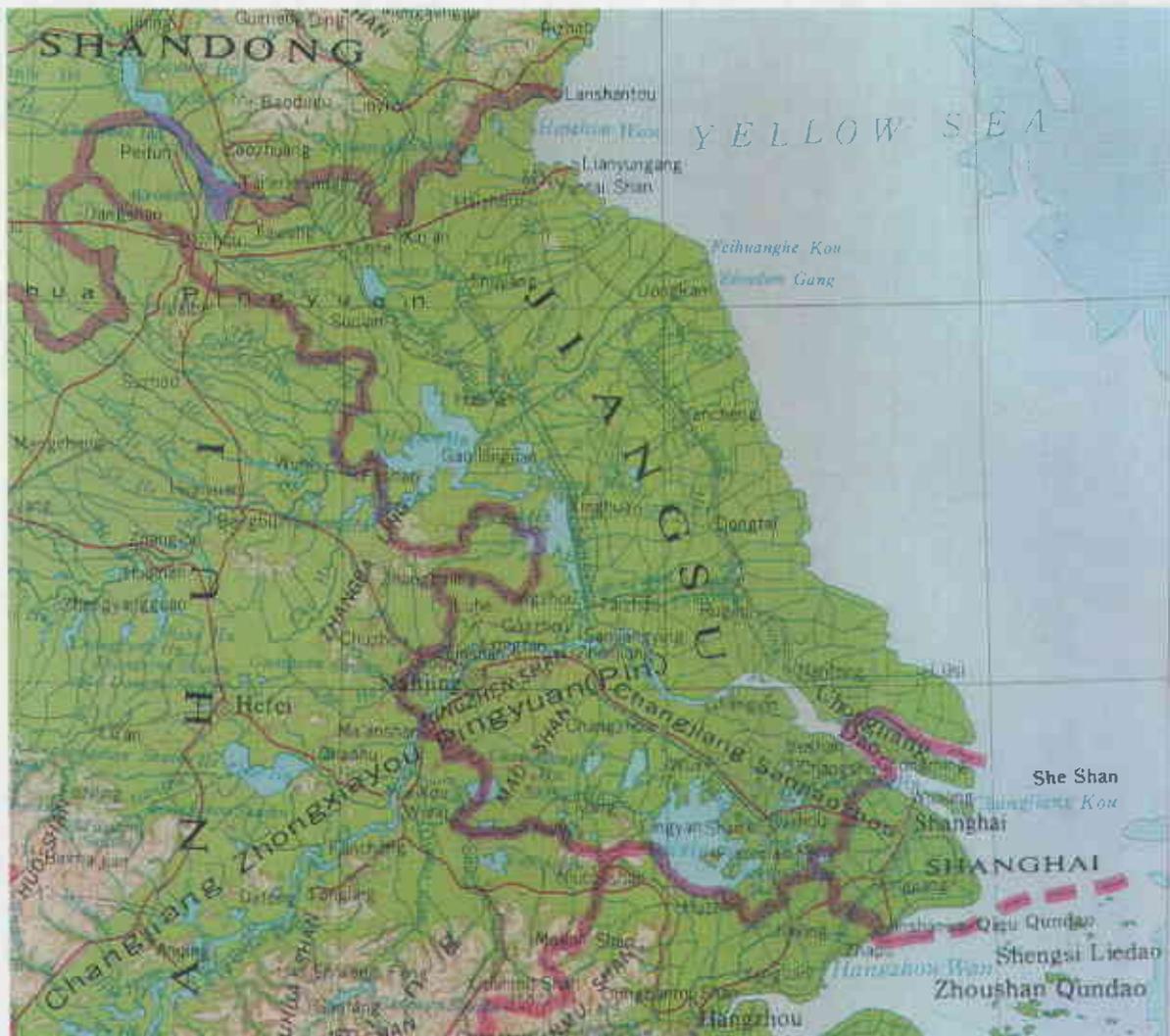


Figure 1-1 Jiangsu Province

Source: Atlas of China, 3rd Edition, May 2001

Jiangsu Province is a rich industrial and economically developed province in China. The economy of Jiangsu Province has been developing most rapidly over the past decade. The Jiangsu provincial government and the municipal governments of the province view the improvement of the economy as crucial. Part of the improvement of the economy is environmental protection. Over the past decade the provincial and municipal governments have sought investment for the cleanup and improvement of air quality and water quality within the province.

The well developed Jiangsu Province's industries are mainly electronics, machinery, chemical, metallurgy, textile, food and papermaking, etc. Southern Jiangsu area (Sunan), a part of the Yangtze River Delta economic region, is the province's economic hub, accounting for 57.26% of provincial GDP in 2001. The area covers five municipalities: Suzhou, Wuxi, Changzhou, Nanjing and Zhenjiang.

Economic performance of the province in 2001 was remarkable in many aspects:

- Its GDP accounted for 9.9% of the national total;

- Its industrial output value accounted for 14% of the national total;
- Its actually utilized foreign capital accounted for 14.8% of the national total;
- Its exports value accounted for 10.8% of the national total;
- Its retail sales value of consumer goods accounted for 7.6% of the national total; and
- Its total investment in fixed assets accounted for about 9% of the national total.

Jiangsu has a strong industry sector which accounted for 57.4% of the province's total industrial output in 2001. Among the heavy industries, machinery and equipment were the largest sectors which accounted for 32.4% of the province's total industrial output, followed by the petroleum and chemistry industry which accounted for 18.4% of the province's total industrial output.

Jiangsu is moving towards the development of new and high technology products. For instance, Suzhou absorbed 20% of Taiwan's investment in the mainland in 2001, most of which was invested in new and high technology industry. Jiangsu pays much attention to three hi-tech industries -- IT, new material and heavy petrochemical and new medicine. Jiangsu has now become an important IT manufacturing base.

Total imports and exports amounted to US\$51.4 billion in 2001. Jiangsu's industries have become more externally-oriented in recent years. Between 1985 and 2001, exports grew 17.2 times and imports grew 55.1 times. In 2001, the ratio of foreign trade to gross domestic product (GDP) rose to 44.7%. During the same period, manufactured goods accounted for 88.0% and 96.7% of the province's imports and exports respectively.

Jiangsu ranked top in attracting foreign-direct investment (FDI) and contract amount among all provinces and municipalities in 2001. Year ending 2001, Jiangsu accounted for 13.3% of China's total utilized FDI. Foreign-invested enterprises (FIEs) are playing an important role in Jiangsu's economy. FIEs accounted for 28.4% of Jiangsu's gross industrial output and 57.6% of exports in 2001. Foreign investments in Jiangsu are mainly engaged in the manufacturing industries (91.1% of FDI at the end of 2001) including computer accessories, computers, mechanical and electrical products, petroleum and chemistry, and hardware and traditional industries such as textile and garments. Table 1-1 shows the major indicators for the provincial economy.

Table 1-1 Economic Indicators for the Province

Economic Indicators	2001		Jan-Sep 2002	
	Value	Growth (% y-o-y)	Value	Growth (% y-o-y)
Gross Domestic Product (RMB bn)	951.2	10.2*	736.3	11.6
Per Capita GDP	12922	10.4		
Added Value Output				
- primary industry (RMB bn)	108.2	3.9*		
- secondary industry (RMB bn)	490.7	11.0*		
- tertiary industry (RMB bn)	352.2	11.1*		
Gross Industrial Output** (RMB bn)	1174.8	12.5		
Fixed-assets Investment (RMB bn)	330.3	10.27	260.4	21.2
Retail Sales (RMB bn)	286.9	10.9	233.2	12.1
Inflation (Consumer Price Index, %)		-1.1		-0.9
Exports (US\$ bn)	29.4	11.4	27.1	27.7
- by FIEs (US\$ bn)	16.6	14.5	16.8	40.4
Imports (US\$ bn)	25.1	10.0	22.3	34.0
- by FIEs (US\$ bn)	17.5	11.5	17.9	39.3
Foreign Direct Investment				
- number of projects	3581	35.4	2598#	
- contractual amount (US\$ bn)	15.1	42.5	9.96#	
- utilized amount (US\$ bn)	7.1	10.9	7.95	56.6

Notes: * In Renminbi real term

** For enterprises with annual sales over RMB5 million

Jan-Jun 2002 statistics

Sources: Statistical Yearbook of Jiangsu, 2002; official announcements

In 2001, the year-end total population (permanent residents) in Jiangsu was 73.5 million. Males accounted for 50.62% of the total population and females accounted for 49.38%. The population density was 717 persons/km².

1.2.2 Project Background

Some believe that economic construction and environmental protection are a contradictory unification. However, this does not need to be true. The environment should be protected while the economy develops. It is an important task for all levels of the government to manage the relation between economic development and environmental protection.

The economy in Jiangsu has developed quickly with heavy pressure being applied to the issue of environmental protection. The Jiangsu Provincial and Municipal Government take the coordination of economic development and environmental protection as very important work. The government has put a lot of investment into environmental treatment while the economy develops. According to present monitoring data, improvements are obvious; however, environmental protection is a long-term responsibility, which should be kept in the forefront at all times.

Environmental monitoring is at the base of environmental protection, and it is one of the key ways to manage the environment. The National Environment Protection Bureau put forward in the meeting of the "National Environment Monitoring Station Heads" in 1999, that the general targets for "the tenth-five year" monitoring work is to clarify the current law status and its alteration of environmental quality, to enhance the modernization level of environmental monitoring, to fulfill the partial urban network organization, management

formality, monitoring work automation, technique standardization, standardize quality control and modernizing the monitoring system. The Jiangsu environment protection units are constantly mindful of the pressures brought on by economic development to the environment of Jiangsu. These units are continuously finding ways to strengthen the monitoring work and improve the monitoring level, which is a key measurement to achieving Jiangsu's long-term environmental treatment target.

Therefore, over the past decade the provincial and municipal governments have aggressively sought investment for the cleanup and improvement of air quality and water quality within the province.

Automatic Air Monitoring and Control System

Within the six-year time frame of 2000 to 2005, JEPD will establish 70 automatic air monitoring substations and three (3) mobile air quality stations in Jiangsu Province. The automatic air monitoring and control system at the provincial level that monitors NO_x, SO₂, TSP and PM₁₀, will be established to realize the purpose of real-time data acquisition, distant monitoring, and real-time transmission. The monitoring of PM_{2.5}, mobile pollution sources, organic pollutants, and the forecast of air pollution will be implemented gradually.

Automatic Water Monitoring and Control System

Within the same time frame as above, the JEPD will build 38 automatic water quality monitoring stations (will expand further to 50) and three (3) mobile stations in major watersheds, sensitive areas, on the sections of major administrative boundaries, and important urban drinking water resources. The automatic water monitoring and control system will be based on on-line monitoring techniques. The parameters that will be monitored include COD_{Mn}, pH, temperature, conductivity, DO, turbidity, etc. It is intended to build up the system in a phased approach that is scientifically laid out, technically advanced, and quick to respond to water quality changes in the entire province. The preset objective is to help shed light on water quality change, main pollutant quantity, and to sound a warning alarm when drinking water quality changes.

Environmental Information Processing System

This system includes an environmental information center and environmental monitoring data transmission mechanism. The center takes the peer-peer communication means, collects data in a set time frame, and implements distant monitoring. Two systems will be running in operation-backup mode to ensure around-the-clock operation.

The Feasibility Study has provided the technical, financial and equipment requirements of the environmental monitoring and control system for JEPD. It will be used to assist JEPD in reviewing and evaluating the province's existing air and water quality monitoring capabilities and framework, as well as evaluating equipment and technologies for upgrading the system. The resulting Feasibility Study has provided a comprehensive guide to the implementation of a monitoring

system which can improve the functionality and efficiency of the existing environmental monitoring and control system of Jiangsu Province.

1.2.3 Objectives

As one of the leaders in China's environmental monitoring field, the JPEMC has a basic water monitoring system, but compared with that in developed countries as well as considering its economic growth and the condition of water pollution, both air and water monitoring instrumentation as well as data transmission system need to be increased and strengthened to meet the standards established by the State Council to monitor industrial discharges and environmental quality. This has led to further degrading of the overall environmental quality. Jiangsu Province is therefore in the process of enhancing its automatic environmental quality monitoring and control system by establishing automatic air and water quality monitoring stations to provide real-time data acquisition, distant monitoring, and real-time transmission. In addition, an environmental information processing system will also be developed and implemented.

All Consultants understand that the main goals of the Feasibility Study are to assist the Jiangsu EPD in reviewing and evaluating the province's existing air and water quality monitoring capabilities and framework. In addition, they will be evaluating and making recommendations as to the equipment and technologies to upgrade the overall system.

1.2.4 Scope of Work

The Jiangsu Automatic Environmental Quality Monitoring and Control System consist of two subsystems: an automatic air quality monitoring system, and an on-line automatic water quality monitoring system. The two systems share similar functions – data collection, transmission, statistical analysis, and distribution of information. The Consultants understand that the tasks to be completed for the Feasibility Study should include:

- To fully understand the existing JPEMC air and water quality automatic monitoring framework;
- To review and evaluate the existing air and water quality monitoring descriptions, objectives, and capabilities;
- To provide Technical Assistance to the JPEMC to evaluate the selected air quality monitoring stations and site locations, and identify and locate additional air quality monitoring locations;
- To determine the parameters that should be monitored at different air quality monitoring locations;
- To provide Technical Assistance to the JPEMC to evaluate the present water quality monitoring station, and identify and locate additional water quality monitoring locations;
- To determine the parameters that should be monitored at different water quality monitoring locations;
- The selection of stationary automatic air quality monitoring equipment based on quality, efficiency, and cost;
- The selection of stationary automatic water quality monitoring equipment

- based on quality, efficiency, and cost;
- The selection of mobile automatic air quality monitoring equipment based on quality, efficiency, and cost;
 - The selection of mobile automatic water quality monitoring equipment based on quality efficiency, and cost; and
 - To provide Technical Assistance for automatic monitoring data collection, processing, distant transmission and real-time data acquisition.

The Consultants fully understand the importance of building up the automatic environmental quality monitoring and data system for Jiangsu Province. They have carefully studied the existing air and water quality monitoring capabilities and framework in Jiangsu Province, determined all parameters to be monitored, and will help the Province select the most effective and efficient automatic air and water quality monitoring equipment. In addition, the Consultants will introduce advanced technologies for data collection, processing, distance transmission, and real-time data acquisition.

Chapter II

CHAPTER II JIANGSU AUTOMATIC AMBIENT AIR MONITORING

2.1 Background

2.1.1 General Introduction

Jiangsu Province Environmental Monitoring Center (JPEMC) has existed since the late 1970's. Air quality monitoring stations were established in Nanjing and other key provincial cities in the early 1980's to monitor particulate matter (PM), sulfur dioxide (SO₂), carbon monoxide (CO) and oxides of nitrogen (NO_x), along with meteorological parameters (wind speed and direction, temperature, precipitation, solar radiation and dew point). These monitoring stations were not automated; therefore, the data was collected and collated by the local Environmental Protection Department (EPD) and submitted to JPEMC as requested. With the passage of comprehensive national environmental legislation in the late 1990's, each province was mandated to automate their environmental monitoring systems. Since 1999, 87 stations have been integrated into the JPEMC Automatic Ambient Air Monitoring System (AAMS).

2.1.2 Overview of Pollutants

The AAMS was established to monitor the aforementioned pollutants due to their potential to adversely affect health, the environment and property.

In order to establish a better understanding of why monitoring is so important, the following is a brief overview of each pollutant and their potential impacts

2.1.2.1 Nitrogen Oxides (NO_x)

NO_x is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one of the oxides of nitrogen, nitrogen dioxide (NO₂), in combination with suspended particulate in the air can often be seen as a reddish-brown layer over many urban areas. NO_x is also a major component of acid rain. NO_x forms when fuel is burned at high temperatures, as in a combustion process. The primary sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.

NO_x can potentially impact human health adversely by causing lung damage, and enhancing the development of respiratory related illnesses such as asthma, sinus infections, and bronchitis. Environmental and property related impacts can be observed as NO₂ reacts with other pollutants, such as suspended particulate matter creating acid aerosols, which contribute to acid rain formation and reduces visibility. This combination can damage trees and lakes, reduce visibility and accelerate the deterioration of stone and other building materials.

2.1.2.2 Volatile Organic Compounds (VOCs)

VOCs are the basic organic carbon-based chemicals found in all living things, and in products derived from living things, such as coal, petroleum and refined petroleum products. Many of the organic chemicals we use do not occur in nature, but were synthesized by chemists in laboratories. Volatile organics produce vapors readily; at room temperature and normal atmospheric pressure, vapors escape easily from volatile liquid compounds. VOCs are present in

gasoline, industrial chemicals such as benzene, methylene chloride and methyl chloroform, solvents such as toluene and xylene, perchlorethylene, (the principal dry cleaning solvent), and paints and glues. Many volatile organic chemicals are also toxic; for example, benzene causes cancer. VOCs are also a by-product of fuel combustion from both stationary and mobile sources

Adverse health impacts from exposure to VOCs include burning eyes, respiratory illnesses, and in some instances cancer. High concentrations of VOCs and/or long-term exposure can harm foliage and crops, and due to their volatility, are highly flammable and can be explosive and/or ignite fires if they are not properly handled.

2.1.2.3 Ozone (O₃)

Ozone (O₃) is a gas composed of three oxygen atoms. Ozone occurs in nature; it produces the sharp smell you notice near a lightning strike; however, it is primarily generated by a chemical reaction between NO_x and VOCs in the presence of heat and sunlight. As a result, it is known as a summertime air pollutant. Ozone has the same chemical structure whether it occurs miles above the earth or at ground level and can be "good" or "bad," depending on its location in the atmosphere. "Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays. In the earth's lower atmosphere, ground-level ozone is considered "bad." Many urban areas tend to have high levels of "bad" ozone, but even rural areas are subject to increased ozone levels because the wind is capable of transporting ozone and pollutants from hundreds of kilometers away from their original sources.

Breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, reduced resistance to colds and other infections, and possible accelerated aging of lung tissue are some of the primary adverse health impacts from ozone exposure. Additionally, ozone can damage plants and trees, reduce visibility, and accelerate the deterioration of rubber and fibers.

2.1.2.4 Carbon Monoxide (CO)

CO is a colorless, odorless, poisonous gas that is produced by incomplete combustion of carbon-based fuels. It is a key component of motor vehicle exhaust; therefore, higher levels of CO are generally observed in areas with heavy traffic congestion. In urban areas, 85 to 95 percent of all CO emissions may originate from motor vehicle exhaust. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing), residential wood burning, and natural sources such as forest fires. Woodstoves, gas stoves, cigarette smoke, and unvented gas and kerosene space heaters are sources of CO indoors. The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent. The air pollution becomes trapped near the ground beneath a layer of warm air.

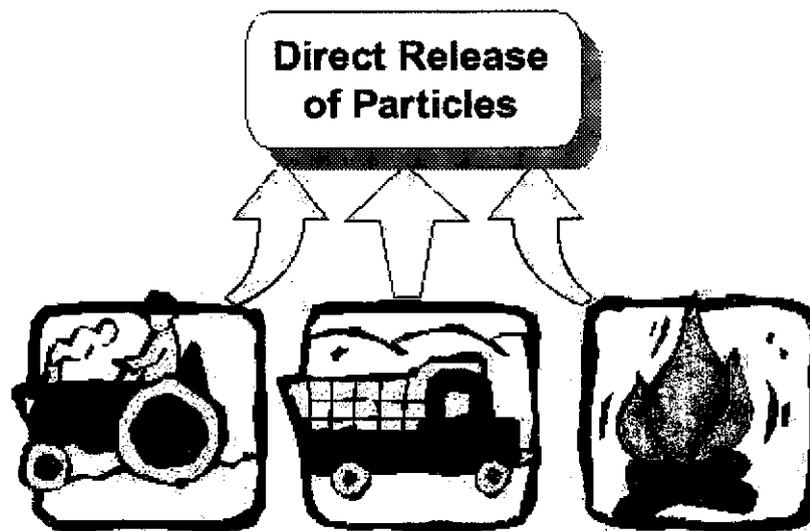
When CO gets into the body, it combines with chemicals in the blood and prevents the blood from supplying oxygen to cells, tissues and organs. The body's parts need oxygen for energy, so high-level exposures to CO can cause serious health effects, with death possible from massive exposures. Symptoms of

exposure to carbon monoxide can include vision problems, reduced alertness, and general reduction in mental and physical functions. Carbon monoxide exposures are especially harmful to people with heart, lung and circulatory system diseases.

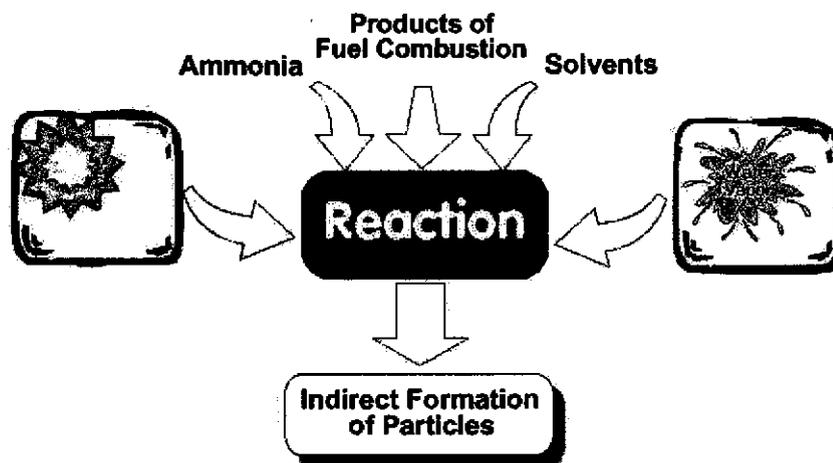
2.1.2.5 Particulate Matter (PM)

PM, or total suspended particulate (TSP) is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that individually they can only be detected with an electron microscope. The smaller size fractions of TSP, 10 microns or smaller, typically referred to as PM_{10} , and 2.5 microns and smaller ($PM_{2.5}$) are regulated pollutants in the US. China does not currently regulate $PM_{2.5}$, however the State Environmental Protection Administration (SEPA) is in the process of developing new $PM_{2.5}$ standards, which may be implemented within the next several years, as more data becomes available.

Some particles are emitted directly into the air. They are emitted from a variety of sources such as cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood.



Other particles may be formed in the air as a result of chemical reactions. They are indirectly formed when gases from burning fuels react with sunlight and water vapor. These can result from fuel combustion in motor vehicles, at power plants, and in other industrial processes.



Particulate pollution can cause eye, nose and throat irritation, lung damage, bronchitis, and contribute to an early death. They are also a primary contributor to the formation of haze that reduces visibility, and acid rain. Acid rain is formed when sulfur and nitrogen compounds adhere to the surface of the particles to create an acidic compound that mixes with the moisture in the atmosphere. Ashes, soot, smoke, and dust can also cause property damage, such as the staining and discoloration of structures, furniture, and clothes.

2.1.2.6 Sulfur Dioxide (SO₂)

SO₂ belongs to the family of sulfur oxide gases (SO_x). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SO_x gases are formed when fuels containing sulfur, such as coal and oil, are burned, when gasoline is extracted from oil, or when metals are extracted from ore. SO₂ dissolves in water vapor to form acid, and reacts with other gases and particles in the air to form sulfates, acid rain, and other compounds that can be harmful to people and their environment.

A significant portion of SO₂ released to the air, comes from electric utilities, especially those that burn coal. Other sources of SO₂ are industrial facilities that derive their products from raw materials such as metallic ore, coal, and crude oil, or facilities that burn coal or oil to produce process heat. Examples are petroleum refineries, cement manufacturing, and metal processing facilities. Also, locomotives, large ships, and some off-road diesel equipment currently burn high sulfur fuel. Industrial processes, such as paper production and metal smelting, also produce sulfur oxides and release large quantities of SO₂ emissions into the air.

Adverse health effects include breathing problems and long-term exposure may cause permanent damage to the lungs. From an environmental standpoint, SO₂ reduces visibility and is a key ingredient in the formation of acid rain (acid aerosol), which can damage the soil, trees, and lakes.

2.1.2.7 Acid Rain

Acid rain is formed when acidic compounds are incorporated into rain, snow, fog, or mist, forming acid aerosols. The "acid" in acid rain comes from sulfur oxides and nitrogen oxides, products of burning fossil fuels, such as coal and oil, and

from certain industrial processes. The sulfur oxides and nitrogen oxides are precursors to two strong acids: sulfuric acid and nitric acid. When sulfur dioxide and nitrogen oxides are released from power plants and other sources, winds transport them long distances from their source. When the acidic compounds are transported into areas of high moisture content, they will condense and fall to earth in the form of rain, snow, fog, or mist. In areas where the climate is dry, the acidic compounds may become incorporated into dusts or smoke. Acid rain can produce large-scale defoliation, acidification of water bodies, and as previously mentioned, cause short and long-term respiratory problems. Acid aerosols can break down fibers and also accelerate the deterioration of stone used in buildings, statues, and monuments..

2.1.2.8 Toxic Air Pollutants

Toxic air pollutants, also known as hazardous air pollutants, are those pollutants known or suspected of causing serious health effects, such as cancer, adverse reproductive effects, and birth defects. Toxic air pollutants can also adversely impact the environment. Examples of toxic air pollutants include benzene, which is found in gasoline; perchlorethylene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. Examples of other listed air toxins include dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

Most air toxins originate from man-made sources, including mobile sources (e.g., cars, trucks, buses), stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., some building materials and cleaning solvents). Some air toxins are also released from natural sources such as volcanic eruptions and forest fires.

Some of the most common types of exposures that can pose health risks are:

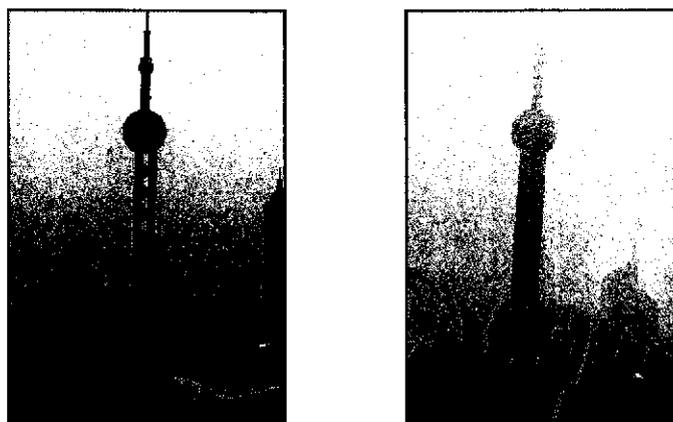
- Breathing contaminated air;
- Eating contaminated food products, such as fish from contaminated waters; meat, milk, or eggs from animals that fed on contaminated plants; and fruits and vegetables grown in contaminated soil on which air toxins have been deposited;
- Drinking water contaminated by toxic air pollutants;
- Ingesting contaminated soil; young children are especially vulnerable because they often ingest soil from their hands or from objects they place in their mouths; and
- Touching (making skin contact with) contaminated soil, dust, or water (for example, during recreational use of contaminated water bodies).

People exposed to toxic air pollutants at significant concentrations, and for long durations, may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, neurological system, reproductive organs (e.g., reduced fertility), developmental processes, respiratory system and other vital organs or functions. Once toxic air pollutants enter the body, some of the more persistent toxins can not be removed by normal body functions and will accumulate in body tissues. In

addition to exposure from inhalation of air toxins, some toxins, such as mercury, can be deposited in soils or surface waters, where it is absorbed by plants and ingested by animals. These toxins continue to accumulate and are eventually magnified up through the food chain. Predators typically accumulate even greater pollutant concentrations than their contaminated prey. As a result, people and other animals at the top of the food chain that eat contaminated fish or meat are exposed to concentrations that are much higher than the concentrations in the water, air, or soil. Like humans, animals may experience health problems if exposed to significant quantities of air toxins over time.

2.1.2.9 Haze

One of the most basic forms of air pollution is haze, which degrades visibility in many cities and scenic areas. During much of the year a veil of white or brown haze hangs in the air of major urban areas blurring the view. Most of this haze is not natural. It is air pollution, transported by the wind often many hundreds of miles from where it originated.



Air pollutants which form haze come from a variety of natural and man-made sources. Natural sources can include windblown dust and soot from wildfires. Man-made sources can include motor vehicles, electric utilities, industrial fuel burning, and manufacturing operations.

Haze is visible to the human eye when sunlight encounters the microscopic pollution particulates in the air. Some light is absorbed by particles, other light is scattered away before it ever reaches an observer. Some haze-causing particles are directly emitted to the air, while others are formed when gases emitted into the air react to form particles as they are transported many kilometers from the source of the pollutants. More pollutants mean more absorption and scattering of light, which reduces the clarity and color of what we see. Some types of particles, such as sulfates, scatter more light, particularly during humid conditions.

2.1.3 Air Quality Regulatory Review

The *Law of the People's Republic of China on the Prevention and Control of Air Pollution* was adopted by the Standing Committee of the NPC on April 29, 2000 and enacted on September 1, 2000. This wide-ranging law covers the formulation of air environment quality standards and pollutant emission standards; the system

for phasing out obsolete equipment and processes that create serious levels of air pollution; the emission fees system under which pollution emission fees can be charged on the basis of the types and quantities of pollution emitted into the air; provisions encouraging use of "clean" energy sources rather than coal; pollution requirements for motor vehicles; and liability to third parties for damages caused by air pollution.

The articles in the law require that air pollutants be monitored to verify the compliance status. Key articles include:

- *Article 3:* The State takes measures to control or gradually reduce, in a planned way, the total amount of the main atmospheric pollutants discharged in local areas. The local people's governments at various levels shall be responsible for the quality of the atmospheric environment under their own jurisdictions, making plans and taking measures to make the quality of the atmospheric environment under their own jurisdictions meet the prescribed standard.
- *Article 13:* Where atmospheric pollutants are discharged, the concentration of the said pollutants may not exceed the standards prescribed by the State and local authorities.
- *Article 14:* The State implements a system of collecting fees for atmospheric discharging on the basis of the pollutants categories and quantities and establishes reasonable standards for collecting the fees, which shall meet the needs of strengthening prevention and control of atmospheric pollution and the State's economic and technological conditions.

2.1.3.1 Ambient Air Quality Standard

China's Ambient Air Quality Standard was implemented on October 1, 1996. The standard was implemented to improve the environmental air quality, prevent ecological deterioration, create clean and sound environment, and protect public health. This standard, registered as GB 3095-1996, is presented in Table 2-1 found on the following page.

Table 2-1					
National Air Quality Standard GB 3095-1996					
Air Quality Standards					
Pollutant	Sampling Period	Class I	Class II	Class III	Unit
SO ₂	Annual Average	0.02	0.06	0.10	mg/m ³
	Daily Average	0.05	0.15	0.25	
	Hourly Average	0.15	0.50	0.70	
Total Suspended Particulates	Annual Average	0.08	0.20	0.30	
	Daily Average	0.12	0.30	0.50	
PM ₁₀	Yearly Average	0.04	0.10	0.15	
	Daily Average	0.05	0.15	0.25	
NO _x	Annual Average	0.05	0.05	0.10	
	Daily Average	0.10	0.10	0.15	
	Hourly Average	0.15	0.15	0.30	
NO ₂	Annual Average	0.04	0.04	0.08	
	Daily Average	0.08	0.08	0.12	
	Hourly Average	0.12	0.12	0.24	
CO	Daily Average	4.00	4.00	6.00	
	Hourly Average	10.00	10.00	20.00	
Ozone	Hourly Average	0.12	0.16	0.20	μg/m ³
Lead (Pb)	Quarterly Average	1.50			
	Annual Average	1.00			
Benzo-a-pyrene (B[a]p)	Daily Average	0.01			μg/d ³ -day
Fluoride (F)	Daily Average	7 ¹			
	Hourly Average	20 ¹			
	Monthly Average	1.8 ²	3.0 ³		
	Plant growth season average	1.2 ²	2.0 ³		
Notes: 1. Application to urban areas. 2. Application to pastoral region, mixed agriculture and pasture, and semi-agriculture regions 3. Applicable to agricultural and forest regions					
Notes: Class I: Required for natural conservation areas, scenic areas, and other special protection areas. Class II: Required for residential areas, mixed commercial/transportation/residential areas, cultural areas, general industrial areas, and agricultural areas (as identified in city plans). Class III: Required for specific industrial areas.					
Key: CO = Carbon monoxide. μg/m ³ = Micrograms per cubic meter. PM ₁₀ = Particulate matter less than ten microns. mg/m ³ = Milligrams per cubic meter. NO _x = Nitrous oxides. SO ₂ = Sulfur dioxide. TSP = Total suspended particulates.					

2.1.3.2 Ambient Monitoring Requirements

Table 2-2 Designated Analytical Methods for Determining Air Pollutant Concentrations

Pollutant	Analytical Method	Standard Method
SO ₂	Colorimetric method (wet chemistry) UV-Fluorescence method	GB-8970-88 GB/T15262-94
TSP	Weighing (mass)	GB/T15432-95
PM ₁₀	Weighing (mass)	GB-6921-86
NO ₂	Saltzman method Chemiluminescence	GB-8969-88 GB/T13906-92
O ₃	Colorimetric method UV photometry Chemiluminescence	GB/T15437-95 GB/T15438-95
CO	Non-Dispersive Infrared	GB-9801-88
Benzo [a] pyrene (B[a]P)	Fluorescence spectroscopy High performance liquid chromatography	GB9871-88 GB-/T15439-95
Lead (Pb)	Atomic absorption spectroscopy	GB/T15264-94
Fluoride (total F)	Fluoride membrane probe method ⁽¹⁾ Fluoride quartz filter fluoride ion specific probe method ⁽²⁾	GB/T15434-95 GB/T15433-95

Table 2-3 Criteria for Validating Air Quality Monitoring Data

Pollutant	Averaging Period	Valid Data Criteria
SO ₂ , NO ₂	Annual	Minimum 144 even-distributed days per year Minimum 12 even-distributed days per month
TSP, PM ₁₀ , Pb	Annual	Minimum 60 even-distributed days per year Minimum 5 even-distributed days per month
SO ₂ , NO ₂ , CO	Daily	Minimum 18 hours of sampling time per day
TSP, PM ₁₀ , B[a]P, Pb	Daily	Minimum 12 hours of sampling time per day
SO ₂ , NO ₂ , CO, O ₃	1-Hour	Minimum 45 minutes of sampling time per hour
Pb	Quarterly	Minimum 15 even-distributed days per quarter Minimum 5 even-distributed days per month
F	Monthly	Minimum 15 days sampling time per month
	Plant growth season average	Minimum 70% Monthly average per growth season
	Daily	Minimum 12 hours of sampling time per day
	1-hour	Minimum 45 minutes of sampling time per hour

2.1.3.3 Comprehensive Emission Standard of Air Pollutants

The *Comprehensive Emission Standard of Air Pollutants (GB16297-1996)* stipulates emission limits and implementation requirements for 33 air pollutants. This comprehensive standard applies to all air pollutant producers and emitters including institutions and private businesses. In cases where the comprehensive standard and a source-specific standard cannot be met simultaneously, all air pollutant emission sources must comply with the comprehensive standard.

2.1.3.4 Other Air Emission Standards

Other source-specific emission standards include:

- *Emission standard of Air Pollutants from Industrial Boilers (GB13271-91)*
- *Emission Standard of Air Pollutants from Industrial Furnaces and Kilns (GB9078-1996)*
- *Emission Standard of Air Pollutants from Thermal Power (GB13223-1996)*
- *Emission Standard of Air Pollutants from Coke Ovens (GB16171-1996)*
- *Emission Standard of Air Pollutant from Cement Industry (GB4915-1996)*
- *Emission Standard of Odor Pollutants (GB14554-93)*
- *Emission Standard of Air Pollutants from Automobiles (GB14761.1-14761.7-93)*
- *Emission Standard of Air Pollutants from Motorcycles (GB14621-93)*

2.1.4 Geography

Jiangsu Province is located at the seaside center of eastern continental China. Jiangsu has a relatively consistent flat topography consisting mostly of lowland areas and roughly 500 kilometers of coastline accompanied by a broad coastal plain. This flat topography allows for air pollutants such as ozone and acid rain to be transported greater distances than in more mountainous regions. The coastal plain has a land/sea breeze which carries pollutants offshore during the morning hours, and then shifts back and carries pollutants back onshore in the afternoon. The majority of the key cities lie inland, with Lianyungang being the only seaside port city, and Yancheng and Nantong being the only other cities truly in the coastal plain. The coastal plain in Jiangsu is less polluted due to the smaller population centers, and fewer industrial facilities in comparison to other regions of the province. In the northern part of the province, the land changes from flat to hilly, and from a geological perspective, the area contains significant mineral deposits and quarries. These features contribute to the concentration of industrial activity and the significant population in Xuzhou, the most significantly polluted city in the province. The western/central part of the province consists primarily of lakes and rivers, and in general, only small population centers are scattered around the region; therefore, this region has reasonably low levels of pollution, primarily combustion related. The Yangtze River dominates the southern part of the province, running west to east through Nanjing, Zhenjiang and Nantong and into the Huang Hai near Shanghai. Significant population centers are scattered along and near the river, with a variety of industrial and barge activities. This is the commercial center of the Jiangsu Province, and hence carries the largest overall pollutant load. This geologic setting, along with prevailing summer winds from the E and SE, transport pollution not only from inside the province, but also from China's largest metropolitan area, Shanghai. This causes an increased pollutant load during the hottest time of the year, and elevates acid rain and ozone levels throughout the southern part of the province.

2.2 Condition of Ambient Air Pollution

From an ambient air pollution standpoint, Jiangsu Province is a low to moderately polluted region, with the more industrialized urban regions carrying a large percentage of the provincial total. In 2002, the overall air quality in the cities of Jiangsu was generally on the moderate pollution level. It should be noted that the air pollution in Xuzhou was more serious than in other cities, with a much higher pollution level. Except for Xuzhou, the other 12 provincial cities had SO₂ indexes

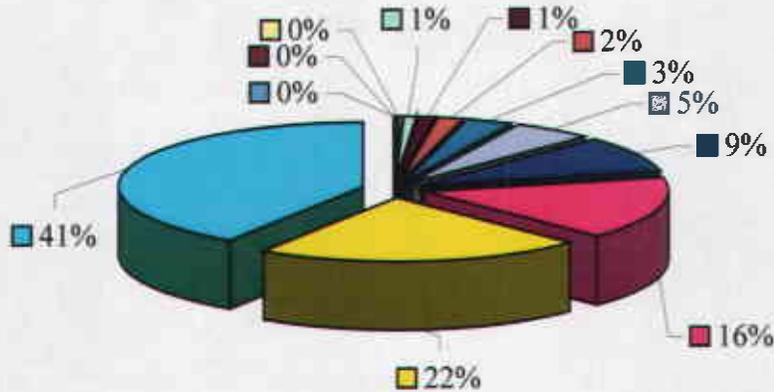
that achieved compliance levels of the National Air Quality Class II Standards (NAQCIIS). For the NO₂ index, all 13 provincial cities achieved compliance levels of the NAQCIIS. All 13 provincial cities failed to achieve compliance levels for the inhalable particles index of the NAQCIIS.

The province is growing, and with it new facilities and additional sources of air pollution are being added. This has increased industrial pollution in the province by approximately 7.06 % from 2001 to 2002, for a total load of 1,448 billion standard cubic meters. Table 2-4 (see page 2-14) shows a comparative breakdown for each of the key cities in 2001 and 2002. One small positive trend can be seen in this data; that is, due to the increased use of natural gas in parts of the province, combustion emissions increased by only 3.29% from 2001 to 2002. In fact, several cities experienced significant decreases in combustion emissions, particularly Changzhou (8.35%), Yancheng (22.04%), and Zhenjiang (19.96%). In Table 2-5 (see page 2-15), a further analysis of pollutant specific emissions during the past two years shows a province wide 3% reduction in SO₂ emissions, and 10.2% and 18.7% reductions in smoke dust and particulate emissions respectively. This reduction is a direct result of the continued implementation of the SEPA requirements for coal-fired combustion units. As previously noted, this has led to almost full compliance for the province for the National Air Quality Class II Standards for SO₂. Particulate matter emissions continue to be a major concern, however, the overall reduction in total particulate emissions is favorable and, if similar reductions can continue to be made, Jiangsu will potentially attain the Class II ambient standard.

From an industrial air pollution standpoint, the overall impact can be broken down by sector, as shown in Figure 2.1. A full breakdown of emissions by sector was not available for 2002, however, in 2001, nearly 90% of the reported total 1,334 billion standard cubic meters came from four primary sectors: the chemical industry, the ferrous metal production industry, the non-ferrous metal industry, and the utility industry (power generation, gas, and water). This mix is not likely to have changed substantially in 2002.

In 2002, based on analytical data collected by the provinces' manual monitoring network, the acid rain (pH<5.6) occurrence rate was 23.5%. The average pH value of annual rainfall was 5.31. The annual average pH value of acid rain was 4.76. Nantong had the highest acid rain occurrence rate, which reached an occurrence rate of 48.1% (highest); next highest were Wuxi, Changzhou, and Nanjing, who all had occurrence rates above 30%. Acid rain did not occur in Huai'an and Suqian. The primary area with acid rain pollution was in the Nantong-Changzhou-Nanjing zone. The general distribution has remained stable, and only slight changes have occurred in the more sensitive areas. The acid rain pollution in Jiangsu has decreased in the last year when comparing it to similar data from 2001.

Figure 2-1
2001 Industrial Sector Air Emissions in Jiangsu Province



- Leather, fur, down and others
- Metal products
- Pharmaceutical
- Oil refining and coking
- Pulp and paper
- Mechanical, electrical and electronic equipment
- Textile
- Other
- Raw materials for chemical industry and its products
- Ferrous metal smelting and rolling
- Non-ferrous metal industry
- Power, gas and water supply

Table 2-4 Key City Waste Gas Discharge Comparison for 2001 and 2002

Municipality	Industrial Air Emissions		Emissions from Combustion		Emissions from Processes				
	2001	2002	% Change	2001	2002	% Change	2001	2002	% Change
Changzhou	4,279,002	4,830,972	12.90%	3,458,984	3,170,285	-8.35%	820,018	1,660,687	102.52%
Huai'an	2,880,870	3,285,438	14.04%	2,160,257	2,417,627	11.91%	720,613	867,811	20.43%
Lianyungang	2,642,168	2,757,576	4.37%	2,423,059	2,527,912	4.33%	219,109	229,664	4.82%
Nanjing	23,634,870	27,242,395	15.26%	12,102,936	14,030,324	15.92%	11,531,935	13,212,071	14.57%
Nantong	8,257,419	8,174,431	-1.01%	7,286,107	7,057,131	-3.14%	971,312	1,117,300	15.03%
Suqian	862,148	930,784	7.96%	436,855	509,582	16.65%	425,293	421,202	-0.96%
Suzhou	31,324,531	33,782,807	7.85%	17,552,443	17,652,550	0.57%	13,772,088	16,130,257	17.12%
Taizhou	1,874,127	2,154,027	14.93%	1,420,774	1,694,355	19.26%	453,353	459,672	1.39%
Wuxi	11,575,279	16,141,689	39.45%	9,057,945	10,636,020	17.42%	2,517,334	5,505,669	118.71%
Xuzhou	14,419,156	16,111,109	11.73%	8,695,868	10,558,133	21.42%	5,723,288	5,552,976	-2.98%
Yancheng	6,927,835	4,757,512	-31.33%	3,436,324	2,678,828	-22.04%	3,491,511	2,078,684	-40.46%
Yangzhou	5,814,496	6,824,097	17.36%	5,155,786	5,509,876	6.87%	658,710	1,314,221	99.51%
Zhenjiang	18,947,973	15,871,734	-16.24%	12,264,667	9,816,538	-19.96%	6,683,306	6,055,196	-9.40%
Total	133,439,874	142,864,571	7.06%	85,452,005	88,259,161	3.29%	47,987,870	54,605,410	13.79%

Note: Emission unit is 10,000 standard cubic meters

**Table 2-5
Comparative Breakdowns of Key Pollutant Amounts in Jiangsu Province for 2001 and 2002**

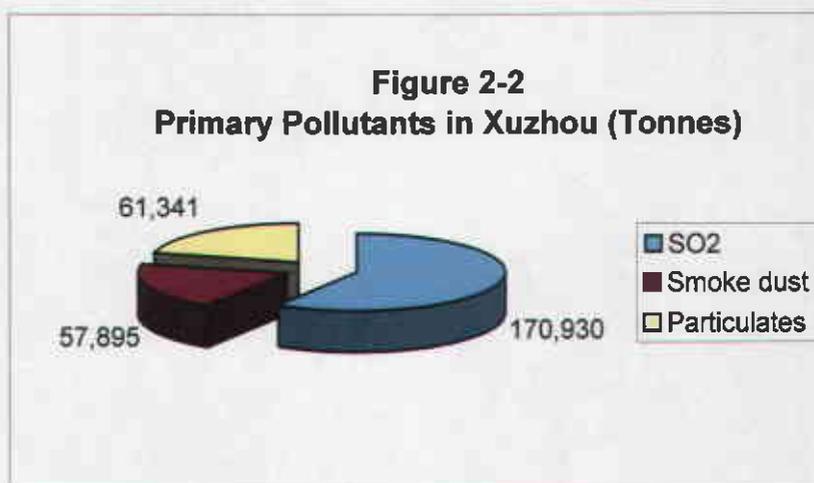
	Industrial SO ₂ (Tonnes)			Industrial Smoke Dust (Tonnes)			Industrial Particulates (Tonnes)		
	2001	2002	% Change	2001	2002	% Change	2001	2002	% Change
Total	1,087,585	1,055,000	-3.1%	407,810	370,000	-10.2%	268,192	226,000	-18.7%

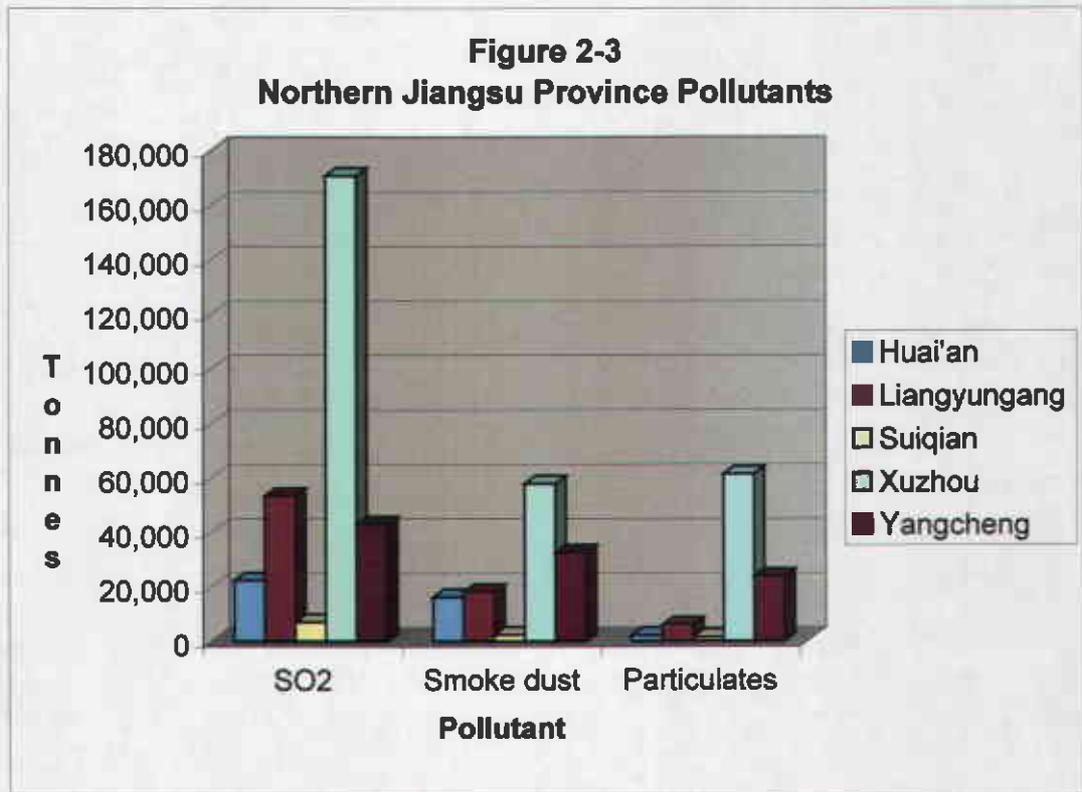
From an airshed standpoint, the province can be separated into three regions, north, central, and south, with a much larger percentage of the total pollution load being located in the south. The southern airshed consists of primarily the Yangtze River Basin, and all cities south of the river. For purposes of this study, the northern and central regions have been combined into one airshed. This airshed encompasses all areas in the province which are north of the southern end of Lake Gaoyou.

2.2.1 Northern Region

The northern region of Jiangsu Province includes the cities of Huai'an, Lianyungang, Suqian, Xuzhou, and Yangcheng. Of these cities, Xuzhou is the most heavily industrialized and contributes approximately 11% of the provinces' total air emissions. Based on the 2001 comprehensive urban air quality assessment, Xuzhou has the highest air pollutant index in the province on a pollutant load basis and is considered low to moderately polluted on relative basis (Figure 2-2).

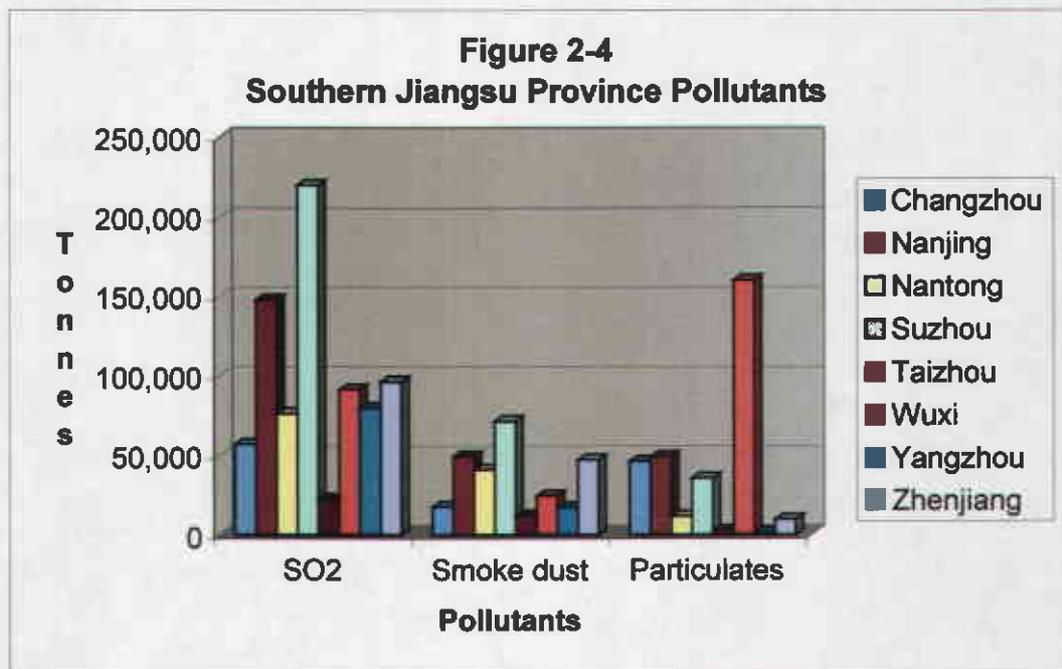
The other four cities combined, contribute an additional 10%, with Yangcheng producing approximately 5% (Figure 2-3). Sulfur dioxide and suspended particulates are the primary pollutants in the northern region, primarily due to coal combustion and the metal production industry.





2.2.2 Southern Region

The southern region of the province includes the cities of Changzhou, Nanjing, Nantong, Suzhou, Taizhou, Wuxi, Yangzhou, and Zhenjiang. Nanjing, Suzhou, Wuxi and Zhenjiang are the most industrialized cities in the south and contribute approximately 64% of the pollution in the province. Suzhou produces the most of any city, with over 23%, followed by Nanjing at nearly 18% and Zhenjiang at 14%. From the 2001 comprehensive ambient air quality assessment, Changzhou was the most highly polluted city in the south on a relative basis, followed by Wuxi. Industrial sources are similar to the north; however, there is much more chemical industry contribution to the pollutant load in the south, in addition to the combustion and metal processing industry (Figure 2-4).



2.2.3 External (Non-provincial) Influences

The major external influence to Jiangsu Province's ambient air quality is Shanghai. Emissions from the industrial facilities in Shanghai can contribute to additional air pollution within the province due to its proximity to the provincial border (~30 km).

2.2.4 Industrial Emissions and Controls

As the regulations within China have tightened, the larger individual air pollutant sources, 16 of which are power generating facilities, have begun to install emission reduction systems and/or upgrade their facilities to reduce the pollutant load. Due to time constraints in the project, an evaluation of the status of each facility has not been performed. However, as part of the site visits, the largest individual facility, Xuzhou Power Plant, was visited. Since 1997, this facility has upgraded its steam turbines, and has added electrostatic precipitators (ESPs) to five (5) of its eight (8) existing combustion boilers. These changes have reduced the coal consumption by over 20 g/kWhr (from 380 to 358 g/kWhr), thereby further reducing emissions as a result of a more efficient process. Xuzhou Power is also evaluating flue gas desulfurization technologies to reduce the sulfur dioxide emissions from the facility. The long-term goal at this facility is to have ESP's installed on each of the combustion boilers, thereby further reducing particulate emissions from the facility. In combination with required reductions in SO₂ emissions which will be realized when the flue gas desulfurization projects are complete; this facility will likely realize an overall reduction of another five (5) g/kWhr.

2.3 Overview of Monitoring Station's Sites Criteria

When establishing an air quality monitoring network, the number of monitoring stations needed is variable, depending on the overall intent of the network. Based on the Terms of Reference for this Feasibility Study, Jiangsu Province's stated

intent is to develop a network which will provide, on a continual basis, reasonably accurate and representative data on the overall air quality in and around the 13 key cities within the province, to broaden the network to establish a background level, evaluate the effect of transport on more rural areas around the province, and, eventually, monitor a larger range of pollutants such as PM_{2.5}, speciated organic compounds and greenhouse gases, particularly Carbon Dioxide (CO₂). The initial effort is focused on determining the effectiveness of the existing AAMS, evaluating the locations of the current monitors, and determining where there are data gaps so that monitors can be installed to create a more representative network.

It should be noted that no monitoring program, however well funded and designed, can hope to comprehensively quantify patterns of air pollution in both space and time. At best, monitoring provides an incomplete - but useful - picture of current environmental quality. Monitoring therefore often needs to be used in conjunction with other objective assessment techniques, including modeling, emission measurement and inventories, interpolation and mapping. Accordingly, monitoring, modeling, and emission assessments should be regarded as complementary components in any integrated approach to determining compliance against air quality criteria.

Quality assurance and quality control (QA/QC) is an essential part of any air monitoring system. It is a program of activities that ensures that measurements meet defined and appropriate standards of quality, with a stated level of confidence. It should be noted that the function of QA/QC is not to achieve the highest possible data quality. This is an unrealistic objective, which cannot be achieved under practical resource constraints. Rather, it is a set of activities, which ensures that measurements comply with the specific data quality objectives (DQOs) for the monitoring program. In other words, QA/QC ensures that data are fit for the purpose. Quality assurance activities cover all pre-measurement phases of monitoring, including determining monitoring and data quality objectives, system design, site selection, equipment evaluation, management and operator training. Quality control functions affect directly measurement-related activities such as site operation, calibration, data management, field audits and training.

Factors that influence the overall number of stations include:

- Meteorology, (relative prevalent winds, coastal marine affects, seasonal variations);
- Size of the airshed being monitored;
- Population density and number of densely populated areas;
- Sensitive environments (agricultural areas, national parks and/or wildlife refuges, historically significant areas, lakes, rivers and streams);
- Inversion prone areas;
- Industrial areas; and
- Air dispersion modeling needs.

Taking into account the above factors, the following basic steps are necessary to determine the number and location of the air monitoring stations:

- Determine where the highest concentrations are expected to occur in each of the 13 key cities;
- Determine representative concentrations in areas of high population density;
- Estimate the relative impact on ambient pollution levels from major air pollution sources;
- Determine representative background concentration levels for each city and the rural regions of the province;
- Evaluate the potential extent of regional pollutant transport; and
- Estimate the overall impact on agriculture and other sensitive rural areas.

The site-selection process must also take into account the spatial distribution and variability of criteria pollutants within urban environments. For example, concentrations of primary traffic pollutants such as CO are highest at roadside locations, whereas O₃ levels have higher spatial uniformity but will be lowest in near-road locations due to scavenging by vehicle NO_x emissions. For this reason, it is usually not possible to optimize measurements for all pollutants at any one site location. In such circumstances, some degree of compromise will often be required. In general, the spatial variability of secondary pollutants, such as NO₂ and O₃, tends to be more homogeneous than for primary pollutants such as CO and SO₂. This greater variability of primary pollutants, in particular in proximity to sources, will have obvious implications for monitoring site density and numbers required in any survey.

Micro-scale site considerations are also important in ensuring that meaningful and representative measurements are made. If baseline concentrations are to be assessed, then monitoring sites should be adequately separated from local pollutant sources (for example, roads or small boilers) or sinks (such as dense vegetation). Probe aerodynamics and site sheltering will also often be important. Free airflow around the sampling inlet will be necessary to ensure representative sampling; for this reason, sampling in a stagnant or sheltered micro-environment should be avoided.

A variety of practical considerations also apply when selecting monitoring sites. They must be accessible for site visits, but the potential for public interference or vandalism must also be recognized. Electricity for pollutant analyzers and station infrastructure must be available, together with a telephone linkage for data telemetry.

The populations of each of the key cities and population density in the urban areas are listed in Table 2-6. Using the number of stations suggested by the USEPA or the World Health Organization (WHO) per population Jiangsu Province should have between 94 and 175 stations. Currently there are 87 automatic stations in the 13 key cities.

Table 2-6 Population of Key Cities and Land Area

City	Population at 2002 Year- end (million persons)	Land Area (km ²)	Density of Population (person/sq. km)
Changzhou	3.43	4,375	784.55
Huai'an	5.17	10,072	513.98
Lianyungang	4.64	7,500	618.71
Nanjing	5.63	6,598	855.03
Nantong	7.80	8,001	975.20
Suqian	5.13	8,555	599.65
Suzhou	5.85	8,488	687.83
Taizhou	5.04	5,791	870.33
Wuxi	4.38	4,788	916.07
Xuzhou	9.04	11,258	803.35
Yancheng	7.95	14,983	531.01
Yangzhou	4.52	6,634	681.67
Zhenjiang	2.67	3,847	694.30

Data source: Jiangsu Statistical Yearbook 2003

There are two types of air quality monitoring stations: trend and background (or reference) stations. In addition to trend and background stations, monitoring networks at the city level should include emission source monitoring stations.

Station types can be further divided into the following:

Trend Stations

Trend stations are generally located in populated areas and are intended to provide information regarding pollutant concentration trends. There are two types of trend stations:

1) Population Stations

Population's stations are located in populated areas, which include urban (i. e., residential, commercial or business, schools and universities, and mixed-use areas), rural, and agricultural areas. These stations are sited to monitor population exposure. In some cases, the stations are located in areas where high pollutant concentrations are expected to occur.

2) Clean Area Stations

Clean area stations are located in city parks, green belts and scenic spots. These stations are intended to provide air quality information for less polluted areas.

Emission Source Stations

There are two types of emission source stations. The first are called Traffic Stations, which are intended to provide information pertaining to pollutant concentrations near heavily traveled roadways. The data from these stations is useful for assessing the effectiveness of motor vehicle emission control programs and estimating the exposure levels of pedestrians.

The second are called Industrial Zone Stations, which are located within or immediately downwind of industrial zones with major emission sources. Each station is intended to provide information on the concentration of primary pollutants in the immediate vicinity of the industrial zone.

Background or Reference Stations

Background stations are sited in pristine locations to generate information on background pollutant levels. The data from these stations can be useful in evaluating and quantifying the possible importance of the long-range transport of air pollutants to the Shanghai area from sources in neighboring provinces. These stations may also be useful in characterizing pollutant recirculation phenomena and in providing data on concentration levels immediately upwind of large urban areas.

Mobile Vans

Mobile monitoring vans provide flexibility and mobility for monitoring pollutant concentrations over limited periods of time at locations other than fixed monitoring stations. In addition, mobile vans can be deployed to a fixed monitoring station to identify possible instrument problems through the collection of collocating data. The vans are also useful in identifying suitable locations for future additions and/or modifications to monitoring networks.

2.4 Condition of the Existing Automated Ambient Air Monitoring Systems (AAMSs)

2.4.1 Physical Condition of Existing AAMSs and Data Management System (DMS)

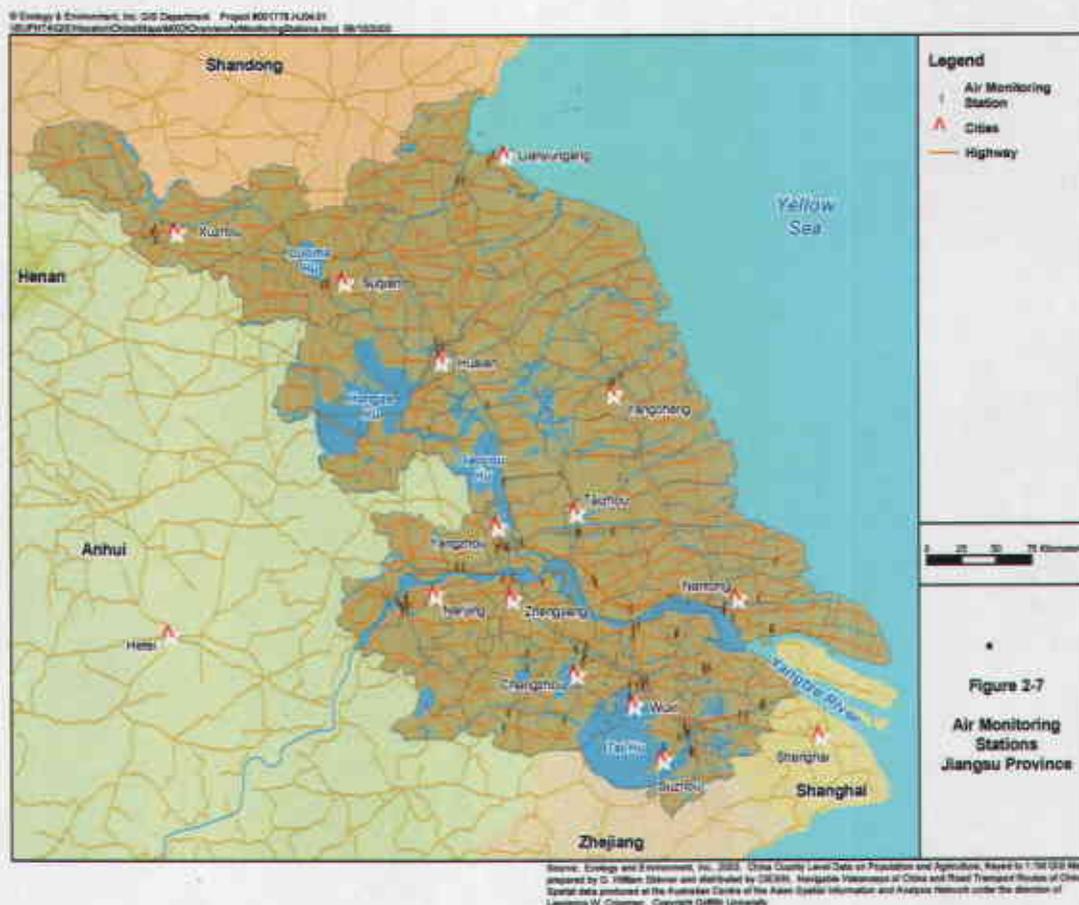
Automated ambient air monitoring systems have been established in all 13 key cities of Jiangsu Province. A total of 87 substations are currently in operation in these cities. In-the-field continuous manual-sampling and laboratory analysis are employed in other cities for air monitoring. Each city's Environmental Protection Bureau (EPB) is responsible for purchasing and maintaining the equipment and keeping the data management systems online. The automated network allows JPEMC to have a real-time check on emissions on an ongoing basis. Based on site visits to several of the substations, the physical condition of the network and DMS is good. The majority of the monitors in the network have been installed since 1999; therefore, the equipment is new and monitors the pollutants currently required by regulation. There is room for expansion if more pollutants are required to be monitored in the future.

2.4.2 Evaluation of the Existing AAMSs and DMS

The existing AAMS is a good start in establishing a province-wide database of ambient air quality. However, it does not fully address the monitoring needs in

some areas, particularly in Nanjing and Xuzhou, from a complete network standpoint. A map of the province with each existing monitoring stations is shown in Figure 2-5.

Figure 2-5 Existing Air Monitoring Stations in Jiangsu Province



Urban air quality monitoring networks must be able to measure the air quality across the various functional zones that typically comprise urban environments. There are seven urban functional zones:

- Industrial zone - Factories and industrial facilities are located in this area;
- Business zone - This area is dedicated to major commercial activities;
- Residential zone - This area is primarily for residential housing;
- Cultural zone - This zone has high concentrations of school, universities and research institutions;
- Heavy traffic zone - This zone has heavy volumes of traffic;
- Industrial and residential mixed zone - Residential areas are mixed with light industries in this area; and

- Clean zone - This area is considered less polluted and typically contains city parks, scenic areas and green belts.

The process of selecting urban monitoring station sites must take into consideration current and projected land use patterns, current and projected types and levels of emissions that could influence urban pollution trends, major transportation corridors, geography/topography, meteorology, population growth and activity, and ease of site access and overall network management. Urban air quality monitoring networks should also contain at least one regional reference or background monitoring station that is located upwind of emission sources.

The monitoring stations should be placed at sites within targeted monitoring areas that contain representative ambient air quality concentrations for the air pollutants of interest. Installed monitoring stations should also meet national monitoring network requirements and meet monitoring station site standards to allow for the comparison of data across monitoring stations. Special purpose monitoring sites are to meet special monitoring objectives.

The total number of required air quality monitoring stations is based on the population of a targeted monitoring area and the air pollutants of interest (Table 2-7; see next page). For example, if air pollutants such as SO₂, NO/NO₂, and particulate matter are to be monitored in an urban city containing a population of 4 million people or greater, a minimum of seven monitoring stations are required. Monitoring parameters monitored are divided into two categories: mandatory and optional (Table 2-8; see next page).

Table 2-7 Air Pollutant Types, Total Number of Stations and Population Distribution

Population Distribution	Number of Stations		
	SO ₂ , NO ₂ , PM ₁₀	O ₃	CO
<500,000	3	1	1
500,000-1,000,000	4	1	1
1,000,000-2,000,000	5	2	2
2,000,000-4,000,000	6	2	2
4,000,000-8,000,000	7	3	3
>8,000,000	7	3	3

Table 2-8 Ambient Air Quality Monitoring Parameters

No.	Mandatory Monitoring Parameters	Optional Monitoring Parameters
1	Sulfur Dioxide (SO ₂)	Hydrocarbons
2	Nitrogen Dioxide (NO ₂)	Benzene family compounds
3	Particulates (PM ₁₀)	Lead (Pb)
4	Carbon Monoxide (CO)	Local significant pollutants
5	Ozone (O ₃)	

Based on the current population of each of the key cities, and the minimum number of stations necessary to achieve a viable AAMS, Table 2-9 (see next page) evaluates each city and determines the minimum number of automatic air monitors needed to comply with these guidelines. Using this technique, an additional 24 monitors would need to be added to the network for it to meet the recommended station density for the urban areas.

Table 2-9 Population of Key Cities and Automated Air Monitoring Station Coverage

City	Population at 2002 Year- end (million persons)	No. of Automated Stations			Minimum Additional Stations
		Existing Urban	Existing Industrial	Total Existing	
Changzhou	3.43	3	3	9	0
Huai'an	5.17	2	1	3	4
Lianyungang	4.64	3	1	4	3
Nanjing	5.63	4	1	6	1
Nantong	7.80	3	3	7	0
Suqian	5.13	2	0	2	5
Suzhou	5.85	4	5	19	0
Taizhou	5.04	3	3	6	1
Wuxi	4.38	6	2	11	0
Xuzhou	9.04	2	1	3	4
Yancheng	7.95	2	1	4	3
Yangzhou	4.52	4	2	9	0
Zhenjiang	2.67	3	0	3	3
Data source: Jiangsu Statistical Yearbook 2003 and Jiangsu Action Plan, 2002			TOTAL	86 ¹	24

Note 1 - Total does not include monitoring station at Xinghua, Lingshong Town

Nine of the cities listed do not have the minimum number of monitors recommended. Due to limited time in the field portion of this project, a visit to each of the key cities was impractical. Site visits were conducted in Nanjing, Xuzhou, and Yangzhou. Nanjing and Xuzhou are two of the cities identified in this table as not having enough monitors. The following is an overview of Nanjing that evaluates the current monitoring network and discusses the critical needs for the city.

2.4.2.1 Nanjing

Nanjing has a relatively moderate climate year-round, with an average annual temperature of approximately 15°C, and 980 mm of precipitation on an annual basis, nearly half of which accumulates during the early to mid summer (late June through July). It belongs to the northern subtropical monsoon climate zone where

the four seasons are clearly demarcated, and has an annual average temperature 16°C. At the extreme's, the absolute maximum temperature 43°C, and minimum temperature minus 14°C; with average temperatures in the summer being approximately 27°C, while in the winter dropping to 3°C.

Table 2-10 Average Meteorological Measurements for Nanjing Area, 1994-1996

°C	Spring	Summer	Fall	Winter	Yearly average
Surface Temperature	14.2	26.6	16.5	2.9	15.1
Dew point Temperature	10.3	23.2	12.9	-1.0	11.5
Precipitation, mm	238.6	465.1	186.2	89.6	979.5



Prevailing winds in the Nanjing are typically from the E and SE in the spring and summer and shift to the NE in the fall and NW in the winter. An annual wind rose based on data collected from 1994 to 1996 shows the primary winds in Nanjing blowing from the NE, E and SE.

Station Name and Location:

Cao Chang Men – Education Area

Zhong Hua Men - Traffic Area

Ruijin Road – Resident Area

Xuanwu Lake – Clean Area

Shanxi Road – Commercial Area

Maigao Bridge – Industrial Area

Zhongshan Ling - Background Point

Source: NEMC., 2003



Table 2-11 Yearly Climate Information for Nanjing

Detailed Information About the Average, Maximum and Minimum Temperatures and the Rainfall in Nanjing.												
Average Data	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Average High (F)	44	47	56	68	78	84	90	90	82	72	61	49
Average High (C)	7	8	14	20	25	29	32	32	28	22	16	9
Average Low (F)	29	32	40	50	60	69	76	75	67	55	43	32
Average Low (C)	-1	0	4	10	16	20	24	24	19	13	6	0
Rain (in)	1.3	2	2.7	3.5	3.7	5.5	7	4.7	3.4	1.8	1.8	1.2
Rain (mm)	32.5	52.5	72.5	87.5	97.5	142.5	177.5	122.5	87.5	47.5	47.5	32.5

According to the data in Table 2-9, Nanjing is reasonably well covered with respect to monitoring (also see Figure 2-5). The JPEMC also has an additional monitoring station that is not included in the database. This test station is being used to test new monitoring devices such as PM_{2.5} and speciated VOCs.

On the following page is Figure 18, which is a map of Nanjing Municipal Automatic Air Monitoring Stations. Nanjing has seven monitoring stations strategically located throughout the city. They are the Cao Chang Men – educational area; Zhong Hua Men – heavy traffic area; Rui Jin Lu – key road through a residential area; Xuan Wu Hu – lake within the city considered ‘clean air’; Shanxi Lu – key road through a commercial area; Mai Gao Qiao – bridge in an older industrial area; and Zhong Shan Ling – background point on the mountain side.

While the central area of Nanjing is reasonably well monitored, the industrial area north of the city does not have any ambient stations. There is a significant amount of chemical and petrochemical processing in the industrial park, along with one of the primary power generating stations for the Nanjing area. Furthermore, SINOPEC is in the process of building a new petrochemical processing complex in the industrial park, which when finished, will be China’s largest. Without ambient monitoring stations in this area, it is not possible to determine the overall impact these industrial facilities are having on the air quality in Nanjing. Emission inventories and individual source continuous emissions monitoring can help quantify these impacts, however, because the facilities are clustered in a relatively small area, the cumulative impact of these facilities on the nearby residential and commercial areas is not being adequately determined. Ideally there would be three or four monitoring sites around and near the industrial park, one located upwind (east of the industrial park), and two to three downwind. This network would provide the Nanjing Municipal EPD with more accurate and efficient information to evaluate the industrial park’s net contribution to the air quality in the region.

2.5 Recommendations for the Expansion of the Existing AAMSs and the DMS

2.5.1 Fixed Monitoring Stations

2.5.1.1 Evaluation of Monitoring Sites

As mentioned in the previous section, siting the monitors is one of the most critical pieces in the air quality characterization effort. To this end, the U.S. Environmental Protection Agency (USEPA) has developed several guidance documents to assist in determining the appropriate location of various types of monitors. The guidelines identify specific siting criteria for locating ambient air monitoring stations depending upon the overall data objectives for monitoring PM₁₀, O₃, SO₂, NO_x and CO. For example, when establishing an ozone monitoring system, to fully characterize the ozone levels, monitors need to be sited in several locations upwind of the urban area, at the city center, and downwind of the urban area where it is most likely the maximum ozone concentration would be located.

The guidance documents are:

- *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)*, EPA-450/4-87-007, US EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1987;
- *On-site Meteorological Program Guidance Regulatory Modeling Application*, EPA- 450/4-87-013, US EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1987;
- *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide to Environmental Quality Assurance*, EPA-600/R-94/ 038a, USEPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, April 1994; and
- *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Quality Monitoring Program Quality System Development Program*, EPA-454/R-98-004, USEPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, August 1998.

Figures 2-6 through 2-17 (see Appendix B) show each of the key city's monitoring stations. As previously mentioned, in general, the AAMS is reasonably adequate for its intended purpose. However, based on these guidance documents and the stated goal, while adequate, the current AAMS does not provide a representative sample of the ambient air quality in a few of the cities, particularly Nanjing and Xuzhou. This area of concern can be corrected through additional monitor sites. Neither Nanjing nor Xuzhou has addressed the need to monitor in and around the industrial areas. The current monitoring network in both cities concentrates on the urban, residential and local sensitive areas, but little, if any, ambient monitoring is being conducted in and around the primary industrial areas. Xuzhou has one monitor that is sited downwind of the industrial

area north of the city, while there are no monitors in the vicinity of the primary industrial park in Nanjing.

2.5.1.2 Sampling Considerations

The most important sampling considerations are the physical properties of the pollutant being sampled, its relative impact on humans and/or sensitive receptors, and the general purpose for the monitor, i.e. characterization of emissions or background information. For instance, in order to accurately characterize PM₁₀ emissions, the monitors should be placed near the primary emission source(s). Similarly, CO monitors should be placed in high traffic areas in the breathing zone where the public typically walks and/or lives. An SO₂ monitor may need to be placed downwind a distance to allow for the transport characteristics to be realized.

2.5.1.3 Selection of Monitoring Parameters

The current mix of parameters monitored at each station is adequate for determining compliance with the Chinese national ambient air quality standards. However, if additional pollutants are added such as PM_{2.5} or hazardous (toxic) air pollutants (HAPs), additional monitoring parameters would need to be evaluated. JPEMC is currently testing the use of a PM_{2.5} monitor and collecting samples of volatile organic compounds to evaluate HAPs emissions. These pollutants are regulated in the U.S. and could eventually be added to the required monitoring list. Multipollutant gas analyzers with internal gas chromatograph/mass spectrometers are commercially available and can be easily integrated into the existing monitoring stations if HAPs become regulated.

Additionally, according to JPEMC, Jiangsu started development of an acid rain monitoring network in 1986, which includes 12 key cities (excluding Suqian city), one county-level city Changshu (under Suzhou municipality) and 40 counties, with a total of 83 monitoring sites. In March 2002, the State Environmental Monitoring Center organized a nation-wide acid rain survey in key cities and areas for one-year period. Jiangsu Province participated in the survey and has increased the number of monitoring sites to over 100. Parameters monitored at the stations include pH, rainfall (all sites), conductivity, SO₄²⁻, NO₃⁻, Cl⁻, F⁻, K⁺, Na⁺, Ca²⁺, Mg²⁺, NH₄⁺ (key city sites). To determine the concentrations, manual analysis is required; therefore, the monitoring system is not fully automated. However, the monitoring results are transmitted in database format through the county-city-province system as soon as it is available and quality assured. JPEMC summarizes all the received data and analyzes the acidity and incidence rate in each area.

2.5.1.4 Overview of Monitoring Methods/Techniques

This section summarizes the measurement techniques available for determining ambient concentrations of the main "classic" pollutants, SO₂, NO₂, CO, O₃, and PM.

(1) Sulfur Dioxide (SO₂)

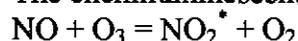
The most widely used method for automatic SO₂ measurement is ultraviolet fluorescence (UVF). SO₂ molecules in the sample airstream are excited to higher,

unstable energy states by UV radiation at 212 nm. These energy states decay, causing an emission of secondary fluorescent radiation with intensity proportional to the concentration of SO₂ in the sample.

Given appropriate attention to system design, calibration and equipment support a typical measurement accuracy of $\pm 10\%$ and a precision of $\pm 3 \mu\text{g}/\text{m}^3$ should be readily achievable in well-run automatic networks.

(2) Nitrogen Dioxide (NO₂)

The reference method for automatic measurement of nitrogen oxide concentrations is the automatic chemiluminescence method. The method is based on the chemiluminescence energy emitted when NO in the sample airstream reacts with O₃ in an evacuated chamber to form an excited energy state of NO₂. The chemiluminescent reaction is:



Emitted light from the excited NO₂* is converted to an output voltage by a photomultiplier tube and amplifier.

Given appropriate attention to system design, calibration and equipment support a typical measurement accuracy of $\pm 8\%$ and a precision of $\pm 6.5 \mu\text{g}/\text{m}^3$ should be readily achievable in well-run automatic networks.

(3) Carbon monoxide (CO)

CO in urban areas results almost entirely (typically ~90%) from road traffic emissions. Since CO is a primary pollutant, its ambient concentrations closely follow emissions. In urban areas, concentrations are therefore highest at the curbside and decrease rapidly with increasing distance from the road.

Baseline ambient CO monitoring is normally carried out using IR analyzers. A number of electrochemical CO analyzers are available, but these are generally of low sensitivity and not suitable for routine ambient monitoring. However, they may have application in areas of high concentrations. A version of this sensor is incorporated in a commercially available roadside pollution monitoring system.

CO analysis is based on the absorption of IR radiation at wavelengths of 4.5-4.9 micrometers. Since other gases and particles can also absorb IR, the analyzer must distinguish between absorption by CO and absorption by interferences. In the most common analyzer type, this is done using a gas filter correlation wheel containing a cell of pure nitrogen and a cell of nitrogen plus CO. The cell containing CO removes the CO-sensitive wavelengths before the IR signal enters the absorption chamber, whilst all wavelengths are transmitted by the other cell. The difference in the intensity of the two absorption signals, divided by the intensity of the IR source, provides a measure of the ambient CO concentration.

Given appropriate attention to system design, calibration and equipment support a typical measurement accuracy of $\pm 8\%$ and a precision of $\pm 0.5 \text{mg}/\text{m}^3$ should be readily achievable in well-managed and quality-assured programs.

(4) Ozone (O₃)

O₃ is not emitted directly from man-made sources in any significant quantities, but is formed in the atmosphere by sunlight-driven chemical reactions involving NO_x and VOC. These reactions are not immediate, but may take from hours to days to complete. O₃ is chemically scavenged by primary NO_x emissions from traffic, and is also removed from the atmosphere by deposition to the ground.

Both spatial and temporal distributions of O₃ differ markedly from those of other pollutants. In particular, significant impacts may occur in areas up to hundreds of kilometers downwind of the original precursor emissions, as a result of long-range as a result of long-range transport. Ambient concentrations and population exposure may often be maximized in suburban and rural areas. This has important implications for monitoring system design.

The most commonly used technology is that of UV adsorption. UV absorption is a robust, well-developed technique. Ambient O₃ concentrations are calculated from the absorption of UV light at 254 nm wavelength. The sample passes through a detection cell of known length (l). An O₃-removing scrubber is used to provide a zero reference light intensity, I₀. The analyzer alternately measures the absorption of air in the cell with no O₃ present and the absorption in the experimental sample cell, I_s. The ambient O₃ concentration, c, may be simply calculated using the Beer-Lambert equation:

$$I_s = I_0 e^{-alc}$$

where a is the relevant absorption coefficient at 254 nm.

Given appropriate attention to system design, calibration and equipment support a typical measurement accuracy of 11% and a precision of 4g/m³ should be readily achievable in well-run automatic networks.

(5) Particulate Matter (PM)

PM monitoring is fundamentally different from the measurement of gaseous pollutants, and the methods are generally less precise. The sampling system strongly affects the measurement process and appropriate aerodynamically designed inlets are essential for proper sample-fractionated determinations.

Instruments are commercially available using the following techniques:

- Tapered Element Oscillating Microbalance (TEOM).
- Beta-ray absorption analyzers (ISO/FDIS 1999b).
- Light scattering systems.

Of the automatic instrument types available, the TEOM and β -ray systems have been operated widely for many years and are well tested in the field. The light scattering type of instrument has been developed more recently, and is therefore less well proven in service. Operating experience and co-located measurement campaigns indicate that measurements from the different instruments are not always equivalent or comparable.

For traceable and robust measurements, samplers must be fitted with a tested PM₁₀ inlet head and an accurate flow control system. The PM₁₀ sampling inlet

should be tested to ISO Standard 7708 to ensure accurate size fractionation at the point of sampling. Given appropriate attention to system design, calibration and equipment support a typical measurement accuracy of $\pm 10\%$ and a precision of $\pm 5 \mu\text{g}/\text{m}^3$ should be readily achievable in well-run automatic networks.

(6) Meteorological Data

Having meteorological data is essential. Meteorological data adds significant value to the monitoring data by allowing a more in depth analysis of monitoring data to occur thus helping to:

- Establish the representativeness of monitoring data;
- Explain why events occur;
- Identify sources of pollutants; and
- Identify potential mitigation measures.

Data from closest meteorological station can potentially be used. The relevance of this data to your site will be often determined by fine scale meteorology. Fine scale meteorology will reflect local topography and in many locations this is often complex. An assessment must be made of the relevance of the closest meteorological data source to the area under investigation.

Met data is especially important if you are concerned with short-term events rather than longer term averaging periods. This is because the relationship between short-term pollutant concentrations and meteorology is more complex.

2.5.1.5 Comparison and Selection of Monitoring Instruments

At the present time, each of the automatic monitoring stations is monitoring all same parameters, with the exception of CO and Ozone, which are typically only monitored in the urban setting. Equipment manufacturers vary from site to site, however, the monitors are generally equivalent in their monitoring ranges and reliability, and they are all equally viable for performing the monitoring.

Current equipment at monitoring station

- NOX Analyzer
- Ozone Analyzer*
- SO₂ Analyzer
- PM10 Monitor
- CO Analyzer*
- Multi-gas Calibrator
- Ozone Calibrator
- Zero Air Supply
- Ambient Air Intake Manifold System
- Data Logger
- Strip Chart Recorder
- Uninterruptible Power Supply (UPS)
- Telephone/Telemetry
- Air Conditioner
- Building/Shelter/Trailer
- Computer
- Spare Parts

- Meteorological Station with tower, translator, and cables
- Software, central computer, printers, etc.
- * Urban stations only

Figures 2-19 & 2-20 are examples of the monitoring equipment both outside (samplers) and inside (monitors/DAS).

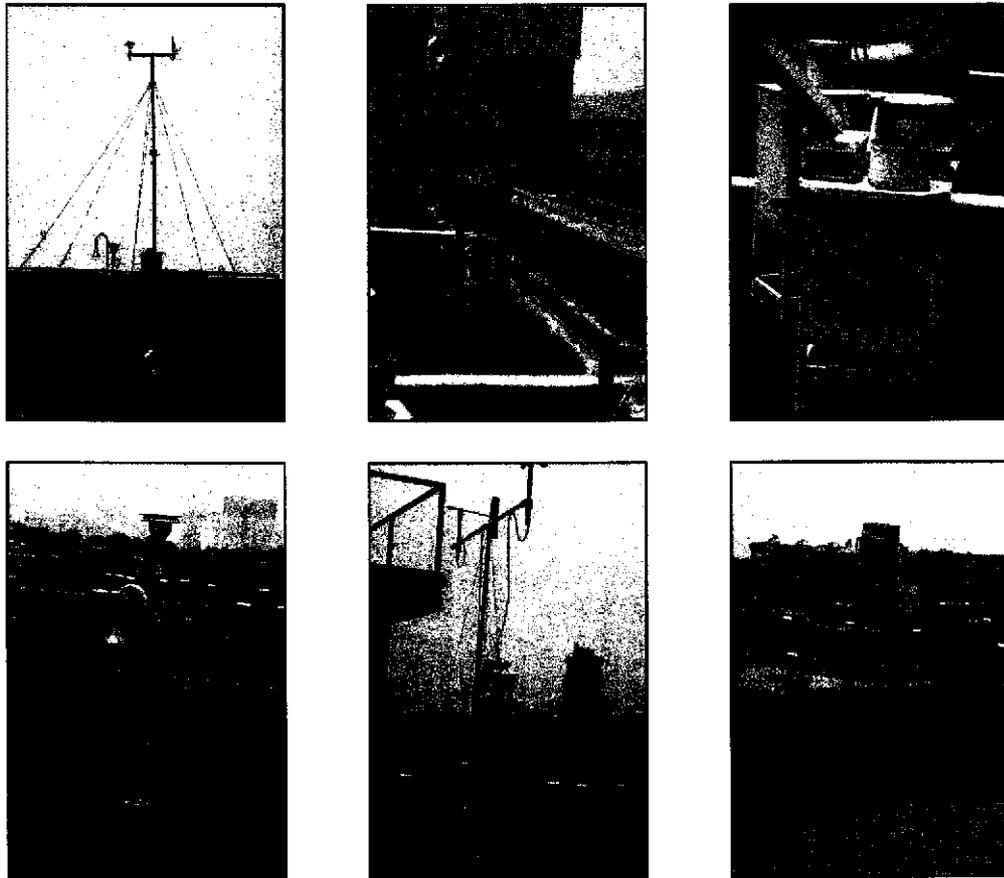


Figure 2-19 – Sampling Systems

- A) Met Tower and PM_{2.5} Sampler (Nanjing);
- B) Dustfall Monitor (Nanjing);
- C) TSP samplers (Nanjing);
- D) PM₁₀ sampler (Xuzhou);
- E) Met Station (Xuzhou); and
- F) Dustfall sampler (Xuzhou).

Equipment suppliers currently providing the above listed equipment are:

- Monitor Labs
- Advanced Pollution Instruments (API)
- American Thermion Company
- Legend Group (China)
- Beijing Analytical Instrument Plant (China)
- Rupprecht and Patashnick (RP)
- MetOne
- DASIBI

- ESC
- ESA (France)
- AFSISO (Germany)
- Advantech
- R. M. Young
- Nanjing EMC
- DANI (Italy)

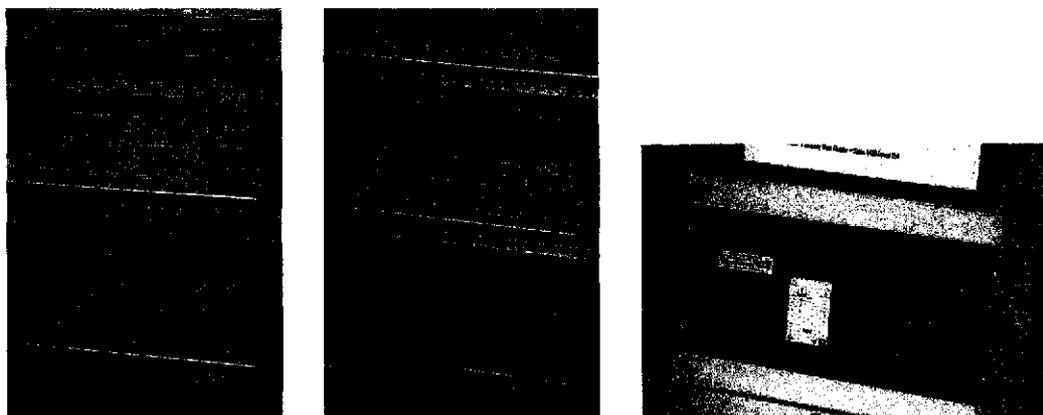


Figure 2-20 – Monitoring Instruments and DAS

Contact information for each of the vendors is included at the end of this chapter.

General specifications for the equipment and installation services are:

- All monitoring data will be validated in accordance with the China National Environmental Monitoring Centre specifications for Ambient Air Quality Reporting, and GB3095-1996.
- All conventional ambient air analyzers should have USEPA Reference Methodology and/or Equivalent Method Identification.
- The supplier provides calibration gases and other items necessary to operation the equipment for the first year of operation.
- The supplier equips all stations with a data logger and a data acquisition/communication system. The stations should have strip chart recorders for backup purposes. The data logger storage capacity should be at least six months. The communication system should have redundancy, also for backup purposes.
- Each meteorological station is equipped to monitor wind speed, wind direction, vertical wind speed, humidity, temperature, barometric pressure, accumulated rainfall and global radiation.
- The analyzers are rack-mounted and installed in an insulated air-conditioned housing unit.
- The system should be installed so that it will not be affected by local emission sources in accordance with generally accepted site criteria.
- The sample manifold inlet should be located at least ten meters away from the nearest building or other object.
- All parts of the monitoring system should be installed safely and out of reach from the public and well protected from potential vandalism.

- The power supply for the analyzers must be protected by automatic voltage regulator and Uninterruptible Power Supply.

2.5.1.6 Calibration, Operation and Maintenance of Monitoring Instruments

An extremely important part of insuring quality data is obtained involves the calibration and routine operations and maintenance (O&M) procedures on the equipment. In order for instruments in the U.S. to be used for such purposes, they are required to meet the specifications in Title 40, Part 53 of the U.S. Code of Federal Regulations (40 CFR Part 53). This section establishes the criteria by which data will be accepted by using a rigorous QA/QC program. In order to meet these criteria, ongoing daily calibration of the instruments and following the recommended O&M procedures provided by the manufacturers is essential. All calibration and O&M procedures included by the manufacturers are tied to 40 CFR Part 53 requirements.

Although many of the automated monitors are self-calibrating, they require constant comparison to similar equipment and periodic QC by comparing analytical results to known standards. The manufacturer and/or system operator must follow the QA/QC guidelines, using QA software and performing equipment QC checks.

Data requires constant QA/QC checks. It is recommended that JP EMC contract a yearly independent audit the O&M contractor and to disperse payment based on performance (data quality). Any manually collected data requires analyses at certified laboratory and independent QA/QC check to certify analytical parameters, holding times, and chain-of-custody protocols.

2.5.2 Mobile Monitoring

One of the major responsibilities of the JP EMC is to provide technical guidance and assistance throughout the province with shorter-term environmental monitoring needs. This can include:

- Providing training at local EPDs for the installation, maintenance, and operation of new monitoring equipment;
- Assisting local EPDs with quick response involving unusual emission events and emergency chemical spills;
- Providing independent monitoring of various pollutants to locate potential new monitoring sites;
- Providing QA/QC activities associated with local EPDs networks to insure that accurate and reliable data is being acquired and sent to JP EMC; and
- Verifying emissions from industrial sources to obtain supplemental area specific information and/or provide additional data for monitoring and modeling needs.

In order to accomplish this objective, JP EMC needs to have mobile monitoring capabilities.

2.5.2.1 Emergency Response Monitoring

Due to a significant number of facilities which handle hazardous materials, particularly the petrochemical processing facilities, Jiangsu Province should have

three (3) to four (4) mobile units for availability for ambient monitoring in the event of a significant plant failure or chemical spill. The cost of these mobile monitoring units could be shared by the JPEMC and the 13 EPD's since such events can occur anywhere within the province. Due to the physical size of the province, these mobile units would need to be located in multiple cities in order to respond in a timely manner to an emergency event. In the case of three (3) mobile units, the most effective locations would be Nanjing, Suzhou, and Xuzhou. If a fourth (4th) unit were added, it should be based in Huai'an to allow for better coverage of the central and northeastern portion of the province.

2.5.2.2 Selection of Mobile Monitoring Vehicles

The most versatile mobile monitoring vehicle is a van. They are very flexible in their capabilities and equipment can easily be added or modified based on the intended use at the time it is deployed. The van must have adequate insulation and shock adsorption to allow more sensitive analyzers to be utilized without constant recalibration if the unit is mobilized to multiple locations for sample collection during an emergency response scenario. Many of the EPD's currently have vans which are utilized for field data collection, primarily regional water sampling. These vans could be utilized in a emergency situation, however, they are not fully equipped to handle multiple sampling needs, and are not insulated to allow for a controlled environment necessary for certain types of analysis to be conducted. Dedicated state-of-the-art mobile monitoring units should be purchased to handle the ongoing needs of the province, rather than attempting to utilize existing field service vans.

Several Mobile Air Pollution Monitoring Laboratories are currently in use for conducting ambient air monitoring. One has been customized by Horiba Instruments and offers the following features and benefits:

- A large amount of space inside the car can be saved: the vehicle employs AP-360 dry-method analysis equipment, which has the smallest size and the largest number of functions in the industry, as well as reference gas adjustment equipment, a data logger, and other devices, all placed in a small, lightweight cubicle base.
- Anyone who has an ordinary driver's license is able to operate the vehicle.
- Environmentally conscious vehicles, such as those using less gasoline or natural gas.
- As daily maintenance is simple, operating costs are minimized.
- A PC network can be installed on board for monitoring atmospheric pollution.
- System extension or alteration can be flexibly carried out. Data from other systems can be used.
- Output in 14 different forms, including monthly reports and wind roses, is possible via a laser printer.
- A variety of marketed software can be used for data analysis and the creation of materials.



Horiba's atmospheric monitoring vehicle is a mobile unit for assessing environmental conditions, monitoring air pollution, and providing support for fixed measurement stations. Despite its compact size, the vehicle is fully equipped with all the instruments necessary for monitoring atmospheric pollution. As the vehicle can be operated by persons with an ordinary driver's license, there is no need for a full-time driver. The extreme versatility of the vehicle allows for more speedy and flexible atmospheric-pollution monitoring. A large telemetry system for the constant monitoring of atmospheric pollution and a data processing system are no longer necessary - instead, their functions can be fulfilled by a more compact and cost-efficient PC network. Horiba also prepares environmentally conscious vehicles, such as those using less gasoline or natural gas.

A second vehicle which was recently commissioned by the Hong Kong Jockey Club for monitoring ambient air pollution in the Hong Kong area is called the *Mobile Real-time Air Monitoring Platform* or MAP. This vehicle has the following specifications:

- Type: 2-ton vehicle;
- Length: 5-5.5 m;
- Width: 1.8-2.0 m;
- Height: 2.8-3.2 m;
- Total engine displacement: Approximately 2,700 cc (natural-gas vehicles: about 4,000 cc);
- Total mass: 5,000 kg or less;
- Fuel: Gasoline or natural gas; and
- Security systems: Oil-pressure jack for vehicle stabilization; back monitor; sonar.



MAP with full exterior decoration, sampling probe and other sensing elements on top of it, in HKUST campus on 7 December 2001.

MAP is a new concept to obtain high intensity and continuous air quality data from a moving platform. MAP is a vehicle equipped with state-of-the-art equipment and instruments to monitor air pollution on the road in a real-time, in situ mode, in contrast to the conventional stationary techniques. Real-time mapping is more cost effective than the stationary because of the high quality and intensity of the data and its ability to cover a much larger territory in a short time. MAP is housed in a Euro III low emission gasoline-powered 24-seater van, and equipped with advanced equipment, including a particle distribution counter, a volatile organic compound analyzer, an elemental carbon analyzer, a global positioning system (GPS), criteria gas monitors and an automatic weather station.

2.5.2.3 Selection of Mobile Monitoring Instruments

The mobile van should be equipped with state-of-the-art monitoring equipment, calibration standards for both ambient and source monitoring, and emergency monitoring instrumentation for volatile, semi-volatile, and non-volatile organic and inorganic analyte associated with emergency response and personnel health and safety monitoring. This would include individual fixed SO₂, NO_x, CO, Ozone, Ammonia/Nitrate, H₂S, and hydrocarbon monitors; a real-time GC or GS/MS analyzer; portable analyzer for particulate sampling (TSP, PM₁₀ & PM_{2.5}); portable Transpositional Infrared Gas (TIG) analyzer; multi-gas calibration system with calibration gases; portable meteorological instrument; zero gas generator; data logger and transmission (satellite and modem options); spare parts; Laser Radar; portable radiation analyzer; portable organic vapor analyzer; and external power supply (generator and electrical tie in for locations with available power supply).

Horiba Mobile Air Pollution Monitoring Laboratory Specifications

Analyzers

Sulfur dioxide	Ultraviolet fluorescence	0-0.5 ppm
Nitrogen oxides	Chemiluminescence	0-1.0 ppm
Floating particles	Beta ray absorption	0-5.000 $\mu\text{g}/\text{m}^3$
Ozone	Ultraviolet absorption	0-1.0 ppm
Carbon monoxide	Non-dispersal infrared light absorption	0-100 ppm
Toxic Air Pollutants *	Gas chromatograph	0-200 ppb

*Benzene, trichloroethylene, and tetrachloroethylene

Weather-monitoring Equipment

	Measurement Methods	Wind direction: tail fin type
		Wind speed: propeller type
		Temperature: temperature-sensitive platinum resistant type
		Humidity: static electricity amount type
	Measurement Ranges	Wind direction: 16 directions
		Wind speed: 0-20 m/s
		Temperature: -20 °C to 40 °C
		Humidity: 0-100%



Mobile Real-time Air Monitoring Platform (MAP) Specifications

Particle size distribution	Electric Low Pressure Impactor (ELPI)	20 - 0.03 μm	3935-10 TSI, USA	In 12 cuts range. 1 scan per second
Volatile Organic Compounds	Fourier Transform Infra Red Analyzer (FTIR)	30 ppb	B-ZME16-C IMACC	300 seconds per scan
SO ₂ , NO _x , and O ₃ analyzers	Ultraviolet absorption		100A, 200A, 400A API, Inc	10 seconds per scan
Elemental carbon analyzer			RTA8-E3-MAN-C Andersen	
GPS (global positioning system)		GPS25-HVS	Garmin	
Automatic weather station			R.M. Young and Campbell Scientific	



Note: This operating data screen onboard MAP is a snapshot captured from the data server. The color track on the map at right of the screen is the route MAP has run. Color intensity of the track is relative concentration of a certain pollutant indicated by the yellow box checked on top left corner of the screen. At bottom of the screen is displayed meteorological information and exact location of the vehicle as delivered by, respectively, AWS and GPS.

2.5.2.4 QA/QC of Mobile Monitoring Instruments and Vans

Ongoing QA/QC of the mobile monitoring instruments and vehicles is vital for these units to provide valid monitoring data. Therefore, they should be maintained by a specified group dedicated to inspection and maintenance of these systems. JPEMC should be in charge of this function. Each unit should be inspected on a quarterly basis, and maintained in accordance with QA/QC procedures established by the equipment manufacturers and JPEMC. At a minimum, equipment calibration procedures and instrument manuals must accompany the mobile units at all times, and all personnel assigned to utilize the equipment must be trained in the use and care of the instruments.

2.5.3 Evaluation and Selection of Data Management Systems

2.5.3.1 Automatic Data Collection, Processing, Distance Transmission and Real-Time Data Acquisition

With the expansion of the AAMS, it is important that the system used to collect and store data at JPEMC is fully capable of the task. This centralized data acquisition system (DAS) is a strategically significant infrastructure necessity for Jiangsu Province to meet the national regulatory requirements. Currently, each of the automated monitoring stations has a DAS which is linked via modem to its respective EPD's computer system. This information is collated with the other monitors in the city and electronically transmitted to JPEMC. In general, this works. However, there are several different DAS's being used across the province, each with slightly different capabilities. In terms of the management of environmental data and information, this leads to problems such as duplication and multi-purpose data collection, redundant data and lack of data sharing, and insufficient use of data.

In order for the DMS to be most effective, it is strongly suggested that one type of DAS should be selected and utilized by each of the EPD's and JPEMC. This eliminates inherent software and hardware interface problems and allows for a mirrored system which can be coordinated and updated simultaneously as data needs change and or additional parameters are monitored. This type of system is routinely used in the US and allows the monitoring center to focus on presenting and utilizing the data, rather than continually having to verify that the incoming data is being transmitted correctly. A good example of such an environmental monitoring system (EMS) is one currently in use in the state of Texas by the Texas Commission on Environmental Quality (TCEQ). The system was established and is managed by an independent contractor, Information Processing Systems (IPS) MeteoStar, Inc. A brief overview of this system is included for reference purposes.

2.5.3.2 MeteoStar® LEADS System Overview

The MeteoStar® LEADS software grew out of Navy and Air Force weather programs at Lockheed Martin in Austin, TX. The LEADS meteorological software and other MeteoStar® products (SMS, EMS, and RWIS) were developed over a fifteen-year period. In August 1994, TCEQ issued a purchase order to Lockheed Martin for a LEADS with the addition of pollution sensor inputs. This new system was to overhaul the existing TCEQ monitoring network and was designed to allow flexible monitoring network expansion and to provide

analysis tools that were previously unavailable. In September 1997, IPS purchased the intellectual property rights for MeteoStar® products from Lockheed Martin.

(1) System Components

The EMS installed at TCEQ consists of two major components, the Leading Environmental Analysis and Display System (LEADS) and the Point Data Collection System (PDCS).

- The LEADS software provides ingest of World Meteorological Organization (WMO) formatted observations, WMO gridded fields and system-based sensors (e.g., NEXRAD, lightning systems, satellite ground stations, profilers, local numerical models, etc.). LEADS also provides a complete set of data manipulation and display tools which enables the system to superpose all data types and generate almost any weather product which can be imagined. All tools can be scripted, so the system can automatically generate user-defined products (e.g., by schedule or event). The TCEQ LEADS ingests data from the National Weather Service (NWS) in the form of surface and upper air observations and gridded forecast fields. The LEADS also ingests high-resolution geo-stationary satellite imagery (visual and IR), and acoustic and radar profiler data. The TCEQ LEADS does not include the NEXRAD, lightning, or polar orbiting satellite interfaces, although these interfaces are available in the LEADS software.
- Point Data Collection System (PDCS). These systems ingest data from mobile or stationary point sources (e.g., data valid at a specific latitude and longitude, elevation and time). The TCEQ PDCS is combined with the LEADS software to provide a complete system with local data collection fully integrated with WMO data and system-based sensors (See Figure 2-21 [following page] for a printed example of the data gathered by the TCEQ PDCS on 9/14/2003). The TCEQ PDCS collects local meteorological data as well as pollutant measurements.

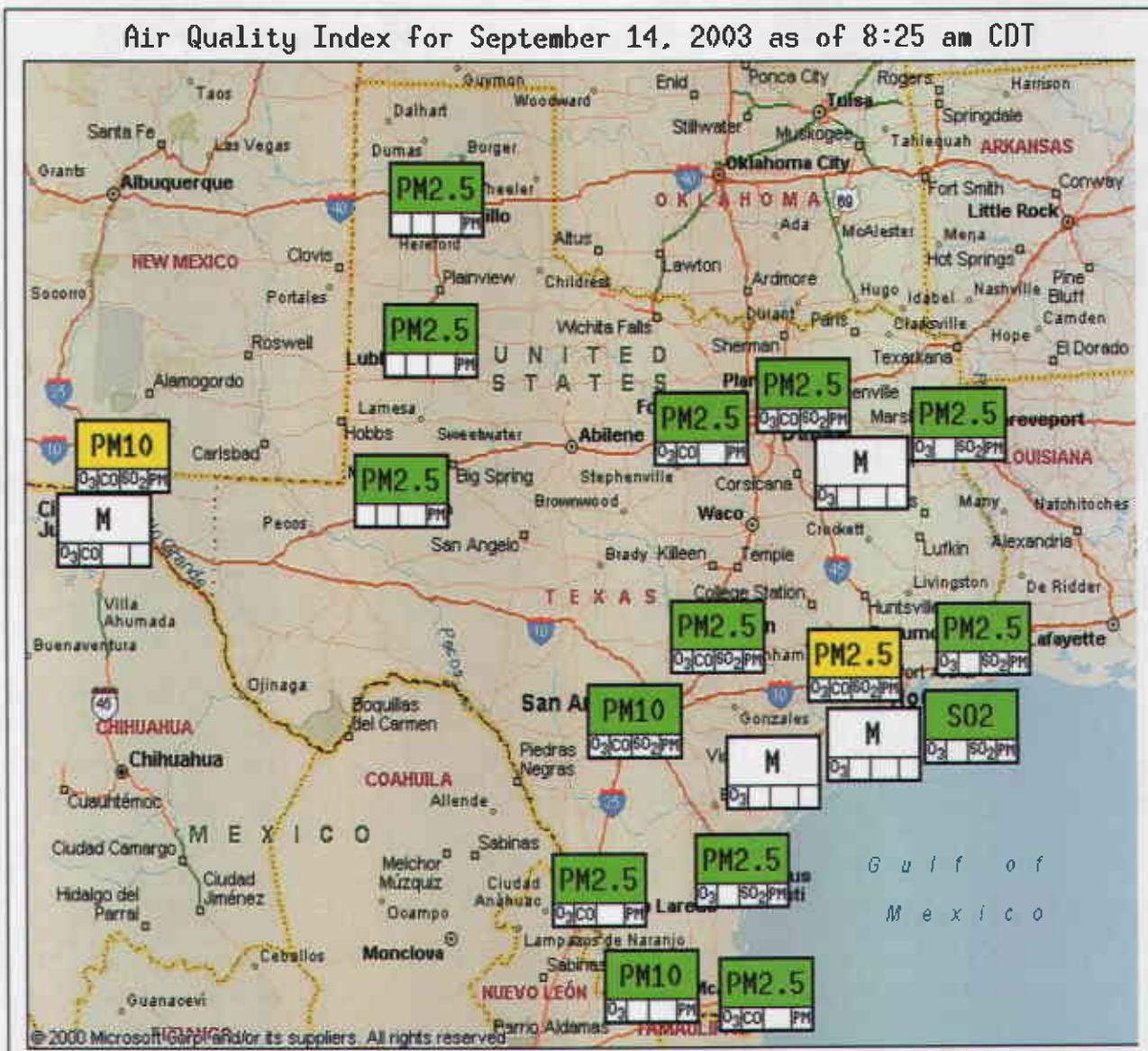


Figure 2-21 TCEQ PDCS – Air Quality Index for 9/14/2003

The TCEQ EMS includes a data logger and calibrators installed at each monitoring station. The old TCEQ data collection equipment was replaced with Coastal Environmental Systems data loggers and Dasibi automatic gas calibrators; however, the existing weather gear and monitors were kept as part of the EMS. The data logger converts meteorological sensor data from voltages to engineering units. Pollutant data is stored in terms of voltages by the data logger, and is later converted to engineering units. The data logger also converts outputs from some special pollutant measuring equipment (such as Beta-gauges) to engineering units. Any parameter that requires calibration is stored as voltages in the data logger. The EMS also includes modems at each of the monitoring stations, and each TCEQ Regional Office received a new UNIX workstation for calling monitoring sites located in the region. The regional UNIX workstations are connected via the TCEQ wide-area-network (WAN).

(2) System Operation

The collected data (meteorological and pollution) from the regional offices is moved over the WAN to a UNIX workstation located in the TCEQ offices in Austin where it is decoded and placed in a database. Multi-point calibrations and span checks are automatically detected in the data stream. The decoding software accumulates calibration and spans information as the data arrives and performs a series of quality assurance tests on the calibration or span check. Slopes and intercepts are calculated for the multi-point calibrations and are applied to subsequent data collected. Failed calibrations or span checks will result in automatic data rejection.

The regional office workstations call each of the monitoring sites located in their regions every fifteen (15) minutes. It takes approximately five to seven minutes for the data to be collected and sent upstream to Austin. Thus, data from across the state is available about twenty to twenty-five minutes after it is measured. This allows near-real-time monitoring of rising pollutant levels as well as real-time ozone action day forecasting.

Once pollution data is stored in the database, it is available immediately for display and analysis using the LEADS tools and other special tools (mostly web-based) designed specifically for TCEQ (product generation). Products range from tabular reports to ozone concentration animation loops. There are many interfaces available for pollution product generation. The LEADS weather interface that will integrate multiple data types (pollution data, local weather sensors and NWS meteorological data). A Manual Validation interface also graphically displays pollution and meteorological data, and allows validators to set or change data flagging codes and to recover data that has been automatically rejected.

Further information on the MeteoStar Program can be viewed at the following website: <http://www.meteostar.com/ems.shtml>. Costs for such a system are included in the following section.

2.6 Instrument Manufacturers/Vendors – Overview And Recommendations

2.6.1 Methods for Evaluation of Instrument Manufacturers/Vendors

All of the instrument manufacturers and vendors currently providing monitoring equipment in Jiangsu Province have systems which utilize methods for measuring ambient concentrations of specified air pollutants which are designated as “reference methods” or “equivalent methods” in accordance with Title 40, Part 53 of the U.S. Code of Federal Regulations (40 CFR Part 53). Such systems are acceptable for use in any ambient air quality monitoring network in the U.S., subject to any limitations stipulated in the applicable designation. Limitations can include a specified operating range or temperature range for the system. Table 2-12 below lists each of air pollutant monitoring methods being used at the monitoring stations around the Province.

Table 2-12 Monitoring Equipment Currently in Use in Jiangsu Province

Pollutant	Manufacturer	Model	Designated USEPA Reference/Equivalent Method
CO	Advanced Pollution Instrumentation (API)	M300	RFCA-1093-093
CO	American Thermion Company (ATC)	48C	RFCA-0981-054
CO	Monitor Labs (Monitor)	9830B	RFCA-0992-088
NO _x	API	M200A	RFNA-1194-099
NO _x	ATC	42C	RFNA-1289-074
NO _x	Environment SA (ESA)	AC31M	RFNA-0795-121
NO _x	Monitor	9841 or 9841B	RFNA-0991-083
O ₃	API	M400	EQOA-0992-087
O ₃	ATC	49C	EQOA-0880-047
PM ₁₀	ATC	FH62C14	EQPM-1102-150
PM ₁₀	ESA	MP101M	Not Designated ¹
PM ₁₀	Met One Instruments (MetOne)	BAM1020	EQPM-0798-122
PM ₁₀	Rupprecht & Patashnick (RP)	1400a	EQPM-1090-079
SO ₂	API	M100A	EQSA-0495-100
SO ₂	ATC	43C	EQSA-0486-060
SO ₂	Dasibi Environmental Corp (Dasibi)	4108	EQSA-1086-061
SO ₂	ESA	AF21M	EQSA-0292-084
SO ₂	Monitor	9850 or 9850B	EQSA-0193-092

1 Used at Nantong-Urban Station

There is only one monitor currently being used within the AAMS that is not listed as a Designated Reference/Equivalent Method under the U.S guidelines. The monitor in question is the MP101M PM₁₀ Monitor made by ESA. The method in question may be under review by EPA for inclusion in this list of acceptable equipment, therefore, it is not recommended that this monitor be changed.

The designation that a monitor is listed as a Reference/Equivalent Method indicates that the method of measuring a given pollutant meets the quality assurance and quality control (QA/QC) requirements established in the U.S. regulations. It should be noted that for the monitors to remain on the list,

- The methods must be used in strict accordance with its associated operation or instruction manual, and with applicable quality assurance procedures, and
- Modifications of a method by its vendors or the user can be cause for the pertinent designation to be inapplicable to the modified method.

40 CFR Part 58 Appendix C discusses the approval mechanism for modifications to a method. EPA keeps an updated list of all approved designated reference and equivalent methods on their web site at <http://www.epa.gov/ttn/amtic/criteria.html>.

2.6.2 Specifications (Monitoring Range, Accuracy and Repeatability, etc)

Table 2-13

Measurement Quality Objectives - Parameter NO ₂ (Chemiluminescence)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.11	
Shelter Temperature Temperature range Temperature control	Daily Daily	20 to 30 C .2 C	40 CFR, Pt. 53.20 Vol II, S 7.1.1 Vol II, MS 2.3.2	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dew point. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment NO ₂ analyzer Air flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to 2 % Accuracy 2 %	40 CFR, Pt 53.9 40 CFR, Pt 50, App F, S 2.2 EPA-600/4-75-003	
Detection Noise Lower detectable level	Purchase specification	0.005 ppm 0.01 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria
Completeness Hourly Data	Quarterly	75 %	40 CFR, Pt 50.11	
Compressed Gases Dilution gas (zero air)	Purchase specification	Free of contaminants	EPA-600/4-75-003	Return cylinder to supplier.
Gaseous standards	Purchase specification	NIST Traceable (e.g., EPA Protocol Gas)	40 CFR, Pt 50, App F, S 1.3 EPA-600/R-97/121	Nitric oxide in nitrogen EPA Protocol Gases have a 24-month certification period and must be recertified to extend the certification.
Calibration Multipoint calibration (at least 5 points)	≥ 1/6 months., after failure of	Residence time ≤ 2 min Dynam. parameter ≥ 2.75 ppm-min	40 CFR, Pt 50, App F, S 1 Vol II, S 12.6	Zero gas and at least four upscale calibration points. Points outside acceptance criterion are reentered. If still outside

Measurement Quality Objectives - Parameter NO ₂ (Chemiluminescence)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Converter efficiency	QC check or after maintenance	All points within 2 % of full scale of best-fit straight line	Vol II, MS 2.3.2	consult manufacturers' manual and invalidate data to last acceptable multipoint calibration or zero/span check.
Zero/span check- level	During multipoint calibrations	96 % Zero drift. 20 to 30 ppb Span drift. 20 to 25 %	40 CFR, Pt. 50, App F Vol II, MS 2.3.2 Vol II, S 12.6 Vol II, MS 2.3.2	Replace or service converter. If calibration factors are updated after each zero/span, invalidate data to last acceptable zero/span check, adjust analyzer, and perform multipoint calibration. If fixed calibration factors are used to calculate data, invalidate data to last acceptable zero/span check, adjust analyzer, and perform multipoint calibration.
Flowmeters	1/2 weeks	Zero drift. 10 to 15 ppb Span drift. 15 % Accuracy 2 %	Vol II, S 12.6 Vol II, MS 2.3.2 Vol II, App 12	Flowmeter calibration should be traceable to NIST standards.
Performance Evaluation (NPAP)	1/3 months			
State audits	1/year at selected sites 1/year	Mean absolute difference. 15 % State requirements	NPAP QAPP Vol II, App 15, S 3	Use information to inform reporting agency for corrective action and technical systems audits.
Precision	1/2 weeks 1/3 months	None 95 % Confidence Interval. 15 %	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Concentration. = 0.08-0.10 ppm.
Accuracy	25 % of sites quarterly (all sites yearly)	None 95% Confidence Interval. 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 3	Four concentration ranges. If failure, recalibrate analyzer and reanalyze samples. Repeated failure requires corrective action.

1/ - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II. The use of "S" refers to sections within Part 1 of Volume II. The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter O ₃ (Ultraviolet Photometric)					
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action	
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.9		
Shelter Temperature range Temperature control	Daily Daily	20 to 30 C. .2 C	40 CFR, Pt. 53.20 Vol II, S 7.1 ^u <i>Determination of Ozone by Ultraviolet Analysis (draft)</i>	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24-hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.	
Equipment O ₃ analyzer	Purchase specification	Reference or equivalent method	40 CFR, Pt 53.9 EPA-600/4-79-057	Air flow controllers must be capable of regulating air flows as necessary to meet the output stability and photometer precision requirements. The photometric measurement of absorption is not directly related to flow rate, but may be indirectly related due to thermal or other effects.	
Detection Noise Lower detectable level	Purchase specification	0.005 ppm 0.01 ppm	40 CFR, Pt. 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.	
Completeness (seasonal) Maximum 1-hour concentration	Daily	75% values from 9:01 AM to 9:00 PM (LST)	40 CFR, Pt 50, App H, S 3	A missing daily maximum ozone value may be assumed to be less than the standard if valid daily maxima on the preceding and following days do not exceed 75 percent of the standard.	

Measurement Quality Objectives - Parameter O ₃ (Ultraviolet Photometric)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Transfer standard Qualification and certification Recertification to local primary standard	Upon receipt of transfer standard 1/3 months (if at a fixed site)	<p> $\leq 4\%$ or ≤ 4 ppb (whichever greater) RSD of six slopes $\leq 3.7\%$ Std. dev. of six intercepts $\leq 1.5\%$ New slope = ≤ 0.05 of previous </p>	<p> EPA-600/4-79-056 EPA-600/4-79-057 " " " " </p>	<p> 6 comparison runs that include, at minimum, 6 concentrations per comparison run including 0 and $90 \pm 5\%$ of upper range. A single six-point comparison run. </p>
Local primary standard Certification/ recertification to Standard Photometer (if recertified via a transfer standard)	1/year "	<p> Difference $\leq 5\%$ (Preferably 3%) Regression slopes = 1.00 0.03 and two intercepts are ≤ 3 ppb </p>	<p> <i>Determination of Ozone by Ultraviolet Analysis (draft)</i> " " " " </p>	<p> The local primary standard is a standard in its own right, but it must be repaired and recertified if the acceptance criterion is exceeded. </p>
EPA Standard Reference Photometer recertification	1/year	<p> Regression slope = 1.00 ± 0.01 and intercept ≤ 3 ppb </p>	<p> Protocol for Recertification of Standard Reference Photometers... (TRC Environmental Document) EPA-600/4-79-057 </p>	<p> 9 replicate analysis over 12 conc. ranges. Disagreement must be resolved. EPA Standard Reference Photometer rechecked with NIST. If OK Network STANDARD REFERENCE PHOTOMETER must be repaired. </p>
Zero air	Purchase specification	Free of O ₃ or any substance that might react with O ₃ (e.g., NO, NO ₂ , hydrocarbons, and particulates)	EPA-600/4-79-057	Return cylinder to supplier

Measurement Quality Objectives - Parameter O ₃ (Ultraviolet Photometric)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Ozone analyzer calibration Zero/span check - level 1	1/2 weeks	Zero drift, 20 to 30 ppb Span drift, 20 to 25 %	Vol II, S 12.6 “ Vol II, S 12.6 “	If calibrations updated at each zero/span, Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration. If fixed calibration used to calculate data, Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration. Zero gas and at least four upscale calibration points. Check accuracy of flow dilution. Redo analysis. If failure persists corrective action required.
Multipoint calibration (at least 5 points)	Upon receipt, adjustment, or 1/6 months	Zero drift, 10 to 15 ppb Span drift, 15% Linearity error <5%	40 CFR, Pt 50, App D, S 5.2.3 EPA-600/4-79-057 S.5 Vol II, S 12.2	
Performance Evaluation (NPAP) State audits	1/year at selected sites 1/year	Mean absolute difference, 15% State requirements	Vol II, S 16.3 Vol II, App 15, S 3	Use information to inform reporting agency for corrective action and technical systems audits.
Precision Single analyzer Reporting organization	1/2 weeks 1/3 months	None 95% CI < 15%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Concentration = 0.08-0.10 ppm.
Accuracy Single analyzer Annual accuracy	25 % of sites quarterly (all sites yearly)	None 95% CI, 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

V - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II. The use of "S" refers to sections within Part I of Volume II. The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter PM ₁₀ (Dichotomous Sampler)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Reporting Units	All data	g/m ³	40 CFR, Pt 50.7	
Filter Checks				
Visual defect check	All filters	See reference	Vol II, MS 2.10.4	Discard any defective filters
Filter Integrity	Purchase specification	99 % 5 g/m ³	40 CFR, Pt 50, App M, S 7.2	As measure by DOP test (ASTM-2988). Reject shipment.
Collection efficiency		<25.0 microequivalents/gram	"	
Integrity		at least 24 hours	40 CFR, Pt 50, App M, S 9.3	Following 2 months storage at ambient temp and relative humidity. Reject filters
Alkalinity		15 to 30 C	40 CFR, Pt 50, App M, S 7.4	Repeat equilibration
Filter Conditioning	All Filters	3 C	"	Keep thermometer in balance room and record temperature daily.
Equilibration time	"	20 to 45 % relative humidity	"	
Temperature range	"	5 % relative humidity	"	
Temperature control	"			
Humidity range				
Humidity control				Keep hygrometer in the balance room and record humidity daily.
Equipment				
Sampler	Purchase specification	Reference or equivalent method	40 CFR, Pt 53.9	
Flow rate transfer standard	Purchase specification	2 % accuracy (NIST traceable)	40 CFR, Pt 50, App M, S 7.3	
Analytical balance	Purchase specification	Sensitivity = 0.1 mg	40 CFR, Pt 50, App M, S 7.5	This acceptance criterion is inconsistent with other acceptance criteria for balance that are in the quality assurance handbook.
Mass reference standards	Purchase specification	NIST traceable (e.g., ANSI/ASTM Class 2)	Vol II, MS 2.10.4	
Detection Limit				
LDL	Not applicable	Not applicable	40 CFR, Pt 50, App M, S 3.1	The lower limit of the mass concentration is determined by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler.

Measurement Quality Objectives - Parameter PM ₁₀ (Dichotomous Sampler)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Completeness	quarterly	75%	40 CFR, Pt 50, App K, S 2.3	
Sampler Calibration Flow control device	On installation, after repairs, after out-of-limits flow check	<4% difference from manufacturers spec and actual	40 CFR, Pt 50, App M, S 7.1 Vol II, MS 2.10.2	Adopt new calibration curve if no evidence of damage, otherwise replace.
Elapsed time meter	On receipt and 1/6 months	15 min	40 CFR, Pt 50, App M, S 7.1 Vol II, MS 2.10.1	Adjust or replace.
Flow-rate transfer Standard	Periodically	2% over the expected range of ambient conditions	40 CFR, Pt 50, App M, S 8.2 Vol II, MS 2.10.1	Checked against NIST-traceable primary standard.
Balance Calibration	1/year		Vol II, MS 2.10.4	Calibrate and maintain according to the manufacturer's recommendations.
Performance Evaluation (NPAP)	1/year at selected sites	Mean absolute difference, 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits
Precision Single analyzer	1/6 days	5 g/m ³ for conc., 80 g/m ³	40 CFR, Pt 50, App M, S 4.1	Both PM10 values must be > 20 g/m ³ .
Reporting organization	1/3 months	7% for conc. >80 g/m ³ 95% CI < 15%	40 CFR, Pt 58, App A, S 5.3 EPA-600/4-83-023	
Accuracy Single analyzer Annual accuracy	25 % of sites quarterly (all sites yearly)	None 95% CI, 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Transfer standards different then those used in calibration. Recalibrate before any additional sampling. Invalidate data to last acceptable flow check if difference ≥ 10%.

Measurement Quality Objectives - Parameter PM ₁₀ (Dichotomous Sampler)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
QC Checks Field calibration flow check	1/month	Percentage difference 7 % from sampler's indicated flow rate or 10 % from design condition flow rate	40 CFR, Pt 50, App M, S 8.2 Vol II, MS 2.10.3	Trouble shoot and recalibrate sampler.
"Standard" filter weighing	at beginning of weighing day	20 g of original weight	Vol II, S 2.10.4	Trouble shoot and reweigh.
Reweighing filters	5 exposed and 5 unexposed/day	20 g of original weight	Vol II, S 2.10.4	Trouble shoot and reweigh.
Balance zero and calibration check	every fifth filter	. 4 g at zero . 2 g at 10 mg	Vol II, S 2.10.4	Trouble shoot and reweigh.

✓ - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II. The use of "S" refers to sections within Part 1 of Volume II.
The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter SO ₂ (Ultraviolet Fluorescence)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.4	
Shelter Temperature Temperature range Temperature control	Daily Daily	20 to 30 C .2 C	40 CFR Pt. 53.20 Vol II, S 7.1 $\frac{1}{2}$ Vol II, MS 2.9	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment SO ₂ analyzer Air flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to 2 % Accuracy 2 %	Vol II, MS 2.9 " "	
Detection Noise Lower detectable level	Purchase specification	.005 ppm .01 ppm	40 CFR, Pt 53.20 & 23 " "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness Annual standard 24-hour standard 3-hour standard	Quarterly 24 hours 3 hours	75% 75% 75%	40 CFR, Pt 50.43 " "	
Compressed Gases Dilution gas (zero air) Gaseous standards	Purchase specification Purchase specification	SO ₂ free, 21 % O ₂ /78 % N ₂ , 300 to 400 ppm CO ₂ , 0.1 ppm aromatics NIST Traceable (e.g., permeation tube or EPA Protocol Gas	Vol II, MS 2.9.2 EPA-600/R97/121	Return cylinder to supplier. It is recommended that a clean air system be used instead of compressed air cylinders. Sulfur dioxide in nitrogen EPA Protocol Gases have a 24-month certification period for concentrations between 40 and 499 ppm and a 36-month certification period for higher concentrations.

Measurement Quality Objectives - Parameter SO ₂ (Ultraviolet Fluorescence)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration Multipoint calibration (at least 4 points) Zero/span check -level 1	Upon receipt, adjustment, or 1/6 months 1/2 weeks	All points within + 2% of full scale of best-fit straight line Zero drift. 20 to 30 ppb Span drift. 20 to 25 %	Vol II, S 12.6 Vol II, MS 2.9.2 Vol II, S 12.6 “ Vol II, S 12.6 “ Vol II, App 12	Zero gas and at least three upscale points. Note: two pages from Section 2.4 (Calibration Procedures) of Vol II, MS 2.9.2 are missing from the 1994 reprinting of the QA Handbook. If calibration updated at each zero/span- Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration If fixed calibration used to calculate data. Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration Flowmeter calibration should be traceable to NIST standards
Flowmeters	1/3 months	Zero drift. 10 to 15 ppb Span drift. 15% Accuracy 2 %		
Performance Evaluation (NPAP)	1/year at selected sites 1/year	Mean absolute difference. 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits.
State audits		State requirements	Vol II, App 15, S 3	
Precision Single analyzer Reporting organization	1/2 weeks 1/3 months	None 95% CI ≤ 15%	40 CFR, Pt 58, App EPA-600/4-83-023 Vol II, S 16, S2	Concentration = 0.08-0.10 ppm.
Accuracy Annual accuracy check- Reporting organization	25 % of sites quarterly (all sites yearly)	None 95% CI. 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, S 16	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

∇ - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II. The use of “S” refers to sections within Part 1 of Volume II. The use of “MS” refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.8	
Shelter Temperature Temperature range Temperature control	Daily Daily	20 to 30 C. < 2 C	40 CFR, Pt. 53.20 Vol II, S 7.1 ^{1/}	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment CO analyzer Flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to 1% Accuracy 2%	40 CFR, Pt 50, App C " "	
Detection Limit Noise Lower detectable level	Purchase specification	0.5 ppm 1.0 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness 8-hour average	hourly	.75 % of hourly averages for the 8-hour period	40 CFR, Pt 50.8	
Compressed Gases Dilution gas (zero air) Gaseous standards	Purchase specification Purchase specification	< 0.1 ppm CO NIST Traceable (e.g., EPA Protocol Gas)	40 CFR, Pt 50, App C " EPA-600/R97/12	Return cylinder to supplier. Carbon monoxide in nitrogen or air EPA Protocol Gases have a 36-month certification period and must be recertified to extend the certification.

Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration Multipoint calibration (at least 5 points)	Upon receipt, adjustment, or 1/6 months	All points within 2% of full scale of best-fit straight line	Vol II, S 12.6 Vol II, MS.2.6.1	Zero gas and at least four upscale calibration points. Points outside acceptance criterion are repeated. If still outside criterion, consult manufacturers manual and invalidate data to last acceptable calibration. If calibration updated at each zero/span , invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration. If fixed calibration used to calculate data , invalidate data to last acceptable check, adjust analyzer, and perform multipoint calibration. Flowmeter calibration should be traceable to NIST standards.
Zero/span check-level 1	1/2 weeks	Zero drift 2 to 3 ppm Span drift 20 to 25 %	Vol II, S 12.6 "	
Flowmeters	1/3 months	Zero drift 1 to 1.5 ppm Span drift 15% Accuracy 2 %	Vol II, S 12.6 " Vol II, App 12	
Performance Evaluation (NPAP) State audits	1/year at selected sites 1 /year	Mean absolute difference 15% State requirements	Vol II, S 16.3 Vol II, pp 15, S 3	Use information to inform reporting agency for corrective action and technical systems audits
Precision Single analyzer Reporting organization	1/2 weeks 1/3 months	None 95% CI, 15%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 5	Concentration = 8 to 10 ppm. Aggregation of a quarters measured precision values.
Accuracy Single analyzer Reporting organization	25 % of sites quarterly (all sites yearly)	None 95% CI, 20%	40 CFR, Pt 58, App A	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

U - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II. The use of "S" refers to sections within Part I of Volume II. The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives- Parameter PM _{2.5}				
Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Filter Holding Times Pre-sampling	all filters	< 30 days before sampling	Part 50, App. L Sec 8.3	Sec. 7.9
Post-sampling Weighing	"	< 10 days at 25° C from sample end date < 30 days at 4° C from sample end date	" "	Sec. 7.11 "
Sampling Period	All data	1380-1500 minutes or value if < 1380 and exceedances of NAAQS	Part 50, App. L Sec 3.3	
Reporting Units	All data	g/m ³	Part 50.3	Sec. 11.1
Detection Limit Lower DL Upper Conc. Limit	All data All data	2 g/m ³ 200 g/m ³	Part 50, App. L Sec 3.1 Part 50, App. L Sec 3.2	
Sampling Instrument Flow Rate	every 24 hours of op "	≤ 5% of 16.67 ≤ 2% CV	Part 50, App. L Sec 7.4 "	
Filter Temp Sensor	"	Measured ≤ 5% average for < 5 min. ≤ 5° C of ambient for < 30min	"	
Data Completeness	quarterly	75%	Part 50, App. N, Sec. 2.1	

Measurement Quality Objectives- Parameter PM _{2.5}				
Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Filter Visual Defect Check Filter Conditioning Environment Equilibration Temp. Range Temp. Control Humidity Range Humidity Control Pre/post sampling RH Balance	All Filters All filters " " " " " "	See reference 24 hours minimum 20-23° C ±2° C SD over 24 hr 30% - 40% RH or ± 5% sampling RH but >20%RH ± 5% SD over 24 hr. ± 5% RH located in filter conditioning environment	Part 50, App. L Sec 6.0 Part 50, App. L Sec 8.2 " " " " Part 50, App. L Sec 8.3.3 "8.3.2	Sec 7.5 Sec. 7.6 " " " "
Filter Checks Lot Blanks Exposure Lot Blanks	3 filters per lot 3 filters per lot	less than 15 g change between weighing less than 15 g change between weighing	not described not described	Sec. 7.7 Sec. 7.7
Lab QC Checks Field Filter Blank Lab Filter Blank Balance Check Duplicate Filter Weighing	10% or 1 per weighing session 10% or 1 per weighing session beginning, every 10th sample, end 1 per weighing session	±30 g change between weighing ±15 g change between weighing ≤3 g ±15 g change between weighing	Part 50, App. L Sec 8.3 Part 50, App. L Sec 8.3 not described not described	Sec. 7.7 " Sec. 7.9 Sec 7.11

Measurement Quality Objectives- Parameter PM _{2.5}				
Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Calibration/Verification Flow Rate (FR) Calibration FR multi-point verification One point FR verification External Leak Check Internal Leak Check Temperature Calibration Temp M-point Verification One-point temp Verification Pressure Calibration Pressure Verification Clock/timer Verification	If multi-point failure 1/yr 1/4 weeks every 5 sampling events every 5 sampling events If multi-point failure on installation, then 1/yr 1/4 weeks on installation, then 1/yr 1/4 weeks 1/4 weeks	± 2% of transfer standard ± 2% of transfer standard ± 4% of transfer standard 80 mL/min 80 mL/min ± 2% of standard ± 2 C of standard ± 4 C of standard 10 mm Hg 10 mm Hg 1 min/mo	Part 50, App. L, Sec 9.2 Part 50, App. L, Sec 9.2.5 Part 50, App. L, Sec 9.2 Part 50, App. L, Sec 7.4 " Part 50, App. L, Sec 9.3 Part 50, App. L, Sec 9.3 " " " Part 50, App. L, Sec 7.4	Sec 6.3 Sec 6.3 & 8.4 Sec 8.4 Sec. 6.6 & 8.4 Sec. 6.6 & 8.4 Sec. 6.4 Sec. 6.4 and 8.4 Sec. 6.4 and 8.4 Sec. 6.5 Sec. 8.2 not described
Accuracy FRM Performance Evaluation External Leak Check Internal Leak Check Temperature Audit Pressure Audit Balance Audit	25% of sites 4/yr 4/yr 4/yr 4/yr 4/yr (?) 1/yr	± 10% < 80 mL/min < 80 mL/min ± 2 C 10 mm Hg Manufacturers specs	Part 58, App A, Sec 3.5 not described not described not described not described not described	Sec 10.2 Sec. 10.2 " " " "
Accuracy Flow Rate Audit	1/2wk (automated) 4/yr (manual)	± 4% of audit standard	Part 58, App A, Sec 3.5	Sec. 10.2
Precision Collocated samples Single analyzer Single Analyzer Reporting Org.	every 6 days for 25% of sites 1/3 mo. 1/ yr 1/ 3 mo.	CV ≤ 10% CV ≤ 10% CV ≤ 10% CV ≤ 10%	Part 58, App. A, Sec 3.5 and 5.5 not described not described not described	Sec. 10.2 not described not described not described

Measurement Quality Objectives- Parameter PM _{2.5}				
Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Calibration & Check Standards Flow Rate Transfer Std. Field Thermometer Field Barometer Working Mass Stds. Primary Mass Stds.	1/yr 1/yr 1/yr 3-6 mos. 1/yr	+2% of NIST-traceable Std. ± 0.1° C resolution ± 0.5° C accuracy ± 1 mm Hg resolution ± 5 mm Hg accuracy 0.025 mg 0.025 mg	Part 50, App. L Sec 9.1 & 9.2 not described not described not described not described	Sec. 6.3 Sec 4.2 & 6.4 " " " Sec 4.3 and 7.3 "

Measurement Quality Objectives - Parameter PAMS Volatile Organic Compounds (VOC)				
Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppbC	TAD, July 1997	
Shelter Temperature range	Daily	20 to 30 C.	Vol II, S 7.1 ^{1/}	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Detection Limit System detection limit		1 ppbC	TAD Sect 2.8.2.3	Calculation based on multiple manual or automated analysis and 40 CFR recommendations
Completeness (seasonal)	Annually	85 %	TAD 2.8.1	
Calibration Multipoint retention time calibration standard	Start of analytical season	correlation coefficient ≥ 0.995	TAD 2.8.2.3	Triplicate analysis of multiple level propane standards over the expected sample concentration range (a minimum of three levels)
Performance Evaluation NPAP	prior to start of sampling season and twice during monitoring season	In absence of specified objectives within 25%	TAD 2.8.2.3	Useful for informing reporting agency for corrective actions and technical systems audits.
Precision Duplicate samples	once/2weeks automated 10% -manual	25% RSD or RPD	TAD 2.8.2.1.1	Comparison of duplicate field samples, or replicate sample analysis using manual or automated field devices.

Measurement Quality Objectives - Parameter PAMS Volatile Organic Compounds (VOC)			
Requirement	Frequency	Acceptance Criteria	Reference
QC Checks Retention time (RT) calibration check Canister cleaning	Weekly	Response Factor within 10% RPD of calibration curve < 10 ppbC total	TAD 2.8.2.3
Background/carryover	weekly and after calibration & RT	< 20 ppbC for both columns or <10 ppbC per column	TAD 2.8.2.3
			Retention time checked versus annual PAMS retention time cylinder provided to each site in the program. Canister cleaning per approved methodology Background testing according to TAD

2.6.3 Costs for Purchasing Instruments

Table 2-14 Estimated Cost for Ambient Monitoring Equipment

Equipment	Cost per unit (US \$)	No. of Units	Total Cost (US \$)
NOx Analyzer	\$11,555	27	\$311,985.00
Ozone Analyzer	\$10,465	4	\$41,860.00
SO ₂ Analyzer	\$10,900	27	\$294,300.00
PM-10 Monitor	\$12,000	27	\$324,000.00
PM-2.5 Monitor	\$18,000	27	\$486,000.00
CO Analyzer	\$10,400	4	\$41,600.00
Multigas Calibrator	\$13,015	27	\$351,405.00
Zero Air Supply	\$5,115	27	\$138,105.00
Air Intake Manifold	\$2,000	27	\$54,000.00
Data Logger	\$6,500	27	\$175,500.00
Strip Chart Recorder	\$4,000	27	\$108,000.00
Uninterruptible Power Supply	\$5,000	27	\$135,000.00
Telephone/Telemetry	\$3,000	27	\$81,000.00
Spare Parts (30% of total cost)	\$40,413	27	\$1,091,151.00
Meteorological	\$8,200	27	\$221,400.00
Software, Central computer	\$100,000	1	\$100,000.00
			\$3,955,306.00

Table 2-15 Estimated Cost for Mobile Ambient Monitoring Vehicle

Item	Quantity	Unit price	Subtotal	Vender	Note
Specially designed van	3	\$100,000	\$300,000.00	TBD	
1. SO ₂ Analyzer	3	\$10,900	\$32,700.00	API, ESA, ML,TECO	UV fluorescence
2. PM ₁₀ Monitor	3	\$12,000	\$36,000.00	R&P,TECO, ESA, MetOne	Beta ray adsorption
3. NOx Analyzer	3	\$11,555	\$34,665.00	API,TECO, ML,ESA	Chemiluminescence
4. Ozone Analyzer	3	\$10,465	\$31,395.00	API,TECO	UV adsorption
5. CO Analyzer	3	\$10,400	\$31,200.00	API,TECO, ML	NDIR light adsorption

Item	Quantity	Unit price	Subtotal	Vender	Note
6. Toxics Analyzer	3	\$16,000	\$48,000.00	IMACC	GC
Meteorological Station	3	\$8,200	\$24,600.00	RM Young	
1. Cylinder gas samplers	30	\$300	\$9,000.00	API,TECO, ML	316 ss, volume=??
2. Gas sample line	6	\$150	\$900.00	API,TECO, ML	Length= One heated line
Air compressor	3	\$500	\$1,500.00	Sears, etc.	100 Psig, 8 gallon
1. Gas cylinders	15	\$250	\$3,750.00	API,TECO, ML	SO ₂ , N ₂ , O ₂ etc. 99.999% purity
2. Accessories for calibration system	3	\$500	\$1,500.00	API,TECO ML	
Computer	3	\$1300	\$3,900.00	Dell, IBM	P4, 256M, 40G, CDRW
Backup hard disk	3	\$200	\$600.00		40G
Generator	3	\$2500	\$7,500.00	Sears, etc.	10 kw Gasoline generator
Tool box	3	\$850	\$2,550.00	Sears, etc.	
Other accessories	3	\$1000	\$3,000.00		
Total			\$572,760.00		

2.6.4 Vendor Contact Information

- Industrial Monitor & Control Corp.
800 Paloma Drive, Suite 100
Round Rock, Texas 78664
(512) 341-8189 Telephone
(512) 341-8993 Fax
<http://www.imacc-instruments.com/index.html>
- Thermo Electron Air Quality
Main Office
27 Forge Parkway
Franklin, MA 02038
United States
Homepage/0,1285,156,00.html
Telephone: 866-282-0430 (toll free US)
Contact Information
Telephone: 508-520-0430

Fax: 508-520-1460

Email: customerservice@thermoei.com

http://www.thermo.com/eThermo/CDA/BU_Home/BU_Homepage/0,1285,156,00.html

<http://www.anderseninstruments.com>

- HORIBA INTERNATIONAL CORPORATION

17671 Armstrong Avenue,
Irvine, California 92614 U.S.A.

Tel: +1 949 250 4811

Fax: +1 949 250 0924

http://global.horiba.com/index_e.htm

-  **Met One Instruments, Inc.**

Corporate Sales & Service

1600 Washington Blvd.,

Grants Pass, Oregon 97526

Phone 541/471-7111, Fax 541/471-7116

Regional Service

3206 Main St., Suite 106,

Rowlett, Texas 75088

Phone 972/412-4747, Fax 972/412-4716

<http://www.metone.com/>

- Environics, Inc.

69 Industrial Park Road East

Tolland, CT 06084-2805 USA

Phone: (860) 872-1111

Fax: (860) 870-9333

Office Hours: 8 a.m. - 5 p.m. Eastern Time

E-mail: info@environics.com

Web Page: <http://www.environics.com>

- Teledyne-API

6565 Nancy Ridge Drive

San Diego, California 92121-2251

Phone: (858) 657-9800

Fax: (858) 657-9818

api-sales@teledyne.com

<http://www.teledyne-api.com/>

- Teledyne Monitor Labs, Inc.

Company Headquarters

76 Inverness Drive East

Englewood, CO 80112

Toll Free: 1-800-422-1499

Phone: 1-303-792-3300

Fax: 1-303-799-4853

<http://www.teledyne-ml.com/>

- Environnement S.A
111, Bd Robespierre - BP 4513
78304 Poissy Cedex
France
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Tel : 01.39.22.38.00
Fax : 01.39.65.38.08
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Fax : +33 1.39.65.38.08
Or by email
info@environnement-sa.com
<http://www.environnement-sa.com/index2.html>

- Rupprecht & Patashnick Co., Inc.
25 Corporate Circle
Albany, NY 12203 USA
Phone 518 452 0065
Fax 518 452 0067
E-mail info@rpco.com
<http://www.rpco.com/company/index.htm>

- Environmental Systems Corporation
200 Tech Center Drive
Knoxville, TN 37912
Phone 865 688-7900
Fax 865 687-8977
Email:escorp@envirosys.com
<http://www.envirosys.com/index.html>

- Industrial eAutomation Solutions
USA Headquarters
1320 Kemper Meadow Drive,
Suite 500,
Cincinnati, OH 45240
USA
Phone: 513-742-8895
Toll Free: 877-294-8989
Fax: 513-742-0554
E-mail: info@advantech.com
<http://www.advantech.com>

- R. M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA
Phone: 231-946-3980
Fax: 231-946-4772
E-mail: met.sales@youngusa.com
<http://www.youngusa.com/>

- TSI Incorporated
500 Cardigan Road
Shoreview, Minnesota
55126-3996
U.S.A.
Telephone:
Toll-free: 1-800-874-2811
Phone: 651-490-2811
Fax: 651-490-3824
E-mail: particle@tsi.com
<http://www.tsi.com/particle/homepage/particlehome.htm>

2.6.5 Recommendations

2.6.5.1 Automatic Air Monitoring Stations

Jiangsu Province has developed a substantial AAMS Network that has allowed the JPMEC to monitor the air quality within the province's key cities on a real-time basis. There are currently 87 automatic monitoring stations around the province. In analyzing the existing ambient air quality monitoring network and making recommendations for improvements and/or expansion of this network, it is clear that JPMEC and the respective EPBs in each of the provinces key cities have spent a lot of time and effort to site the monitoring stations in strategic locations, and have selected appropriate monitoring equipment to collect the data. While our consulting team is recommending additional monitoring stations in several of the key cities, the present network is providing reliable information within the areas being monitored, and is a very good base system.

Based on SEPA recommended monitoring network guidance, however, there are several cities that do not currently have an appropriate amount of air monitoring stations to adequately monitor the local air quality. SEPA's recommendations are based on the population of each city and an estimated minimum number of monitors needed to develop a reasonable ongoing picture of the air quality in the urban areas. A reasonable number of sites based on the area population have been included in this chapter.

Population alone, however, does not establish the full necessity of monitoring sites. In general, most of the key cities have an industrial area, or multiple industrial areas, which generate a concentrated stream of air pollutants. Those industrial areas, along with the increasing number of privately owned vehicles, contribute to ambient air quality deterioration in and around the cities. A good example of this can be seen in Xuzhou. During the site visits in Xuzhou, the Xuzhou EPB indicated that there is an ongoing effort to move the central business district (CBD) and more residential areas further south, away from the primary industrial area. The primary reason for the CBD relocation effort is due to its current location directly downwind of the industrial area and the air pollution generated by its facilities. Based on review of the Provincial Annual Environmental Overview, Xuzhou has the highest monitored pollutant load in the province. Xuzhou currently has three (3) ambient air quality monitoring stations, one of which is a background site. It is not possible to adequately monitor the air

quality for a city of approximately 9 million people with two monitoring stations, particularly with the heavy concentration of industrial facilities and a complete reliance on coal for electric power production. With this information, and a basic review of monitoring network criteria, it is highly recommended that further monitoring stations be added in the Xuzhou area. This will better quantify the overall pollutant loads in the area and could potentially help determine the most appropriate long-term location for business development if industrial pollution continues to be a factor in the process.

Table 2-16 summarizes the additional monitoring stations needed to complete the network in accordance with the SEPA guidelines. The additional monitors for Nanjing are based on the need to further delineate the impacts on local air quality from the Industrial Park north of the city. If these additional monitoring stations were installed, the province would have a network that meets the minimum recommended stations for each key city. The five other key cities not listed in this table (Changzhou, Nantong, Suzhou, Wuxi, and Yangzhou) all have monitoring networks that meet or exceed the recommended minimums.

Table 2-16 Recommended Additional Stations and Equipment for Jiangsu Province

City	Number of Monitoring Stations	Monitoring Equipment Required
Huai'an	1 Urban	SO ₂ , NO ₂ , PM ₁₀ , CO, Ozone (O ₃), Meteorological Parameters (MP)
Huai'an	3 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Lianyungang	3 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Nanjing	4 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Suqian	1 Urban	SO ₂ , NO ₂ , PM ₁₀ , CO, O ₃ , MP
Suqian	4 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Taizhou	1 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Xuzhou	1 Urban	SO ₂ , NO ₂ , PM ₁₀ , CO, O ₃ , MP
Xuzhou	3 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Yancheng	1 Urban	SO ₂ , NO ₂ , PM ₁₀ , CO, O ₃ , MP
Yancheng	2 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP
Zhenjiang	3 Industrial/Area	SO ₂ , NO ₂ , PM ₁₀ , MP

There are several ways to site ambient monitoring stations. The most effective way to do so is by incorporating a modeling analysis to verify that a selected location will provide reasonably accurate data based on the proposed purpose of the station. In order to perform air modeling for determining that the sites are reasonable and representative, however, there is a significant amount of information necessary to proceed. The air modeling effort requires full access to long term meteorological data, area wide emissions inventories and site-specific data to include in the model. This information was not readily available for the project, nor was a modeling study included in the scope of work. The current

scope of work was directed at evaluating the current monitoring stations and making recommendations on how to make the network better through upgrades at the existing sites and/or the addition of new sites.

Recommendations were made on upgrading the data management system to make it consistent throughout the province, and adding new monitoring stations to cover monitoring data gaps in several of the key cities. If Jiangsu Province plans to expand its monitoring network to site the new stations that have been recommended in this feasibility study, the actual siting of these monitoring stations would need to be addressed under a separate work order. The scope of work for siting should include a modeling analysis to help determine the most appropriate locations for monitoring stations based on the specific focus of the monitoring at each site (background, neighborhood, industrial, urban, or transport).

Air quality modeling for siting monitoring stations would need to be done on a city-by-city basis and would likely take 4-6 months to complete for the entire province. The recommended models for siting stations would be use of a combination of stationary source and mobile source models to allow for including both industrial and transportation related emissions to be factored. U.S. EPA's Industrial Source Complex Version 3 (ISC3) Model and the Multi-scale Motor Vehicles & Equipment Emission System (MOVES) Model would be the most appropriate models to utilize for this study.

It also should be mentioned that the addition of PM_{2.5} monitors at each of the stations was only briefly discussed in this study. PM_{2.5} is not a regulated pollutant in China currently; however, there is some discussion about expanding the network to begin monitoring to establish a baseline. The capital cost for the monitoring equipment and collection system is approximately \$17,000 per station or \$1,477,000 U.S. if each of the 87 existing stations were to add this pollutant.

2.6.5.2 Data Management System

JPEMC's existing DMS meets the general needs of the province for collecting, analyzing and presenting the information collected at each of the monitoring stations. Due to the potential for expanding the network and eventually adding other pollutants and parameters, and the variety of data loggers and DAS's across the province, however, it is recommended that JPEMC consider integrating an advanced DMS and establish minimum standards for the data loggers and DAS's at each site to increase the functionality of the system and allow JPEMC to concentrate on presenting and utilizing the data instead of continually having to QA/QC it. Having an integrated DMS will also increase the quality of the data due to it being a single system and allow the province to develop a training program for ensuring the monitoring network (monitors and DAS) is being maintained the same way at each site.

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Chapter III

CHAPTER III JIANGSU AUTOMATIC WATER MONITORING

3.1 Background

3.1.1 General Introduction

Jiangsu is a rich industrial and economic developed province in China. High economic growth in the province during the past two decades since China implemented an open-market policy has brought a rapid development of industries; mainly in the machinery, paper-making and chemical industrial sectors. This fast economic development has had a serious impact on water environment. In particular, large quantities of pollutants discharged from factories without being properly treated have resulted in serious water pollution in rivers, lakes, canals and coastal water areas. Furthermore, economic growth has accelerated mass consumption in life styles, which has resulted in a sharp increase of domestic pollutants. A sharp increase in the pollutant load resulted in various types of water environmental damage in many areas of the province.

Under these circumstances, effective and reliable monitoring of surface water as well as municipal and industrial wastewater discharge sources is the most crucial step toward implementing effective water protection and restoration plan by the Jiangsu Environmental Protection Department (JEPD).

As one of the leaders in China's environmental monitoring field, the JPEMC has a basic water monitoring system, but compared with that in developed countries as well as considering its economic growth and the condition of water pollution, the system is still inadequate; thus it does not fit in with the needs of the present or future social and economic development. At present, the number of monitoring sites, the monitoring parameters and frequency, as well as the data analysis and transmission can not meet the requirements for total discharge load control and the social-economic development plan.

The JEPD is in the process of developing and enhancing its automatic and mobile water quality monitoring and data acquiring system. It is planned that during the period from 2000 to 2005, 38 (will expand further to 50) automatic water quality monitoring stations (AWMSs) and three (3) mobile monitoring vehicles will be built or purchased for monitoring water qualities of major water systems as well as important water supply sources and some key industrial pollution sources.

3.1.2 Regulatory Review

The Law of the People's Republic of China on Water Pollution Prevention and Control (also known as the *Water Pollution Control Law*) was promulgated on May 11, 1984 and amended on May 15, 1996. *The Water Pollution Control Law* is the principal legislation to battle water pollution problems in China. It defines the role and responsibility for government agencies relevant to the implementation and enforcement of the law. There is also the *Law of the People's Republic of China on Environment Impact Assessment* which was adopted October 28, 2002 and became effective September 1, 2003.

Guidelines on Implementation of the Water Pollution Control Law was issued and enacted on March 20, 2000, to facilitate the implementation of the law. The guidelines provide details on how to implement the law to prevent the surface water and ground water from polluting. The guidelines also set detailed penalties applicable to those responsible for polluting the water.

Water Pollution Monitoring Requirements

Technical Specifications of Surface Water and Wastewater Monitoring (HJ/T 91-2002) and *Technical Specifications of Wastewater Total Discharge Monitoring (HJ/T 92-2002)* were issued as recommended industrial standards and became effective on January 1, 2003. The issuance of the two specifications is also to facilitate the implementation of the *Water Pollution Control Law*, and to better protect human health and preserve water resources. They also provide authoritative technical reference to local EPDs and various agencies in their monitoring works.

National Water Quality Standards

National water quality standards such as *Environment Quality Standard for Surface Water (GB3838-2002)*, *Fishery Water Quality Standards (GB11607-89)*, and *Agriculture Irrigation Water Quality Standards (GB5084-92)* have been formulated to ensure the water quality for various uses.

The *Integrated Wastewater Discharge Standard (GB8978-1996)* stipulates discharge limits and implementation requirements for 69 water pollutants. This comprehensive standard applies to all water pollutant producers and discharger including institutions and private businesses. In the case where the comprehensive standard and a source-specific standard cannot be met simultaneously, all water pollutant sources must comply with the comprehensive standard.

Recommended methods for monitoring and analysis of the main parameters indicating the water quality are also stipulated in the standard. There are also other source-specific water discharge standards such as:

- The *Discharge Standard of Water Pollutants from Petroleum Refinery (GB3551-83)*;
- The *Discharge Standard of Water Pollutants from Hospitals (GBJ48-83)*;
- The *Discharge Standard of Water Pollutants from Petrochemical Industries (GB4281-84)*;
- The *Discharge Standard of Water Pollutants from Steel Industries (GB13456-92)*; and
- The *Discharge Standard of Water Pollutants from Municipal Wastewater Treatment Plant (GB18918-2002)*.

Other important laws that affect water pollution monitoring are:

- The *Determination of Water Temperature: Thermometer or Reversing Thermometer Method (GB/T 13195-91)*;
- The *Determination of Water Turbidity (GB/T 13200-91)*;

- *The Determination of Total Organic Carbon in Water (HJ/T 71-2001);*
- *The Determination of pH in Water (HJ/T71-2001);*
- *The Determination of NH₃-N in Water (GB 7479-87);*
- *The Determination of COD_{Mn} in Water (GB 11892-89); and*
- *The Guidance on Water Sampling Techniques (GB 12998-91).*

3.1.3 Geography

Jiangsu Province lies in the center of China's East Coast with a total land coverage of 102,600 km² occupying 1.06% of the whole country's territory. The landform of the province is mainly plain with numerous rivers, lakes and canals. The coastline of the province is 1,000 km long.

The province has a rich and extremely complicated water system. All of the surface waters in Jiangsu are classified into three water systems: the Yangtze River, the Huai River and the Shu River. The Yangtze River flows over 400 km from east to west within the province. The section of the river from Nanjing to Zhenjiang is about one (1) to two (2) km wide with the widest section being more than 18 km between Nantong and the estuary. The Huai River flows into Hongze Lake. The Grand Canal crosses over 690 km from south to north. The Qihuai River is in the southwest. The North Jiangsu Irrigation Collecting Channel, the Xinshu River, and Tongyang River are all in the northern area of the province. Tai Lake and Hongze Lake are listed as two of China's "Five Great Freshwater Lakes"; they are 2,425km² and 1,960km² in area, respectively. Two other important lakes in the province are the Yangcheng and Gaoyou.

3.2 The Conditions of Water Quality in the Province

3.2.1 The Huai River

According to the Jiangsu Provincial Environmental Bulletin in 2002, the overall water quality of mainstream of the Huai River is Grade III. The main pollutants were ammonia nitrogen, potassium permanganate, petroleum and BOD, the contributions of which for pollution were 24.9%, 24.3%, 15.7% and 15.6% respectively.

Among the 18 water monitoring points on the 14 branches of the Huai River, Grade II-III account for 27.8%, Grade IV accounts for 27.8%, Grade V accounts for 16.7%, and worse than Grade V accounts for 27.8% (see Figure 3-1). The major pollution indicators are ammonia nitrogen, potassium permanganate and petroleum. Compared with year 2001, the regulatory compliance rate for attaining the standard for Grade II-IV declined from 66.7% to 55.6%.

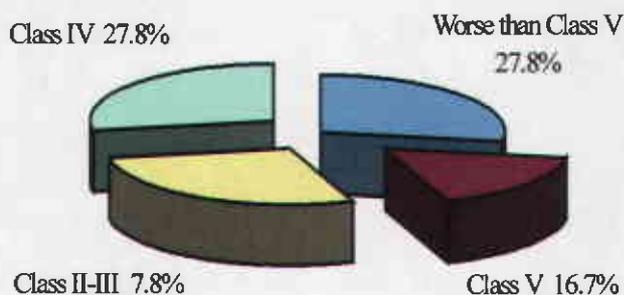


Figure 3-1 Percentage of Water Class in the Huai River

3.2.2 Tai Lake

Tai Lake is located in the center of the Yangtze Delta; it is the third largest freshwater lake in China. The lake plays a large role in living water supply, industry and agriculture in the basin. Since the 1980s, the lake's water pollution has been serious, especially with organic pollution. The condition of eutrophication remains at a medium level.

Of 96 water-monitoring points, there are 20 in the lake, 21 in the key rivers that surrounding the lake and 45 in the waters at the administrative borders of the lake. Compared with the year 2001, the water quality remains almost the same.

Due to the pollution of total nitrogen, the overall water quality of the lake is worse than Grade V. The central and eastern parts of the lake are Grade IV-V, and other parts are worse than Grade V. Among the major pollution indicators, total nitrogen rose 12% compared with that in the year 2001, but the potassium permanganate and the total phosphorus reduced 6.6% and 7.0%, respectively, when compared with that in the year 2001.

Among the 20 water monitoring sections on the key rivers surrounding the lake, Grade III accounts for 35.0%, Grade IV accounts for 15.0%, Grade V accounts for 5.0%, and worse than Grade V accounts for 45.0% (see Figure 3-2). The major pollution indicators are ammonia nitrogen and potassium permanganate. Compared with the year 2001, the regulatory compliance rate for attaining the standard for Grade II-IV declined from 45.0% to 30.0%.

In the 45 water monitoring sections at the administrative borders, Grade III accounts for 13.3%, Grade IV accounts for 33.3%, Grade V accounts for 15.6%, and worse than Grade V accounts for 37.8%. Again, the major pollution indicators are ammonia nitrogen and potassium permanganate. Compared with the year 2001, the regulatory compliance rate for attaining the standard for Grade II-IV at the provincial borders rose from 45.5% to 54.5%, at the municipal borders rose from 20% to 40%.

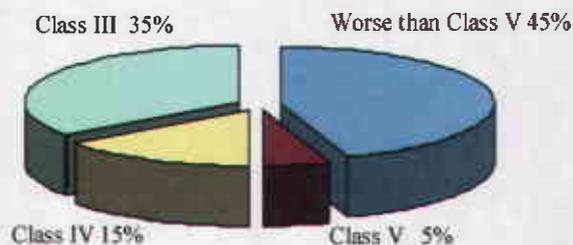


Figure 3-2 Percentage of Water Class in the Rivers Surrounding Tai Lake

3.2.3 The Jiangsu Section of the Yangtze River

The Yangtze River basin covers eight (8) municipalities of Jiangsu Province. The area of the basin is 38,700 km² with the population of 30 millions.

The section of the Yangtze River in the province is 450km long. The average flow is 30,800m³/s. along the river, a great quantity of industrial and domestic wastewater as well as several polluted rivers converged into the river, which formed a so called "shore-side pollution belt".

In the 11 water monitoring points along the river, the water quality of most points are Grade II, except the points of Xiaoligang and Yanggang, which are Grade III. Compared with the year 2001, the regulatory compliance rate for attaining the standard of Grade II at the monitoring points reduced from 100.0% to 81.8.5%.



Figure 3-3 Percentage of Water Class in the Branches of the Yangtze River

Among the 29 water monitoring and control sections on the waters converging to the river, Grade III accounts for 24.1%, Grade IV accounts for 27.6%, Grade V accounts for 20.7%, and worse than Grade V accounts for 27.6% (see above – Figure 3-3). The major pollution indicator is ammonia nitrogen.

3.2.4 The Grant Canal

The Beijing-Hangzhou Grant Canal flows through eight (8) cities, 18 counties from north to south in the province. It is an important water source for agriculture irrigation and industries, as well as being a water carriage channel and the water sources of water supply for some cities and counties. But the water quality is seriously polluted because large amounts of sewage along the Canal are being discharged.

Among the eight (8) water monitoring sections of the cities along the Canal, the water quality of the Zhenjiang section is Grade III, the sections of Suqian and

Huai'an are Grade IV, the Yangzhou Section is Grade V, and the sections of Suzhou, Changzhou and Wuxi are worse than Grade V. The major pollution indicators are ammonia nitrogen, dissolved oxygen (DO), volatile phenol and BOD.

3.2.5 Other Main Lakes

According to the monitoring data in 2002, the water quality of the Hongze Lake is Grade V; the Yangcheng, Zhongtai and the Ge Lakes are worse than Grade V; and the Luoma Lake is Grade IV. The major pollution indicators are total phosphorus, total nitrogen and index of potassium permanganate.

3.2.6 Industrial Discharge and Treatment

According to the China Environment Report in 2002 published by the SEPA, the total annual industrial wastewater discharge load was 2.627 billion tons in the province. Table 3-1 shows the industrial wastewater discharge in the province.

A Pesticide Polluted Channel



An Industrial Wastewater Discharge Source

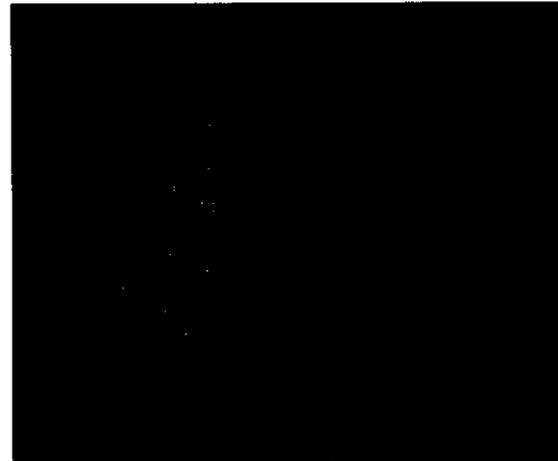


Table 3-1 Industrial Wastewater Discharges in Jiangsu Province

		Unit (10,000ton/year)
Total Amount of Discharge of Industrial Wastewater		262,714.79
Pollutants Discharged in Industrial Wastewater	Hg	0.025
	Cd	0.31
	Cr ⁶⁺	10.91
	Pb	26.54
	As	7.67
	Volatile phenol	69.14
	CN ⁻	59.27
	COD	302261.36
	Petroleum	1831.53
	NH ₃ -N	17621.67

3.2.7 Water Supply and Sources

Surface water is the major water supply source in Jiangsu Province. By 2002, there were 25 municipal water supply treatment plants in the 13 municipalities of the province; the total capacity for treatment is 1,4899 billion m³/year, which is about 85% of the total amount of water supply in the 13 cities. The cities of Nanjing, Nantong, Zhenjiang, Taizhou and Changzhou take water from the Yangtze River as their major water sources; the total amount of water taken from the Yangtze River in 2002 was 713.353 million m³. Tai Lake, Yangcheng Lake, and the Beijing-Hangzhou Great Cannel are also major water sources for the province. Table 3-2 describes the water supply capacities and water sources for the province.

Table 3-2 Water Supply Capacities and Water Sources in the Municipalities

City	No. of Water Supply Treatment Plant	Total Amount of Annual Water Supply (km ³)	Water Source
Nanjing	3	360,298	Yangtze River
Wuxi	2	246,662	Tai Lake
Xuzhou	1	31,745	Great Cannel
Changzhou	1	101,300	Yangtze River
Suzhou	3	195,697	Tai Lake, Yangcheng Lake
Nantong	4	137,255	Yangtze River
Lianyungang	2	60,537	Qiangwei River
Huai'an	2	45,251	Abandoned Yellow River
Yancheng	1	49,992	Xinyanggang Stream
Yangzhou	2	128,104	Liaojia Channel, Yangtze River
Zhenjiang	1	78,000	Yangtze River
Taizhou	2	38,503	Yangtze River, Nanguan River
Suqian	1	16,560	Great Cannel
Total	25	1,489,906	

Among the 25 water supply sources, 12 failed to meet the water standard of Grade II in the "Environmental Quality Standard for Surface Water, GB 3838-2002" in 2002. The major pollutants are ammonia nitrogen, DO, potassium permanganate index, fecal coliform, petroleum and BOD.

3.3 Evaluation and Suggestions for the Existing Water Monitoring System

The JPEMC as well as the municipal environmental monitoring laboratories of the thirteen municipalities and the county level monitoring laboratories are responsible for monitoring surface water quality from the major rivers, streams, lakes, and canals in the province. In the year 2002, they monitored 1,243 sections of the 394 rivers, streams and canals, and 232 monitoring points of the lakes and reservoirs.

3.3.1 The Existing Automatic Water Monitoring Stations

By the end of June 2003, there were 21 existing automatic water monitoring stations in the province. Table 3-3 presents the locations, monitoring parameters and operating units for the stations.

Table 3-3 Existing Automatic Water Monitoring Stations

No.	Name & Location Station	Management	Owner	Monitoring Parameter
1	Tuqiao	Nanjing	Province	pH, DO, Turbidity, Conductivity, Temperature
2	Wumu	Huishan	Province	pH, DO, Turbidity, Conductivity, Temperature
3	Baita	Jintan	Province	pH, DO, Turbidity, Conductivity, Temperature
4	Taixi	Taizhou	Province	pH, DO, Turbidity, Conductivity, Temperature
5	Zhoujia Wharf	Zhangjiagang	Province	pH, DO, Turbidity, Conductivity, Temperature
6	Jiuli	Changzhou	Province	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, COD _{Mn} , TOC, Volatile phenol, Petroleum, TP, Fecal coliform
7	Xiaowuchang	Lianyungang	Province	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, COD _{Mn} , TOC, Volatile phenol, Petroleum, TP
8	Zhangguo	Nantong	Province	pH, DO, Turbidity, Conductivity, Temperature
9	Suqianzha	Suqian	Province	pH, DO, Turbidity, Conductivity, Temperature
10	Xiaodaqiao	Xiaodaqiao	Province	pH, DO, Turbidity, Conductivity, Temperature
11	Pingqiao	Huai'an	Province	pH, DO, Turbidity, Conductivity, Temperature
12	Taidong	Yancheng	Province	pH, DO, Turbidity, Conductivity, Temperature
13	Wangting	Suzhou	Province	pH, DO, Turbidity, Conductivity, Temperature
14	Panjiaba	Wuxi	Province	pH, DO, Turbidity, Conductivity,

No.	Name & Location Station	Management	Owner	Monitoring Parameter
				Temperature
15	Yuyangshan - Eastern Tai Lake	Suzhou	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, TOC,
16	Lanshanzui - Western Tai Lake	Wuxi	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, TOC
17	Jiajiang	Yangzhou	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, COD _{Mn} ,
18	Linshan	Nanjing	Nation	pH, DO, Turbidity, Conductivity, Temperature, COD _{Mn}
19	Aishanxi Bridge	Pizhou	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, COD _{Mn} ,
20	Huihe Bridge	Xuyi	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, TOC
21	Shazhu - Northern Tai Lake Lake)	Wuxi	Nation	pH, DO, Turbidity, Conductivity, Temperature, NH ₃ -N, TOC

Seven stations, (No.15 to No.21) in the above table, were built by the National Environmental Monitoring Center and are operated by each municipal environmental monitoring center on behalf of SEPA. They monitor the water qualities across the provincial boundaries.

Table 3-4 lays out the monitoring parameters and the monitoring methods for the existing automatic water monitoring stations.

Table 3-4 Monitoring Parameters and Methods of the Existing AWMS

Monitoring Parameter	Monitoring Method
pH	Glass Electrode Method
Conductivity	Conductivity Electrode Method
Turbidity	Nephelometric Method
Dissolved Oxygen	Amperometric Method (temperature-compensated polarographic membrane-type sensor)
Temperature	Thermistor Method
COD _{Mn}	Potassium Permanganate Oxidizing Method
NH ₃ -N	Ammonia-selective Electrode Method
Total Phosphorus (TP)	Persulfate Digestion Method
Total Nitrogen (TN)	Persulfate Digestion-UV Spectrophotometric Method
TOC	Persulfate -Ultraviolet Oxidation NDIR Method
Petroleum Hydrocarbons	Infrared Spectrophotometric Method
Volatile Phenols	Distilling-Spectrophotometric Method

3.3.2 Surface Water Sampling Methodology and Frequency in the Province

Surface Water sampling methodology and frequencies vary depending on the type of station, the function of water bodies, the monitoring parameters, and the purposes of the monitoring. The current sampling frequencies in the province are hourly, monthly, bi-monthly, or during dry/average/wet seasons as summarized in Table 3-5.

Table 3-5 Surface Water Sampling Frequencies in the Province

Water Body	Sampling Frequency
Drinking water sources	Monthly
Jiangsu section of the Yangtze River	Bi-monthly (odd months, sampling during rising tide and falling tide separately)
The Great Canal, the Mainstream of the Huai River, and the Northern General Irrigation Channel	Bi-monthly (odd months)
Main Rivers and Tourist Water Bodies	Bi-monthly (odd months)
Tai Lake, Hongze Lake, Xuanwu Lake, Yunlong Lake, Souxi Lake and the rivers surrounding the lakes.	Bi-monthly (odd months)
The clean lakes that are larger than 100km ² in area or the polluted lakes that are larger than 50km ² in area	Three times per year (dry, average, and wet seasons)
Other lakes	Twice a year (dry and wet seasons)

The method of most samplings in the province is "manual grab" samples. A manual grab sample is a single sample collected at a specific spot at a site over a short period of time (typically seconds or minutes). Thus, they represent a "snapshot" in both space and time of a sampling area because water quality changes over time; the representativeness of manual grab sampling is limited.

The sampling method is generally to collect a water sample at 0.5m below water surface. Manual sampling is typically achieved from the top of a bridge crossing or with vessels, while automatic sampling is conducted using a stationary automatic sampling station on a pier extending approximately 40 meters into the river.

3.3.3 Water Monitoring Parameters

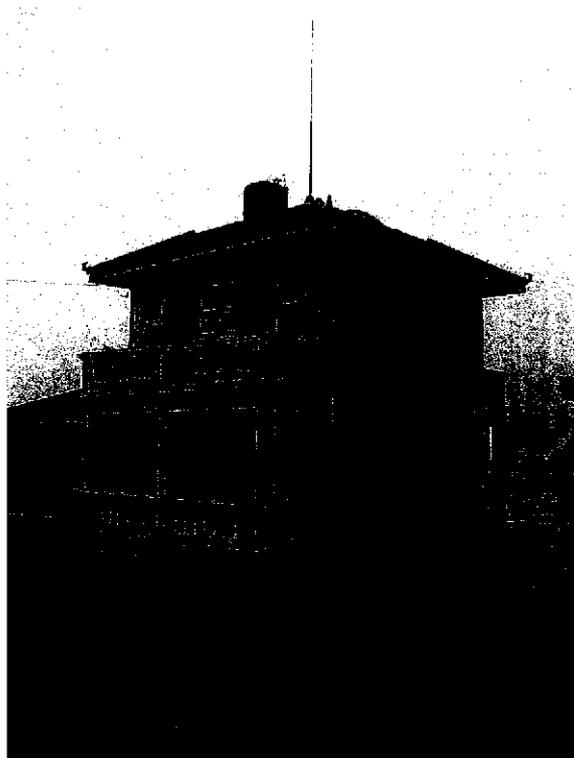
In accordance with the new Chinese National Surface Water Quality Standard (GB3838-2002), the functionality of the water body and its corresponding numerical objectives are the basis for water quality assessment. Therefore, proper selection of monitoring parameters is essential in determining whether a water body meets the designated beneficial use. The currently effective standards, as shown in Table 3-6 and Table 3-7, set numerical water quality objectives for five water body classifications (Class I through V) in China.

- Class I water is the headstream of rivers and national natural conservation zones.
- Class II-Class III waters are suitable to be used as drinking water resources and habitat and spawning for aquatic living beings.
- Class IV waters can be considered for industrial processing uses.
- Class V waters are suitable for agricultural or landscaping beneficial uses.

The JPEMC as well as the municipal environmental monitoring centers conduct routine and scheduled monitoring of the 24 physical, chemical and microbiological water quality parameters for the surface water bodies. The maximum monitoring capacities of the JPEMC and most municipal environmental monitoring centers are 178 parameters including physical properties, metals, inorganic nonmetallic constituents, organic constituents, toxicity, radioactivity and microbiological examinations.

The instruments are being used for determination of the above parameters in the laboratories are atomic absorption spectrophotometer, gas chromatography, liquid chromatography, GC/MS, ion chromatography, UV spectrometer, infrared spectrometer and electrochemical analyzers, etc.

The Existing Sanjiangying Automatic Water Monitoring Station in the City of Yangzhou



Left: Sanjiangying Water Monitoring Station in the city of Yangzhou
Right: Automatic Monitoring Instrument for five parameters



Floating Device for sampling pump

Table 3-6 Water Quality Standards for Surface Water (GB 3838-2002)
(Unit: mg/L unless specified otherwise)

No.	Parameters	Standard of Water Class				
		I	II	III	IV	V
1	Temperature	Maximum weekly average temperature increase due to human activities: $\leq 1^{\circ}\text{C}$; Maximum weekly average temperature decrease due to human activities: $\leq 2^{\circ}\text{C}$				
2	pH	6-9				
3	Dissolved Oxygen	>90% sat. or 7.5	6	5	3	2
4	Permanganate (KMnO ₄) Index	2	4	8	10	15
5	COD _{Cr}	15	15	20	30	40
6	BOD ₅	3	3	4	6	10
7	Ammonium Nitrogen (NH ₃ -N)	0.5	0.5	0.5	1	1.5
8	Total Phosphorus (TP)	0.02	0.02	0.02	0.2	0.2
8	Total Phosphorus (TP, lake & reservoir)	0.01	0.025	0.05	0.1	0.2
9	Total Nitrogen (TN, lake and reservoir)	0.2	0.5	1.0	1.5	2.0
10	Copper	0.01	1	1	1	1
11	Zinc	0.05	1	1	2	2
12	Fluorides	1	1	1	1.5	1.5

No.	Parameters	Standard of Water Class				
		I	II	III	IV	V
13	Selenium	0.01	0.01	0.01	0.02	0.02
14	Arsenic	0.05	0.05	0.05	0.1	0.1
15	Mercury	0.00005	0.00005	0.0001	0.001	0.001
16	Cadmium	0.001	0.005	0.005	0.005	0.01
17	Chromium (VI)	0.01	0.05	0.05	0.05	0.1
18	Lead	0.01	0.05	0.05	0.05	0.1
19	Cyanide	0.005	0.05	0.2	0.2	0.2
20	Phenols	0.002	0.002	0.005	0.01	0.1
21	Petroleum Hydrocarbons	0.05	0.05	0.05	0.5	1
22	Anionic Surfactants	0.2	0.2	0.2	0.3	0.3
23	Sulfide	0.05	0.1	0.2	0.5	1
24	Fecal E. Coliform (no/L)	200	1000	2000	5000	10000

Table 3-7 Supplementary Parameters for Drinking Water Source (GB 3838-2002)

NO.	Parameters	Standard (unit: mg/L)
1	Sulfate	250
2	Chloride	250
3	Nitrate (NO ₃ -N)	10
4	Iron	0.3
5	Manganese	0.1

3.3.4 Water Monitoring Data Evaluations

Water monitoring data can be used in several different ways to determine its significance. Comparison of water monitoring parameters from different sampling events shows changes of water quality with respect to temperature, flow, and other factors. When accumulating sufficient amounts of data, a trend can be developed for a particular monitoring parameter, which allows advanced planning or preventive measures to be undertaken to mitigate the pollutants.

Arithmetic means of the annual monitoring data from a particular water body are being used to compare with numerical water quality objectives designated for its beneficial use to determine presence or absence of water quality exceedances as well as potential sources of pollutants. The comparisons could also be made between different years to establish trends for the pollutants. These types of

comparisons can generally be found in the Jiangsu Environmental Annual Reports.

In Jiangsu Province, the key monitoring parameters (combined pollution index, P) are also being used to describe condition of water pollution, the key monitoring parameters include Permanganate Index, BOD₅, COD_{Cr}, NH₃-N, petroleum hydrocarbons, phenols, total P, total N and total Hg.

3.3.5 Suggestions for the Current Water Monitoring System

Based on the review and inspection of the existing AWMSs as well as the lab water monitoring programs and sampling procedure conducted by the JP EMC and the municipal monitoring centers, the consulting team has the following assessments and suggestions.

(1) A Detailed QA/QC Manual for Operating AWMSs should be Formulated:

The instruments in the existing AWMSs are generally good, but the operating documents are too simple; only manufacture's manuals and a simple on-wall regulation with several items is available and these are not enough. A detailed operational manual for AWMS is the basis for obtaining accurate data. Based on these circumstances, we suggest that the JP EMC work out detailed operating manuals for each of the existing station, which would include the following:

- Monitoring Methods
- Frequencies and Methods for Calibration
- Frequencies and Methods for Maintenance
- Trouble-shooting;
- Data Quality Objective and QA/QC Procedure;
- Data Reporting and Regulation for Significant Figures;
- Preparation of Testing Water and Reagents;
- Training and Qualification of Operation Personnel;
- Health and Safety;
- Budget for Operation, Calibration and Maintenance;
- Accessories and Spare Parts Storage and Reserves;
- Waste Liquids Minimization, Treatment and Disposal; etc.

(2) The Frequencies of Sampling and Monitoring are Insufficient

As a populous and industrial province in China with complicated and polluted water bodies, the current manual sampling and monitoring frequencies are scarce. As shown in the Table 3-6, the sampling/monitoring frequencies for the major rivers, lakes and water supply sources are monthly, bi-monthly or even only two to three times per year. Sampling/monitoring frequency is an important step to reach a reliable monitoring data; in general, sampling/ monitoring frequency depends on numerous facts, such as condition of pollution, parameters to be determined, functionality of the water body, purpose of monitoring, history of unsatisfactory samples and sampling method, etc.

According to usual practice in some developed countries, for the parameters which are related to human health, such as Cadmium, Total Cyanide, Lead, Arsenic, Mercury, PCB, Thiobencarb, Benzene, etc. the sampling/monitoring frequencies should be conducted at least once a month.

For the parameters which are related to living environment, such as pH, DO, BOD₅, COD_{Mn}, Coliform, TN, TP, etc. the sampling/monitoring frequencies should be conducted more than once a month. As a rule, water samples should be collected four times a day.

Base on the current water monitoring program in the province, we strongly believe that the current sampling and monitoring frequencies are obviously insufficient to reach any reasonable desired level of confidence.

(3) In-situ Monitoring Method Should be Used for Determination of DO and Temperature:

The flow-through monitoring methods have been used for monitoring DO and temperature in the existing AWMSs. These parameters should only be monitored under an in-situ condition (sensors are set directly in the water) since their results are likely to change after the water has been pumped from the source. Other parameters such as pH, conductivity, and turbidity can be monitored with either in-situ or flow-through monitors. The JPEMC should review its monitoring configuration at the existing AWMSs and make appropriate adjustments for the measurements.

(4) Recommendation of Using Automatic Water Samplers:

With the insufficient numbers of the AWMSs and the limited automatic monitoring parameters, the province relies heavily on manual sampling (grab samples) to assess the trend and change of water quality in its major rivers and lakes. A grab sample can represent only the composition of its source at the time and place of collection. However, when a source is known to be relatively constant in composition over the extended time or over substantial distances in all directions, then the grab sample may present a longer time period and/or a large volume than the specific time and place at which it was collected. In such circumstances, a water source may be represented by a grab sample. When a source is known to vary with time, composite-sampling method should be used. Composite-samples can be obtained by combining porting of multiple grab samples or by using specially designed automatic water samplers.

Many commercial water automatic samplers with reasonable prices are available in the States; they are computerized and programmable, some of which are equipped with optional detectors, such as pH, DO, temperature, flow meter and conductivity, etc. The brief principle is as follow: Sequential (time) composite-samples are collected by using continuous, constant sample pumping or by mixing equal water volumes collected at regular time interval. Flow-proportion composites are collected by continuous pumping at a rate proportion to the flow, by mixing equal volumes of water collected at time intervals that are inversely proportional to the volume of flow, or by mixing volumes of water proportional to the flow collected during or at regular time intervals.

The automatic sampling can eliminate human errors in manual sampling, can reduce labor costs, and may provide the representative and mean water quality for variable water bodies. Since rivers and lakes in the province of Jiangsu change over time, the discharge points are numerous and complicated, and the sampling frequencies are scarce (monthly or bi-monthly). We strongly recommend that the JPEMC as well as the municipal and county-level monitoring centers use automatic water samplers to collect water samplers in the future. (An auto sampler is also an essential tool for a monitoring vehicle, which will be discussed in detail in the section below.)

(5) Recommendation of Using Instruments with Multiparameter Combined Water Electrodes:

Nowadays, there is increasing interest in the States to use multiparameter electrodes integrated in a compact unit (or "Sonde") to conduct manually or continuous monitoring of water quality parameters. Several reasons for using the Sonde are: (1) the shift of monitoring focus on trace priority pollutants that can not be monitored onsite or in-situ; (2) monitoring of the traditional organic indicators such as COD_{Mn}, BOD₅, or TOC onsite using automatic flow-through monitors is expensive and no longer appropriate to indicate actual water quality; and (3) operation and maintenance issues related to the automatic monitors. Sonde has the ability to conduct real-time measurements of DO, pH, conductivity, ORP, turbidity, temperature, nitrate, ammonium, chloride, depths and pressure, etc.

Additionally, the multiparameter water analyzers can be completely self-sufficient for operation (with internal data logger and battery) in the field with both remote telemetric or manual data transferring capability. The cost for a Sonde is extremely affordable comparing to other flow-through type monitors.

Several U.S. vendors, such as YSI, In-Situ, or HydroLab offer similar, but slightly different units that can be tailored to the specific needs of the client. For example, an instrument manufactured by YSI, the quotation of which is about 1,500 US dollars, has the following features and specifications:

- Measure salinity, conductivity, DO and temperature with one instrument;
- Build-in chamber provides a water-saturated air environment for convenient calibration;
- Internal memory stores up to 50 data sets for simplified data collection;
- Single calibration adjusts instrument for both mg/L and % air saturation measurements;
- Meters are factory-calibrated for conductivity; and
- All monitoring parameters are automatic compensation.

However, automatic flow-through monitors can still play an important role for determination of some parameters by using AutoChem methods, such as COD, BOD₅, ammonium nitrogen, etc. But for some points where only the sensor-monitoring-parameters need to be monitored, we recommend the JPEMC consider using self-contained multiparameter instruments for its continuous and/or manual water monitoring.

(6) Coordination and Cooperation between Different Government Entities

There are several water monitoring stations in the province that are under the jurisdiction of the Provincial Hydraulic Bureau (PHB). Unfortunately, at this time the data and the facilities of PBH are not shared with JPEMC. The provincial government should clearly define responsibility and jurisdiction of various government entities, minimize redundancy or the overlap of functions and operative initiatives, and improve inter-agency cooperation for facilities, data or information sharing.

For example, selection of appropriate water quality sampling locations in many cases requiring similar conditions as hydraulic stations. Flow rate, velocity, the shape of the river, and configurations of the riverbed all dictate the flow pattern and level of mixing. Therefore, arrangement or inter-office agreement should be made with the PHB to allow proper access to all necessary hydraulic information/records by the JEPD personnel. Similarly, most of the wastewater monitoring data is currently provided by the plant operations. Automatic on-line monitoring capability and procedures or access for compliance sampling by JPEMC needs to be established to ensure full compliance of the effluent quality with discharge standards.

(7) Build More AWMSs at the Drinking Water Sources

The most important sites of AWMSs are those for monitoring drinking water sources. According to the Jiangsu Province Yearbook (2002), the drinking water for about 11 million urban persons in the 13 cities is taken from the water sources.

The health of people depends, to a great extent, on the quality of drinking water supply. Drinking water quality is largely determined by sources of incoming water. The majority of urban and some suburban residents in Jiangsu Province now have access to tap water, but the current water treatment process in most of the treatment plants is conventional, which can not remove toxic and even carcinogenic compounds, especially organic chemicals and heavy metals. The large portion of the rural population in the province now still fetch water directly from rivers, lakes, ponds, or wells, with little or no treatment at all. Recent epidemiological studies suggest that exposure to organic and inorganic chemicals in drinking water may significantly contribute to chronic disease. Mortality rate of malignant cancer in the province is 50% higher than the average in the Nation. Liver and stomach cancers are the leading causes of cancer mortality in the province. Many studies in China and abroad have shown a strong association between drinking water pollution and cancer incidence and mortality. So the problem of "Drinking Water and Health" is a critical issue for the province and the country.

The water qualities critically affect public health. But among the 21 existing AWMSs, the sites for monitoring drinking water sources are insufficient. We strongly suggest that Jiangsu should set up more AWMSs at the drinking water sources of the cities, at least one for each, the more the better.

Figure 3-4 shows the planned locations of the 13 AWMS sites for monitoring the drinking water sources.

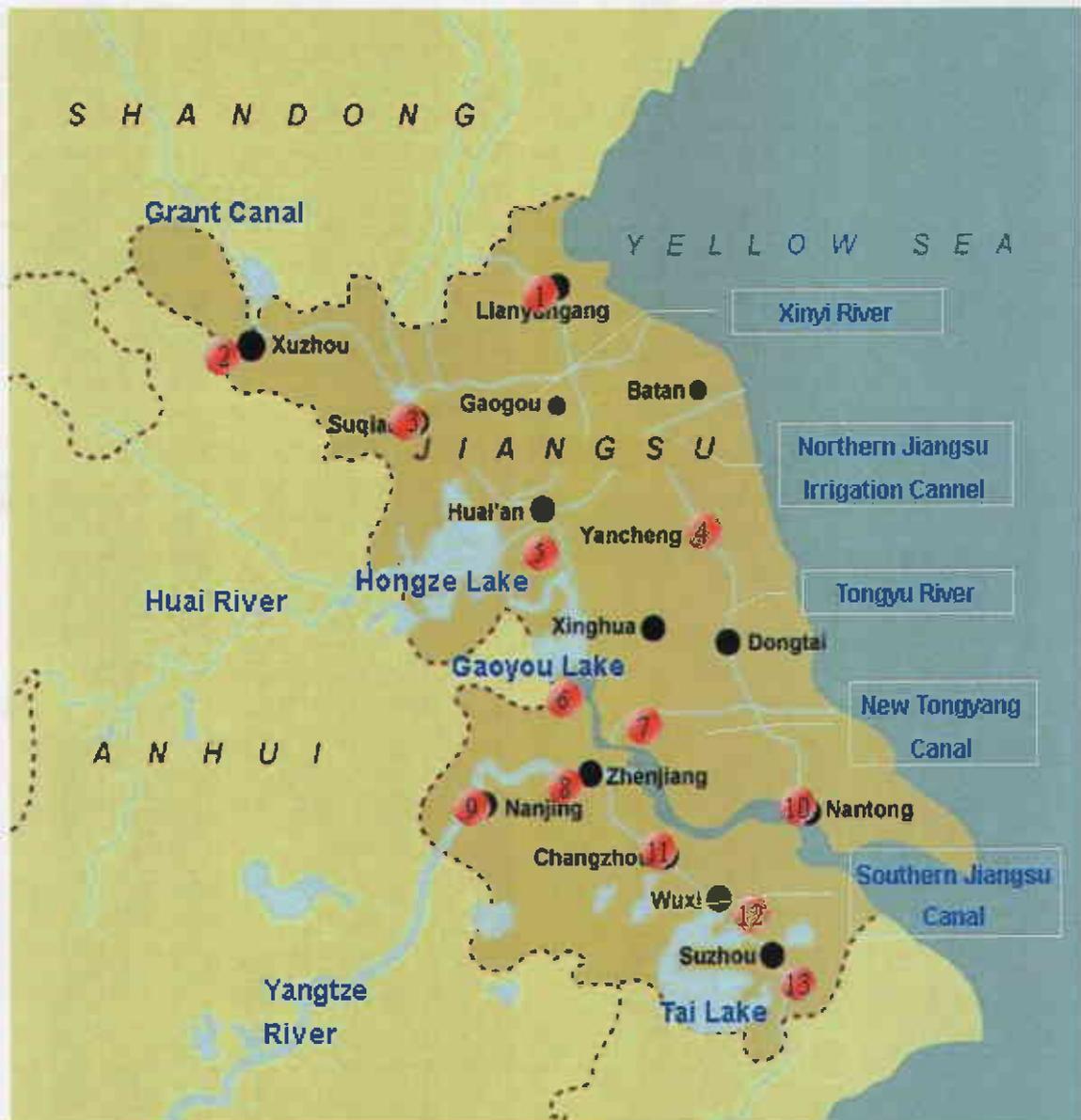


Figure 3-4 Planned AWMSS for Monitoring Drinking Water Sources for the 13 Cities

- | | |
|---|--|
| 1. The Qiangwei River in Lianyungang City | 7. The Yangtze River in Taizhou City |
| 2. The Linjia Dam in Xuzhou City | 8. The Yangtze River in Zhenjiang City |
| 3. The Suqian Dam in Suqian City | 9. The Yangtze River in Nanjing City |
| 4. The Xinyang Port in Yancheng City | 10. The Yangtze River in Nantong City |
| 5. The Abandon Yellow River in Huai'an City | 11. The Yangtze River in Changzhou City |
| 6. The Liaojiagou/Guazhouyuan in Yangzhou | 12. The Tai Lake in Wuxi |
| | 13. The Yangcheng Lake and the Tai Lake in Suzhou City |

(8) Sediment Samples Should be Collected and Monitored

Sediment must be examined if the quality of water is believed to be affected by polluted sediments on the bed of rivers, lakes and canals. In the current sampling/monitoring program of the province, the only sediment samples are collected once a year in some serious polluted waters; it is insufficient.

The usual practice in the States is that sediment samplings are taken once a month for sites where water qualities are obviously affected by polluted sediment. Sediment sampling points must be set at a uniform interval if the distribution of sediment is unknown, whereas these points must be set at a higher concentration for areas such as the mouth of a river; and where a frequent change in the distribution of sediment is expected. The sampling point should be: 1) areas close to major pollution sources or the mouth of a river; and 2) areas where sediment is expected to accumulate significantly, due to land profile or tidal current, and where sediment quality is expected to worsen.

Sediment samples should be collected from one location by gradually changing the collecting points. Columnar sampling should be performed as necessary.

3.4 Discussion and Recommendations on Designing Automatic Water Monitoring Stations (AWMSs)

Rivers flow day and night, and wastewaters may discharge into water bodies at any time, therefore water quality changes over time, thereby water quality determination in rivers and lakes can be conducted at discrete intervals to provide a nearly continuous record of the water bodies using an automatic monitoring station. Major considerations for design and operation of an AWMS include: site selection and construction, selection of sensors and monitoring instruments, location of the sensors, monitoring configuration, calibration and maintenance of sensors/ instruments, and the actual operation of the AWMS.

This section provides guidelines and procedures for sites selection and construction of the AWMSs, instruments configuration, as well as monitoring methods that widely used in the western countries for monitoring each of the parameters and their adaptability. The consulting team believes that it will be benefit to Jiangsu for designing and establishing their future AWMSs.

3.4.1 Selection and Optimization of AWMS Locations Using Remote Sensing Technologies

The locations of the existing and planned AWMSs in Jiangsu Province are generally classified into three groups: those in the first group are for monitoring drinking water sources; the second group is for rivers which flow into or out of Tai Lake; and the third group is for monitoring water areas at cross sections of borders between cities and provinces. Based on the number of planned AWMSs, the budget, the administrative divisions, and the distribution of the water systems, as well as giving consideration to "Drinking Water and Health", the arrangement for the locations are ideal. But if considering the province's complicated water systems, the tremendous quantities of waste waters discharged from numerous discharge points [especially since there are some provincial-shared lakes and rivers], and water qualities that are difficult to control by only the province, there is no doubt that the numbers and monitoring parameters should be increased, and advanced methods such as technologies of modeling and modern remote sensing (RS), should be used for the work.

Selection and optimization of AWMS sites are very important, but both are costly and time intensive. Establishing a model for the work would require the acquirement of great amounts of data and information on hydrology,

meteorology, water quality, tide, hydrophytes; as well as data regarding amounts, points and frequencies of wastewater discharge. In addition, methods such as statistics, empirical formula, water quality modeling, fuzzy-analogy and combined analysis, etc. would have to be adopted to establish the model. The model should also be verified in practice and be revisable as changes to hydrological conditions and water qualities happen in the future. Since the modeling work was not included in the TOR for this TDA project, the Consultants have obtained limited data and information, thus, a detailed introduction and discussion is not included in this report. However, a brief introduction about selection and optimization for AWMS locations using modern RS technologies has been included.

In the past few years, there has been increasing interest in the USA, to use airborne and/or space-borne RS technologies for water pollution monitoring and environmental assessment. A satellite or an aircraft carries modern compact instruments such as multispectral imager, laser fluorescence radar, UV spectral imager, CCD camera, and wide-angle video camera, etc. to scan a large area of specific water surface (such as Tai Lake). Then RS data is obtained by receiving the radiation reflected by the water surface observed and that data is converted to clustered images. The tests must be carried out many times throughout the four seasons and different days. For scanning and clustering, all of the wavelength regions from UV to microwave have practical applications. Each kind of water pollutant has a sensitive response on a specific wavelength band; for example, UV spectral image can determine water pollution status from oil spills and turbidity; Laser fluorescence radar is suitable for monitoring chlorophyll to understand the situation of eutrophication; and Infrared Spectral scanning can help to have a synoptic overview about industrial and municipal wastewater pollution. However, for a quantitative interpretation of remote sensing data, a correlation with in-situ water examination (the sampling on water surface and detection in a ground laboratory) or a validation using ground truth data is still necessary.

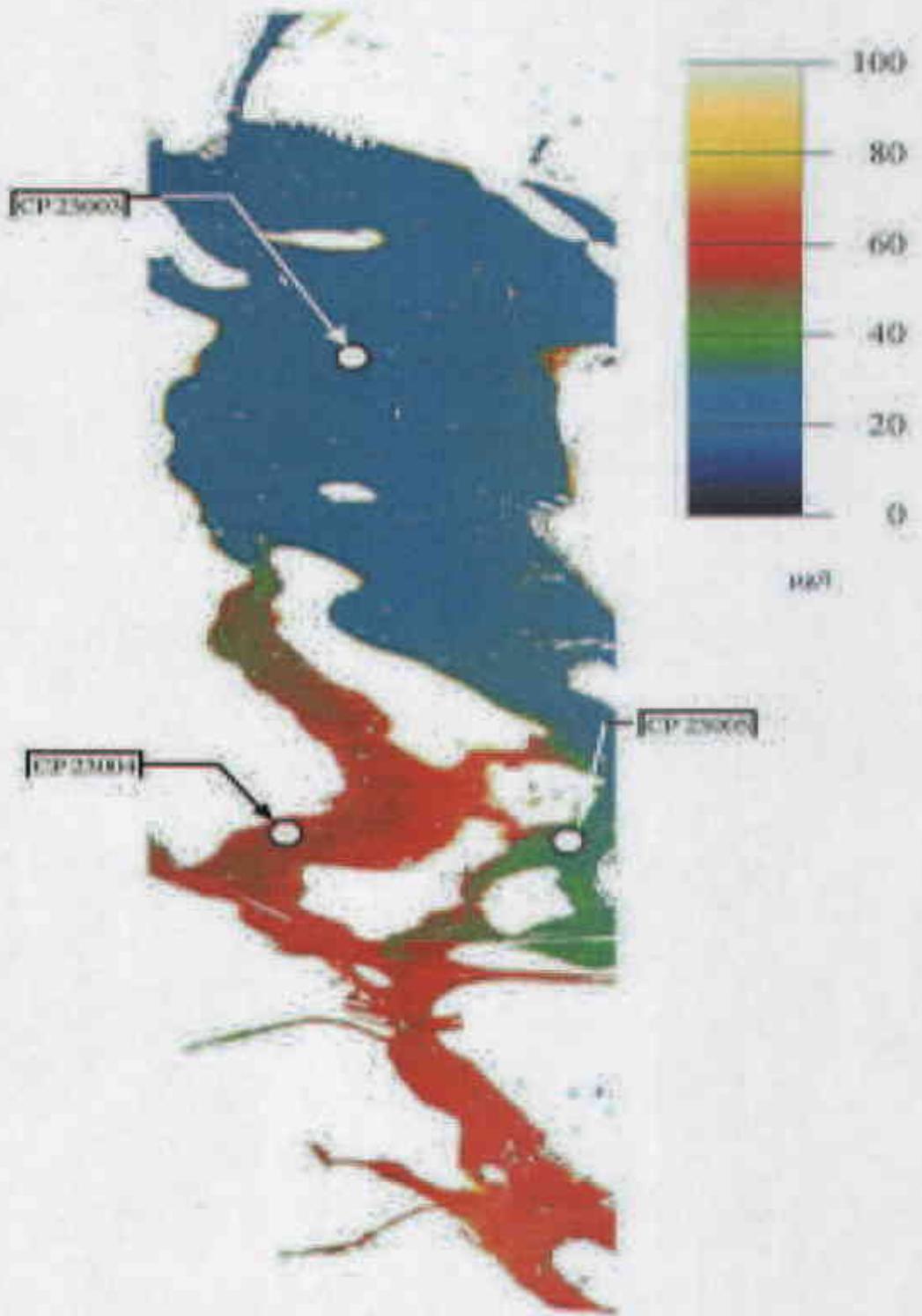
After analyzing the data and the clustered images at a correct scale, the data and images can help decide how many AWMSs are needed and at which locations in order to be representative of the whole body of water in the province. The data and images can also be used to evaluate if existing AWMSs are optimally located.

RS is a helpful tool for deciding the appropriate number and the location for AWMSs. Integration with the Geographic Information System (GIS) and Geographic Positioning System (GPS) makes RS technology become a more powerful tool for determination and optimization of AWMS locations. Since China has its own satellite system, Jiangsu has the capacity to begin research and development in this field. The Consultants, at this point, know nothing about the application, if any, of China's RS technology.

Table 3-8 shows water pollutants and the relevant wavelength range. The picture on the next page is a clustered image for distribution of chlorophyll concentration on the water surface of a lake.

Table 3-8 Water Pollutants and Relevant Wavelength Range

Band	Wavelength range (µm)	Remarks
1	0.4299---0.4600	Chlorophyll a, carotenoids
2	0.4706---0.5007	Chlorophyll a and b, yellow substance, suspended matter
3	0.5060---0.5345	Chlorophyll a, suspended matter
4	0.5505---0.5790	Chlorophyll a, suspended matter
5	0.6122---0.6399	Chlorophyll a, inorganic suspended matter
6	0.6650---0.6866	Chlorophyll a
7	0.6902---0.7100	Fluorescence of chlorophyll a
8	0.7424---0.7569	Atmospheric turbidity, aerosol
9	0.8546---0.8746	Atmospheric turbidity, aerosol



Clustered Image for Distribution of Chlorophyll Concentration on the Water Surface of a Lake

3.4.2 Site Selection and Construction of AWMSs

(1) Site Selection

According to the requirements of the JPEMC and the current situation of the province, the sites of the existing and the proposed AWMSs are classified into three groups:

- Sections for water quality control at municipal and provincial administrative boundaries;
- Sections at the rivers that inflow into or outflow from the major lakes and reservoirs; and
- Points at the drinking water sources of the 13 municipalities.

In general, there are numerous considerations for site selection of the AWMSs. The following are major factors for selection and placement of an AWMS.

- Representativeness of a water body
- Purpose of monitoring
- Flow rate and velocity
- Shape of water body
- Turbulence
- High-water debris damage
- Protection from vandalism
- Difficulty and cost for installation
- Accessibility of site
- Frequency of maintenance
- Sensors fouling and calibration frequency
- Influence by flooding and drought
- Proximity to electrical power or telephone service
- Need for real-time reporting
- Facility sharing with other public entities (such as hydraulic monitoring station)

Balancing all the considerations for placement of an AWMS is difficult. The optimum site consideration for achieving the data-quality objectives is placing the pump intake or the self-contained sensors in a location that best represents the section of the water body being monitored. Lateral mixing in big rivers, however, is often incomplete for tens of miles downstream from a tributary or outfall. A location near the riverbank may be more representative of local runoff or affected by point-source discharges upstream, whereas a location in center channel may be

more representative of areas farther upstream in the drainage basin. Turbulent flow may aid in mixing, but may create problems for some monitored parameters, such as DO or turbidity. For a medium to small water body with alternating pools and riffles, the best flow and mixing occurs in the riffle portion of the stream; however, flooding may change the locations of shoals upstream from the monitoring site, and the monitoring point may no longer represent the overall water quality characteristics of the water body. As a rule-of-thumb, sufficient cross-section measurements must be made at the intended AWMSs to determine if a prospective site is sufficiently well mixed and to ensure that the site will not be subject to a significant difference in a cross section. If significant horizontal or vertical variability exists, an alternative site or a different monitoring approach must be selected to meet the data quality objectives.

The monitoring point in the vertical dimension for larger flow systems needs to be appropriate for the primary purpose of the monitoring installation. The location should be able to measure water in various rates.

Selection of the site is also determined by the data quality objectives, the best site location is capable of monitoring surface water discharge. Although hydraulic factors in site location must be considered, it is more important to focus on factors that affect the water quality.

The general principles for selection of AWMS sites are as follows:

- A site for monitoring drinking water source should be set up at a nearby point to water intake of a water supply treatment plant. There is no point-pollution discharge between the site and the water intake.
- The station is far enough upstream from a confluence with another stream or from tidal effect to avoid any variable influence from the other stream or tied on the stage at the gauge site.
- The geographic & geological conditions of the site should be suitable for construction of the AWMS; the banks are permanent, high enough to contain floods, and free of brush.
- Point at which polluted water mixes adequately with a river after flowing into it, and point upriver from where the polluted water is introduced.
- Point at which tributary water mixes adequately with a river after the tributary flows into it, and point upriver from where each tributary joins the river.
- Water in the intake point is rich enough for pumping representative water samples to the station during dry seasons.
- Water & power supply, transportation and communication conditions are available for building the station.
- The site is readily accessible for ease of installation and operation of the station.
- The riverbed is not subject to scour and fills and is free of aquatic growth.
- The site is not susceptible to manmade disturbances, nearby tributaries, or point-source discharges.

- Avoid sampling areas near structures such as harbors, boat ramps, piers, fuel docks, unless these structures are part of the study.
- To avoid locations with vibration, such as bridges, to prevent analyzers from being affected by vibration.
- To avoid locations with significant corrosive gas and dust.
- To avoid locations with high temperature or humidity (air conditioning will be necessary).
- To choose locations allowing easy access and safe maintenance.

(2) Buildings Construction and Auxiliary Facilities:

Buildings and auxiliary facilities should be determined by taking into account requirements of analyzers, space needed for easy calibration and maintenance, and facilities to prepare and store reagents. The prevention of leakage from pipes of sampling or tap water and waste liquid treatment pipes should also be taken into account. The following is a summary of basic requirements for building construction and auxiliary facilities.

Floor: The floor area should be 20 to 25 m² or more, to provide space for calibration and maintaining analyzers. The floor should be waterproof for easy cleaning and dust prevention.

Ceiling: The ceiling should be about 2.8 meters high for easy cleaning of control tanks and pipes.

Windows: Security windows should have wired glass or protective grills. Direct sunlight should be avoided by using curtains or blinds. Sunlight promotes photosynthesis, resulting in propagation of algae in water pipes and tanks.

Protection against Lightning and Earthquake: A lightning rod should be installed if the monitoring station is located in an area with frequent lightning. Analyzers should be fixed with anchor bolts to prevent unwanted movement or overturning due to an earthquake or heavy vibration.

Electric Facilities: AC power source should be provided for sampling pumps, compressors and air conditioners. The power panel should have enough margins to cope with future increases in power consumption due to system expansion. Since automatic analyzers are easily affected by electrical noise, voltage stabilizers should be used, and power distribution to equipment with heavy load fluctuations should be separated from the line to analyzers. Each power line should be provided with a circuit breaker and must be grounded.

Ventilation and Air Conditioning: Ventilating fans should be installed to protect analyzers from moisture and gas inside the station. An air conditioning device with temperature controls should also be installed to maintain the reliability and accuracy of analyzers.

Tap Water Facilities: Tap water facilities are necessary for automatic water pollution analyzers and their maintenance. Normally, water pressure capacity of 2.2kg/m² and flow rate of 20 liters/min or more are required. Faucets should be laid out for easy use when cleaning analyzer tanks.

Waste Liquid Treatment Facilities: Waste liquid discharged from automatic analyzers includes acidic liquid from COD analyzers and alkaline solution from cyanide analyzers, etc. Each station should be provided with equipment to neutralize these liquids. The neutralized liquid is discharged together with overflow water from samples.

Others: AWMSs are often located near rivers, and there may be no available lavatory nearby. A lavatory should be provided as necessary. The station building and sampling facilities should be surrounded with a fence for security. Parking should be provided for calibration and maintenance vehicles.

(3) Sampling Facilities:

In addition to requirements for building an AWMS, sampling methods play an important role in ensuring the precision of data collected by automatic analyzers. The following is a summary of requirements for sampling water from rivers, lakes and reservoirs; for conveyance pipes from the sampling points to the station building; and for discharge pipes and control tanks, with reference to Figure 3-5.

Sampling Points: When monitoring is performed to evaluate conformance to Environmental Quality Standards, sampling points should be selected so that their samples fairly represent water quality in the target area. Sample water should be taken at a prescribed depth (in a river, about 20% of total depth).

Sampling Pumps: Submerged pumps or suction pumps are used to collect water samples. Self-cleaning submerged pumps are more popular than suction pumps, due to higher reliability and easier operation.

A submerged pump should be installed at a location with easy access for maintenance, a winch and a work platform should also be provided. To prevent a discontinuation of measurement, install a backup pump. A filter for the pump intake port may be necessary if the target area is significantly contaminated with solid materials such as garbage. The pump should also be protected from damage by objects carried rapidly downstream, such as logs. A common way to prevent the clogging of a pump intake is to program the system so that compressed tap water periodically flushes the pump intake.

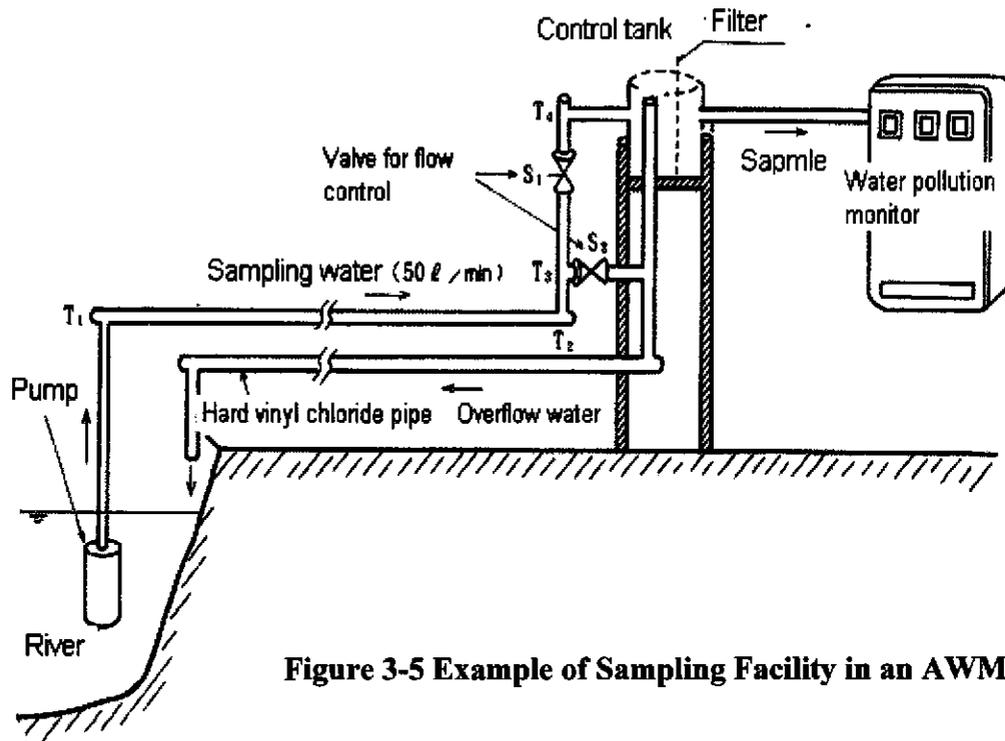


Figure 3-5 Example of Sampling Facility in an AWMS

A submerged pump with a sufficient margin of excess capacity should be selected to avoid a fluctuation of water quality in collected samples due to water temperature, DO and turbidity. A stainless steel pump is recommended due to its lightweight and resistance to corrosion.

If the sample collection pipe is less than 50m long and its lift is about 5m, use a pump with a capacity of 750 watts.

Suction pumps are installed on the ground with easy access for maintenance. However, many of them require primers and protection filters. When selecting a suction pump, consider the amount of sample required and the flow rate in conveyance pipes. Lift and maintenance requirements should be carefully evaluated.

Conveyance Pipes: Contamination in conveyance pipes is one of the main causes of deteriorating monitoring accuracy in an AWMS. Therefore, pipes must be kept thoroughly clean inside. Conveyance pipes from sampling points to the analyzer should be as short as possible, with no bends.

Use steel pipes with an internal surface coating of vinyl chloride, or pipes made of hard vinyl chloride. An inner diameter of 45 to 50mm with a flow rate of more than 80cm/s provides self-cleaning to remove microorganisms produced inside the pipe. For connecting conveyance pipes to the submerged pump, use a thick-walled flexible vinyl hose.

Conveyance pipes may be cleaned automatically or manually. Automatic cleaning methods are roughly classified into two types. One method uses reverse water flow, with alternate pumps, changeovers valve and tap water to clean the pipes.

The other method periodically blows off contamination with compressed air. In the case of manual cleaning, pipes are periodically disassembled and cleaned with a brush. The conveyance pipes should have flanges for easy dismantling.

Control Tank: Sample water is carried through conveyance pipes into a control tank before being fed into the analyzer. The control tank is used to remove undissolved contaminants by filtering sample water with rough and fine screens, and to control the pressure and flow rate of water fed into the analyzer. The screens are automatically cleaned by flushing them with tap water. Water distribution pipes, overflow pipes, and connection pipes between the control tank and automatic analyzers should be designed for easy dismantling and cleaning. Installation of valves on these pipes should be minimized to prevent clogging. If a valve is indispensable, use a ball-cock type valve.

Discharge Pipes: Waste liquids are discharged either by natural flow or forced drainage. Natural flow uses gravity, or the difference in height between the AWMS and the river; forced drainage depends on a pump installed at the waste liquid pit. Forced drainage is used when natural flow is not possible. In either case, waste liquids from an AWMS must be discharged downstream of the sampling point to avoid mixing discharged liquids with water being collected as a sample. When waste liquids are discharged by natural flow, the diameter of the discharge pipe should be larger than that of the sampling pipe. Pipes with an inner diameter of about 100mm are generally used.

When using forced discharge, a waste liquid pit of about two square meters is necessary as well as a drainage pump with the capacity equal to or greater than that of a sampling pump must be installed. As a countermeasure against pump failure, the drainage pump should be designed to automatically shut off upon receiving an alarm signal indicating that the upper water level limit of the waste liquid pit has been reached.

3.4.3 Selection of Monitoring Configuration

The most widely used water monitoring sensors in the States are temperature, conductivity, DO, pH, turbidity, oxidation-reduction potential (ORP), salinity, $\text{NH}_3\text{-N}$, nitrate ($\text{NO}_3\text{-N}$), chloride, total residual chlorine, total dissolved solids (TDS), total organic carbon (TOC), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and chlorophyll. The sensors/instruments needed to measure these properties are available as single instruments or in various combinations.

There are two types of AWMS configurations are commonly used worldwide:

- **The Flow-Through System:** A pump takes water from a water body to a tank inside a station that contains the monitoring sensors or other devices, such as AutoChem instruments, which are the same as those currently used in Jiangsu. The flow-through monitoring system is the most widely used configuration largely because it offers flexibility to accommodate both sensor and AutoChem types of monitoring instruments.
- **In-Situ System:** Sensors in the in-situ monitoring system are placed at the monitoring point in a water body. Cables run from the sensors to the

recording equipment that is housed in a room. In-situ water-quality monitoring systems can be installed at remote locations where AC power is not available. A special kind of the in-situ-system is multi-parameters combined system. The self-contained electrodes and a recording system that requires no AC power and is placed directly in the water.

Both the advantages and disadvantages of the two configurations are indicated in Table 3-8.

According to the requirements of the JPEMC, the factors indicated in Table 3-8, and the running situation of the existing AWMSs in the province, we recommend that in sites where AutoChem monitoring methods are conducted for determination of ammonia nitrogen, COD, TN and TP, etc., flow-through monitoring systems should be considered for the configuration of future AWMSs. But in sites where only electrode/sensor methods are conducted for determination of pH, DO, conductivity and temperature, etc. self-contained Sonde systems should be considered.

Table 3-8 Comparisons of the Configurations

Configuration	Advantages	Disadvantages
Flow-Through Monitoring System	<ul style="list-style-type: none"> • Use both electrode and AutoChem methods for monitoring more parameters • Timely standard-solvents-calibration increases accuracy • Indoor instruments last operation life • Membrane fouling can be reduced by chlorination 	<ul style="list-style-type: none"> • Pumps may be clogged in streams by algal or dirt. • Corrosive waters may damage pumps. • AC power source is needed. • Higher installation costs. • Pumping may cause changes in water quality.
In-Situ Monitoring System (includes sonde type)	<ul style="list-style-type: none"> • The monitoring device is protected from vandalism. • Needs small shelter • Needs no AC power • Needs no pump • Location may be remote 	<ul style="list-style-type: none"> • Limited monitoring Parameters. • Sensors are easy to be damaged • Freeze protection is needed • Electrode calibration and maintenance during flooding are difficult. • Electrodes are susceptible to debris or high flow. • Shifting channels may cause movement of the instrument. • Data may lose if batteries run down

3.4.4 Monitoring Methods and Instruments

Commercial instruments are available for continuous monitoring many physical and chemical parameters. In the Jiangsu's existing AWMSs, the configurations of five-parameters (temperature, DO, turbidity, conductivity, and pH) plus ammonia nitrogen are being used. Considering the current condition of water pollution, we suggest that additional monitoring parameters, such as, TOC, COD, TN, TP, Chlorophyll, Permanganate (KMnO₄) Index and Cyanide, etc. should be added in the future AWMSs.

In this section, we will discuss different methods and analyzers for each of the parameters, their advantage and disadvantage, and adaptability as well; it is a reference to establishment of the future AWMSs.

The following briefly describes and discusses the methodologies and the instruments for AWMSs, which are widely used in the States and other developed countries.

(1) pH Meter

In practice, a pH value is defined by the equation: $\text{pH} = -\log_{10} [\text{H}^+]$. This equation means that the pH value is a common logarithm expressing the reciprocal of the hydrogen ion concentration. The pH value of a neutral solution is obtained as 7 from the following calculation: $[\text{H}^+] = 10^{-7}$. When the hydrogen ion concentration decreases (e.g., $[\text{H}^+] = 10^{-10}$), the pH value is 10 showing that the solution is alkaline. When it increases (e.g., $[\text{H}^+] = 10^{-3}$), the pH value is 3 showing that the solution is acid.

Dissolved gases, such as carbon dioxide, hydrogen sulfide, and ammonia, appreciably affect pH. Degasification (for example, loss of carbon dioxide) or precipitation of a solid phase (for example, calcium carbonate) and other chemical, physical, and biological reactions may cause the pH of a water sample to change appreciably immediately after sample collection.

A large number of animals and plants inhabit lakes, rivers, and oceans. The pH values of those water areas differ depending on the kinds of animals and plants that can live there. In general, the pH values which allow animals and plants to live are in the neutral range. Animals and plants can no longer live if the pH values of their habitat become acidic or alkaline. The cause of such pH changes are mainly wastewater from factories and households.

The monitoring methods for pH values include using an indicator reagent, the metal electrode methods (hydrogen electrode method, quinhydrone electrode method, and antimony electrode method), and the glass electrode method. The glass electrode method is considered to be the standard measuring method. In practice, however, pH values are obtained from hydrogen ion activity (thermodynamic activity) rather than hydrogen ion concentrations.

Monitoring Method Using pH Electrodes: When two solutions with different pH values exist inside and outside a glass membrane, an electromotive force occurs in that membrane (electrode membrane), which is in proportion to the difference between the two pH values. Since the solution typically used inside the glass membrane has a pH value of 7, the pH value of the solution outside the membrane can be obtained by measuring the electromotive force generated in the membrane.

The pH meter consists of a glass electrode and a reference electrode. It allows the pH value of the sample to be obtained by measuring the potential difference between the two electrodes with a potential difference meter. To calibrate the pH meter, a standard solution with a known pH value is used. As to standard

solutions, pathalic acid (pH4.01), neutral phosphate (pH6.86), and borate (pH9.18) are mainly used.

(2) Dissolved Oxygen (DO) Meter

Life of animals and plants are dependent on their energy, which is obtained when their food is oxidized and decomposed with atmospheric oxygen. Thus, oxygen is indispensable to life. The life of aquatic animals and plants is similarly dependent on dissolved oxygen. Thus, dissolved oxygen is critical for living organisms. This means that the life of aquatic animals and plants is greatly affected by the concentration of dissolved oxygen. Therefore, water with a low concentration of dissolved oxygen is considered to be polluted.

Oxygen is supplied to water directly from the air or from the oxygen generated through photosynthesis by phytoplankton. The range of observed DO in surface waters typically is from 2 to 10mg/L at 20°C. The value for 100% saturation of DO decreases with increased temperature and salinity and increases with increased atmospheric pressure. Occasions of excess oxygen (Supersaturation) often are related to extreme photosynthetic production of oxygen by aquatic plants as a result of nutrient (nitrogen and phosphorus) enrichment, sunlight, and low-flow conditions. Occasions of saturated oxygen commonly are related to cascading flow condition, both natural and artificial. DO may be depleted by inorganic oxidation reactions or by biological and chemical processes that consume dissolved, suspended, or precipitated organic matter.

Dissolved oxygen can be measured with membrane-type dissolved oxygen electrodes using a galvanic cell or membrane-type dissolved oxygen electrodes using a polarograph. The most commonly used technique, for measuring DO concentrations with continuous water quality sensors, is the Amperometric Method, which measures DO with a temperature-compensated paleographic membrane-type sensor. While paleographic membrane-type sensors generally provide accurate results, they are generally sensitive to temperature and water velocity and are prone to fouling. Because the permeability of the membrane and solubility of oxygen in water changes as a function of temperature, it is critical that the DO sensors be temperature-compensated.

The measuring process consumes DO; therefore, water flowing past the sensor is critical. If water velocity at the point of measurement is less than 1 ft/s, an automatic or manual stirring mechanism or a different measurement technique is required. DO sensors are prone to inaccuracies from algal fouling, sedimentation, and low or very high velocities.

(3) Electric Conductivity (EC) Meter

Deionized water hardly conducts electricity, but when salts are dissolved in the water, they dissociate into ions, making the deionized water electrolytically conductive. This conductive degree is called electrolytic conductivity. As the amount of salts becomes larger, the electrolytic conductivity increases.

Electrolytic conductivity is the reciprocal of the electric resistance of a solution existing between two electrodes which have a cross section area of 1cm^2 and are separated 1cm from each other. Substance can not be identified by measuring electrolytic conductivity of the solution, but the approximate amount of salt dissolved in the solution can be determined.

Measuring Principle: Assume k [S/cm] for the electrolytic conductivity of a solution, R [Ω] for the resistance of the solution, and K [1/cm] for the cell constant which is determined by the shape of each electrode. Now the electrolytic conductivity, k , is expressed as $k = K/R$.

For the electrodes, platinum or platinum black is used. However, for a system which continuously measures a sample solution, stainless steel or special steel electrodes are often used instead.

Measuring Method: Electrolytic conductivity can be measured by either the alternating bipolar method or the electromagnetic induction method.

a. Electrolytic conductivity meter using the alternating bipolar method:

An electrode with two poles is immersed in a solution to measure its electrolytic conductivity. AC voltage is applied across the two poles. The electric current flowing across the poles is used to measure the solution's resistance (R), and then the electrolytic conductivity. Since the electrolytic conductivity varies depending on the temperature, the measured electrolytic conductivity is converted to that at 25°C by using a temperature compensation element.

b. Electrolytic conductivity meter using the electromagnetic induction method:

Two electrodes made by covering transformers T1 and T2 with insulating material are immersed in a solution. When AC current is applied to the primary coil C1, induced current I in proportion to the electrolytic conductivity of the solution flows through C2. On the other hand, voltage E is generated, in proportion to the induced current I , in the secondary coil C3 of the transformer T2 using C2 as its primary coil. This voltage is measured to obtain the electrolytic conductivity. Figure 3-6 is a configuration of an electrolytic conductivity meter using this method.

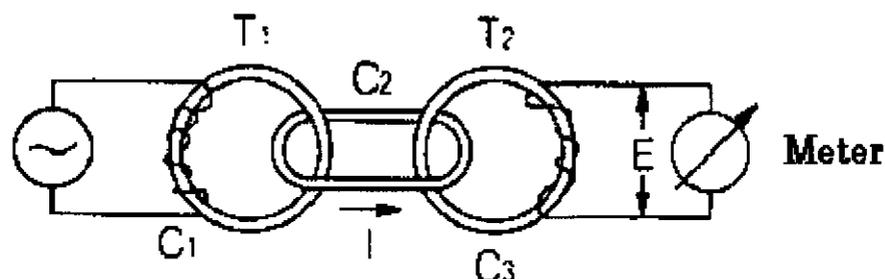


Figure 3-6 Configuration of EC Meter Using Electromagnetic Induction Method

(4) Temperature Meter

Temperature in water is an indicator for heat pollution, such as same high-temperature industrial wastewater discharge into a water body. Temperature has an important influence on the density of water, the solubility of constituents in water, the rate of chemical reactions, and the biological activity in water. An AWMS usually measures temperature with a thermistor which is a semiconductor with resistance that changes with temperatures. Thermistors are reliable, accurate, and durable sensors that require little maintenance and are relatively inexpensive.

Modern thermistors can easily measure temperature to $\pm 0.10\text{C}$. Typically, temperatures are reported to the nearest 0.50C because the thermistor is located at one point, which may not be representative of the entire water body being detected.

(5) Turbidity Meter

Turbidity means how turbid a water sample is. In general, the turbidity value of water flowing in a mountain stream is low, showing that the water is clean. The turbidity of water flowing near the mouth of a river is high, showing that the water is dirtier. The components responsible for water being turbid are inorganic substances in some cases and organic ones in other cases. From an environmental viewpoint, contamination with organic substances often causes a problem. When the turbidity value of environmental water is high, the water is, in many cases, significantly polluted with organic substances.

Turbidity readings are affected by suspended sediment particle size, entrained air bubbles, floating debris, and other particles in the water that may collect on or near the optic sensor during measurements. The effect of temperature on turbidity sensors is minimal and the software for modern sensors provides temperature compensation. Sensors that are maintained and calibrated routinely will be relatively error free and are capable of providing valid data consistently. There are many methods available for measuring turbidity. When the same sample is measured by different methods, the obtained values are different. For this reason, a standard solution is employed. There are two types of standard solutions, the kaolin standard solution (labeled as "ppm") and the formazine standard solution (labeled as "FTU").

Measuring Principle of Turbidimeter: The turbidimeter uses surface light scattering, light scattering/transmission, light transmission, or integrating sphere to measure turbidity.

- a. **Surface light scattering method:** The sample is sent to the measurement chamber, and light is radiated to the surface of the liquid being measured. The light scattered from that surface is used to measure the turbidity. The intensity of the scattered light is in proportion to the concentration of suspended substances in the sample. This relation is used to obtain the turbidity. Since this method requires no window exposed to the sample to be measured, there is no error which would result from a contaminated window.

- b. **Light scattering/transmission method:** Light is radiated to the sample cell. The scattered light resulting from the suspended substances in the sample and the light which passes through the sample are measured. The difference between the two values is in proportion to the concentration of suspended substances in the sample. Using this relation, the turbidity is obtained. In this method, the ratio between the scattered light and the transmitted light is obtained. Therefore, the effects of fluctuations of the power source, deterioration of the lamp, and the color of the sample are minimized as they offset each other. Thus, stable measurements of the sample can be obtained (see Figure 3-7).
- c. **Other methods:** Other methods include the transmitting light method and the integrating sphere method.

In the light scattering method, light is radiated to the sample cell. The radiated light is attenuated by the suspended substances in the sample. The transmitted light attenuates according to the amount of the suspended substances, and is used to measure the turbidity (see Figure 3-8).

In the integrating sphere method, parallel beams are radiated to the cell. The light scattered with the suspended substances is focused with the integrating sphere. The ratio between the scattered light and the transmitted light is used to measure the turbidity.

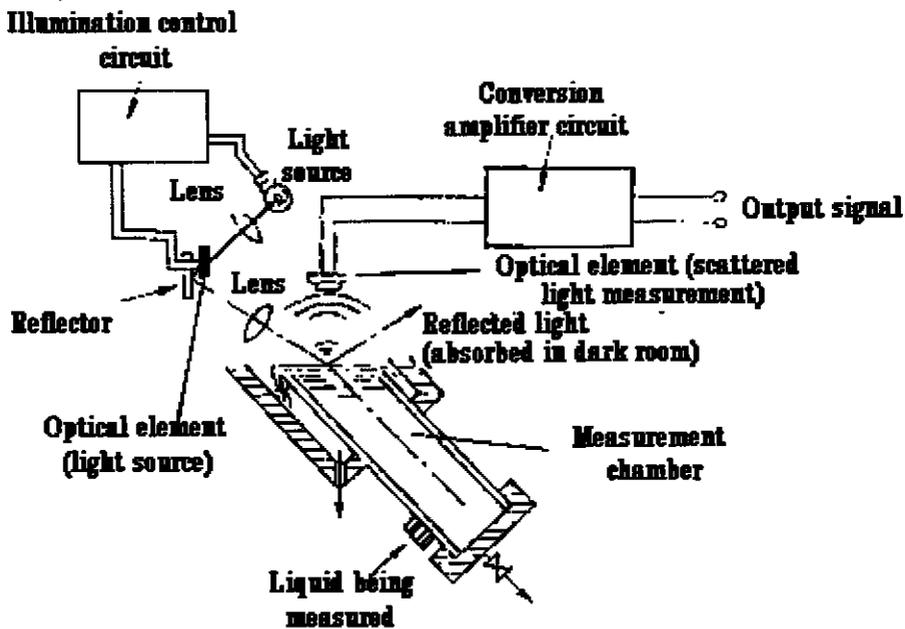


Figure 3-7 Turbidity Meter Using Light Scattering at Sample Surface

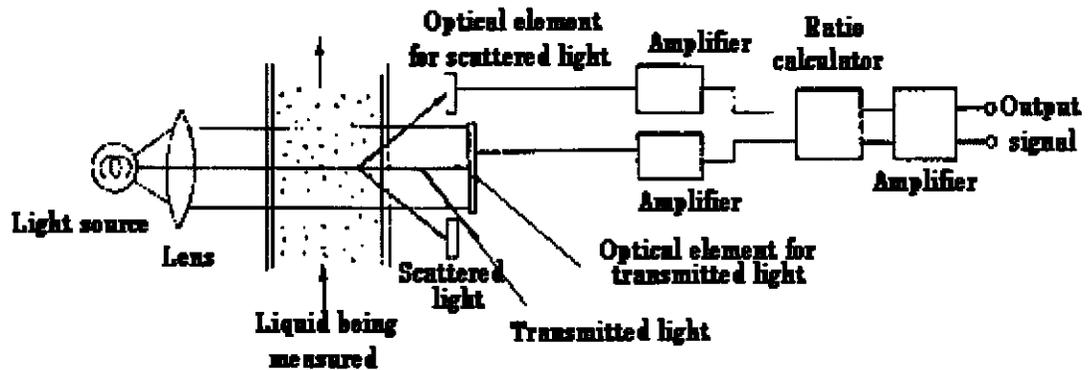


Figure 3-8 Turbidity Meter Using the Scattered/Transmitted Light Method

(6) Ammonia-Nitrogen Analyzer

Ammonia is naturally present in all water systems and is a primary nutrient for aquatic plant growth when found in low concentrations. Ammonia concentrations become problematic when concentrations in the water are high enough to either cause eutrophication and/or kill fish outright. This is usually the result of urbanization or agricultural practices (livestock).

Automatic ammonia monitoring systems use a colorimetric liquid to gas-phase transfer principle that is both easy to maintain and reliable. Measurable ranges of ammonia-N are between 0.5 and 1200 mg/L, with accuracies of $\pm 2.5\%$ of the measured value. Samples can be analyzed as often as every 13 minutes.

(7) Total Organic Carbon (TOC) Analyzer

The organic carbon in water and wastewater is composed of a variety of organic compounds in various oxidation states. Some of these can be oxidized further by biological or chemical processes, and the biochemical oxygen demand (BOD) and the COD may be used to characterize these fractions. However, there are organic compounds that are not easily oxidized and can not be quantified by the BOD or COD analyses. Quantification of these hard-to-oxidize organic compounds is only achieved via the methods used for TOC.

The TOC measurement methods can be classified into two types, one is the differential method and the other is the direct method.

In the differential method both Total Carbon (TC) and Inorganic Carbon (IC) are determined by separately measuring them and TOC may be calculated by subtracting IC from TC. This method is suitable for samples in which IC is less than TOC, or at least of similar size.

In the direct method, first the IC is removed from a sample by purging the acidified sample with a purified gas, and then TOC may be determined by means of TC measuring method as TC equal TOC. This method is also known as Non-purgeable Organic Carbon (NPOC) due to the fact that Purgeable Organic Carbon (POC) such as benzene, toluene, cyclohexane and chloroform may be partly removed from a sample by gas stripping. The direct method is suitable for surface water, ground water and drinking water because of, in most cases, less TOC comparing with IC and negligible amount of POC in these samples.

Below indicates the three methods available for continuous water monitoring.

- a. **Combustion / NDIR Method:** TC is measured by injecting a portion, tens or hundreds microliter, of the sample into a heated combustion tube packed with an oxidation catalyst. The water is vaporized and TC, the organic carbon and the inorganic carbon, is converted to CO₂. The carbon dioxide is carried with the carrier gas stream from the combustion tube to a non-dispersive infrared gas analyzer (NDIR) and concentration of carbon dioxide is measured. The TC concentration of the sample is obtained by using the calibration curve prepared with standard solutions. IC is measured by injecting a portion of the sample into an IC reaction chamber filled with phosphoric acid solution. All IC is converted to CO₂ and concentration of CO₂ is measured with a NDIR. TOC may be obtained as the difference of TC and IC.

In the direct method the sample from which IC was removed previously, injected into the combustion tube and TOC (NPOC) is measured directly.

The combustion / NDIR method is applicable to a wide variety of samples such as surface water, ground water, drinking water and waste water including intake water and discharged water for a waste water treatment facility. The strong points of this method are quick operation and strong oxidation capability for any kind of organic substance including suspended particulate organic substance. The weak point is a lack of sensitivity needed to apply to pure water analysis for semiconductor, pharmaceutical and power-generation industries except some TOC analyzer which has a capability of measuring down to 0.01 mg/L.

- b. **Persulfate Oxidation / NDIR Method:** There are two types of methods; persulfate oxidation supported with UV (Ultraviolet) irradiation activation and heated persulfate oxidation.

TC is converted to CO₂ in an oxidation chamber by being acidified with phosphoric acid and reacting with persulfate in the irradiation of UV light if provided. The CO₂ produced in the oxidation chamber is carried with the carrier gas stream to a NDIR and the concentration of CO₂ is measured. IC, TOC and NPOC are measured in the same manner with the combustion / NDIR method mentioned above.

The persulfate oxidation / NDIR method is a rapid, precise method for the measurement of lower levels of TOC in purified water used mainly in semiconductor, pharmaceutical and power-generation industries. But since this method has some restrictions regarding samples which contain difficult oxidizable organic substances, suspended organic particles and salts, it is necessary to check the operational performance of the TOC analyzer beforehand when the TOC analyzer which employs this method is apply to domestic and industrial wastes, surface and saline waters and ground water. Check efficiency of oxidation with selected model compounds representative of the sample matrix as mentioned in U.S. Standard methods 5310 C or with samples containing particulates as mentioned in EPA method 9060.

- c. **UV oxidation / conductivity method:** Oxidation of organic carbon in a sample to carbon dioxide is carried out by UV radiation with oxidation catalyst or persulfate. Conductivity change of water in conductivity detection cell separated from the sample with a gas permeable membrane or a gas-liquid separator is measured.

The application of these methods is restricted to low polluted waters that have no suspended particles by the reasons mentioned above.

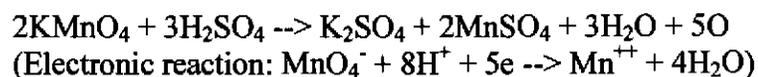
(8) Permanganate Index Analyzer (COD-KMnO₄)

The Permanganate Index indicates the quantity of oxygen required for the chemical oxidation of organic matters present in water. The value measured provides a quantitative estimate of everything that can be oxidized, i.e. most of the organic compounds and some oxidizable mineral salts.

The Permanganate Index (Value) is an International Method used to monitor the water pollution by oxidizing organic and inorganic matters. This method is mainly used to control the quality of potable and surface water.

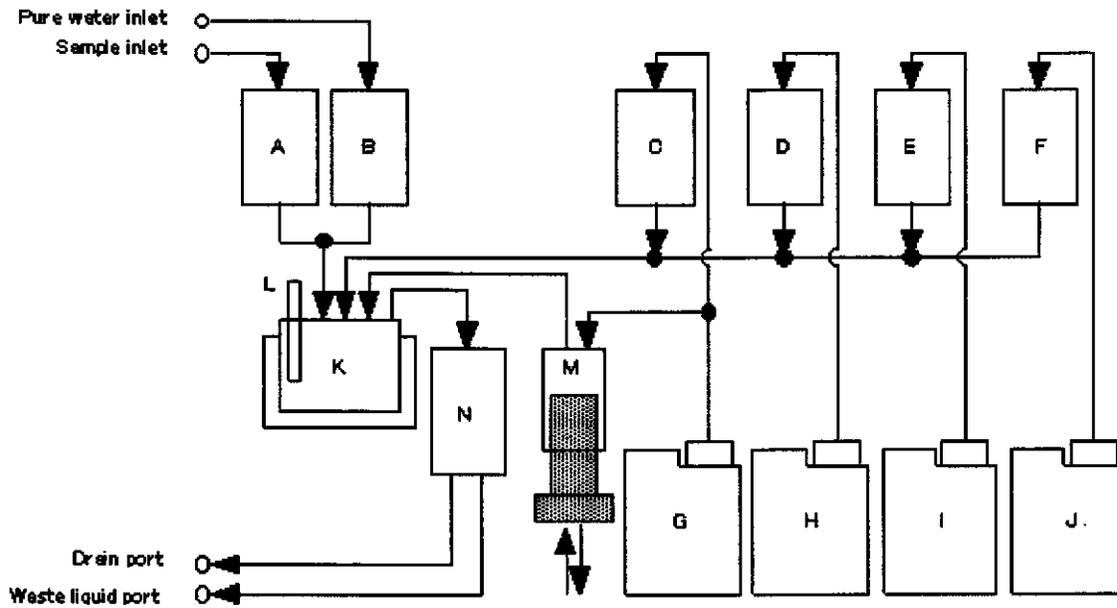
The Permanganate Index method is not recommended for wastewater due to the fact that some organic compounds are not oxidized.

- a. **Potassium permanganate acidic method:** Sample is adjusted to acidic solution using sulfuric acid. Potassium permanganate is added to the sample and the mixture is heated at 100°C for the specified period for reaction. The amount of potassium permanganate consumed for the reaction is measured and expressed by the corresponding oxygen amount. An example of the Permanganate Index analyzer using acidic potassium permanganate method is illustrated below in Figure 3-9. The sample is weighed and put into reaction chamber. Sulfuric acid, potassium permanganate solution and silver nitrate solution are added to the sample and the mixture is subject to reaction for 30 minutes in boiling water bath or oil bath. The oxidation of permanganate is expressed as below:



Then sodium oxalate is added so that the remaining potassium permanganate reacts with sodium oxalate and the excess of sodium oxalate remains after the completion of reaction. The remaining sodium oxalate is titrated with potassium permanganate solution and the end point is detected by oxidation-reduction potentiometric titration or by potentiometric titration at constant current.

- b. In case of concentration of chloride in water body is above 300mg/L, the Potassium permanganate alkaline method should be used.



- | | |
|---|--|
| A: Sample weighing apparatus | G: Potassium permanganate solution container |
| E: Dilution water weighing apparatus | H: Silver nitrate solution container |
| C: Potassium permanganate solution weighing apparatus | I: Sulfuric acid solution container |
| D: Silver nitrate solution weighing apparatus | J: Sodium oxalate solution container |
| E: Sulfuric acid solution weighing apparatus | K: Reaction chamber |
| F: Sodium oxalate solution weighing apparatus | L: End point detection electrode |
| G: Potassium permanganate solution container | M: Titration pump |
| | N: Drain tank |

Figure 3-9 Example of COD Analyzer of Potassium Permanganate Acidic Method

(9) Chemical Oxygen Demand (COD)

COD is the amount of oxygen required to chemically decompose organic compounds in water; thus, the larger the COD value is, more oxygen is required from the body of water. Thus, waters having elevated COD values have the added risk of depleting oxygen supplies.

There are three methods widely used for the continuous monitoring of COD; the potassium dichromate oxidation-titrimetric method, the potassium dichromate oxidation-colorimetric method, and the UV method.

- a. **Potassium Dichromate Oxidation-Titrimetric Method:** A sample is refluxed in strong acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$), after digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with ferrous ammonium sulfate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter is calculated in term of oxygen equivalent. The method is similar to the China national standard method and is applicable to COD values between 40 and 400mg/L. In addition, use higher concentrations of $K_2Cr_2O_7$ to determine greater COD values.

- b. Potassium Dichromate Oxidation-Colorimetric Method:** The oxidization procedure is the same as that in the above 'method a'. When a sample is digested, the dichromate ion oxidized COD material in the sample. This results in the change of chromium from the hexavalent (VI) state to the trivalent (III) state. Both of these chromium species are colored and absorb in the visible region of the spectrum. The dichromate ion ($\text{Cr}_2\text{O}_7^{2-}$) absorbs strongly in the 400nm region, where the chromic ion (Cr^{3+}) absorption is much less. For this method to be applicable, all visible light-absorbing interferences must be absent or be compensated for. This includes insoluble suspended matter as well as colored components. In case of either types of interferences occurs, use method "a" for the determination.
- c. UV Method:** The COD can be quantified using an UV Organic Analyzer, which measures the absorption of UV light by organic matter. The colorimeter lays down a measurement beam at the UV wavelength of 254 nm and a second, reference beam at 550 nm. The attenuation of the measurement beam is due primarily to the presence of organic matter, while the attenuation of the reference beam is due primarily to the presence of undissolved solids (turbidity).

The instrument measures spectral absorbance coefficients (XAC), a physical parameter, and correlates the SAC value to one of three organic parameters (COD, BOD₅, or TOC). The range of this configured to read out directly in one of those parameters in units of mg/L or g/L. The range of this analyzer is 0-1, 5000⁻¹ SAC, with an accuracy of ±10%. Measurements can be taken as often as every minute.

(10) *Chlorophyll Analyzer*

Chlorophyll, in various forms, is bound within the living cells of algae, phytoplankton, and other plant matter found in environmental water. Chlorophyll is a key biochemical component in the molecular apparatus that is responsible for photosynthesis, the critical process in which the energy from sunlight is used to produce life-sustaining oxygen. In general, the amount of chlorophyll in a collected water sample is used as a measure of the concentration of suspended phytoplankton, the magnitude of which can significantly affect the overall quality of the water. Monitoring the Chlorophyll in water is very important as a signal of fertilization, because it has good relation with concentrations and activities of planktons. The measuring method is fluorescence and it enables high resolution and linear measurement.

One key characteristic of chlorophyll is that it fluoresces, that is, when irradiated with the light of a particular wavelength, it emits light of a higher wavelength (or lower energy). The ability of chlorophyll to fluoresce is the basis for all commercial fluorometers capable of measuring the analyte in vivo. Fluorometers of this type have been in use for some time. These instruments induce chlorophyll to fluoresce by shining a beam of light of the proper wavelength into the sample, and then measuring the higher wavelength light, which is emitted as a result of the fluorescence process. Most chlorophyll systems use a light emitting diode (LED) as the source of the irradiating light that has a peak wavelength of approximately 470 nm. LEDs with this specification produce radiation in the visible

region of the spectrum with the light appearing blue to the eye. On irradiation with this blue light, chlorophyll resident in whole cells emits light in the 650-700nm region of the spectrum. To quantify the fluorescence, the system detector is usually a photodiode of high sensitivity screened by an optical filter that restricts the detected light. The filter prevents the 470nm exciting light from being detected when it is backscattered off of particles in the water. Without the filter, turbid water would appear to contain fluorescent phytoplankton and produce false-positive results, even though none were present (see Figure 3-10).

Configuration: The sample pump (A) injects sample water into the flow cell (B) where exciting light exposes. Exposed by the exciting light, Chlorophyll emits fluorescent light. The photomultiplier (I) detects the fluorescence light.

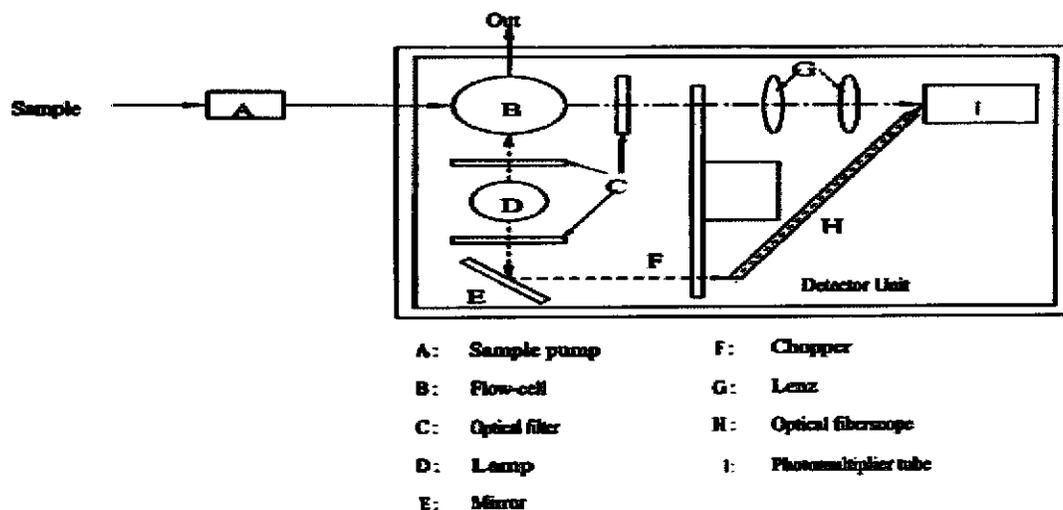


Figure 3-10 Configuration of Chlorophyll Analyzer

(11) Oil Content Meter

Domestic wastewater contains animal and vegetable oil from cooking, and petroleum oils such as kerosene from factories. In addition, much vegetable, animal, and mineral oil are used at manufacturing plants, and part of them may be discharged. When such oils drain into the natural environment, the life of animals and plants is endangered by pollution. Recently, crude oil tanker accidents have dumped large quantities of crude oil into the sea. In addition, crude oil contains carcinogenic substances in many of its volatile substances, which greatly influence fish, shellfish, and humans. For these reasons, it is important to monitor oil content.

Measuring Principle of Oil Content Meter: There are a variety of measuring methods available for oil content meters. We describe here only the solvent extraction/infrared analysis method.

With this method, the infrared absorption band of the oil content (wavelength between 3.4 and 3.6 micro-m) is used to measure the concentration of oil content.

Solvent and hydrochloric acid are added to the sample, and the mixture is mixed well with a vibrator. The oil content in the sample is extracted to the solvent, and

water is separated from the solvent. The solvent is introduced to the infrared analyzer to measure the concentration of oil content. For the solvent, florochlorocarbon-316 is used.

The substances extracted with the solvent include hydrocarbons, hydrocarbon derivatives, animal and vegetable oil, and fatty acids.

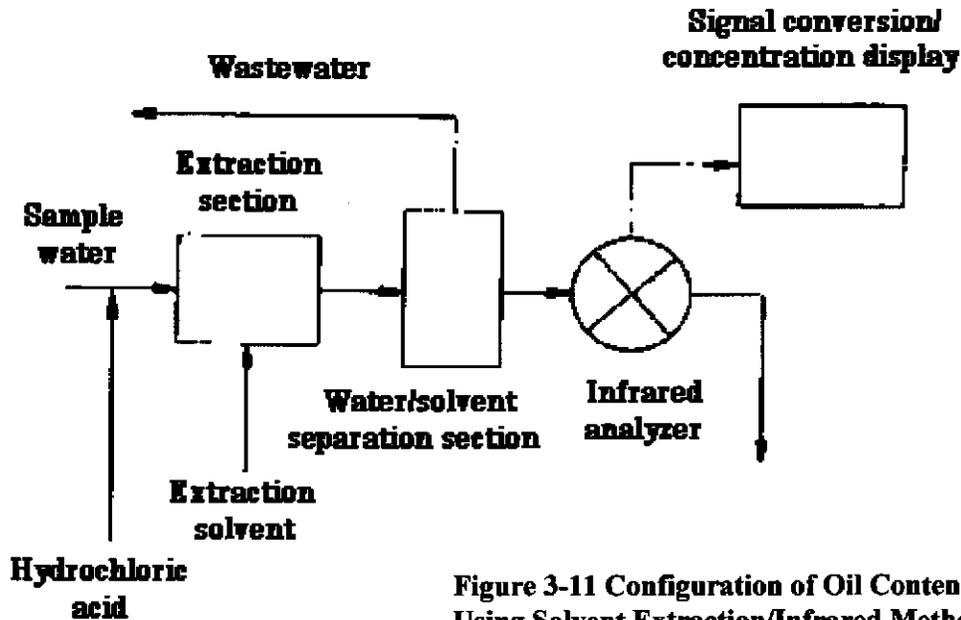


Figure 3-11 Configuration of Oil Content Meter Using Solvent Extraction/Infrared Method

The oil content meter (see Figure 3-11) is calibrated with an OCB-mixed standard solution. The extracted oil content is displayed as a value for OCB. The OCB-mixed solution is a standard mixture of 2,2,4-trimethylpentane (iso-octane), hexadecane (cetane), and benzene.

Cyanide Analyzer

The great toxicity to aquatic life and humans of molecular cyanogen (HCN) is well known. It is formed in a solution of cyanide by hydrolytic reaction of CN^- with water. The toxicity of CN^- is less than HCN.

To continuously monitor total cyanide in water, the analyzer utilizes the ultraviolet decomposition and membrane gas separation techniques to enable safely, stable and continuous measurement.

Firstly, the cyanide compounds are decomposed to cyanide ions by the ultraviolet lamp. Secondly the ion becomes the HCN under acidic condition. The gas permeates through the membrane into the carrier, NaOH solution, and turns back to be the cyanide ion again. Lastly the ion-selective electrode measures the cyanide concentration contained in the carrier. This configuration is demonstrated in Figure 3-12 below.

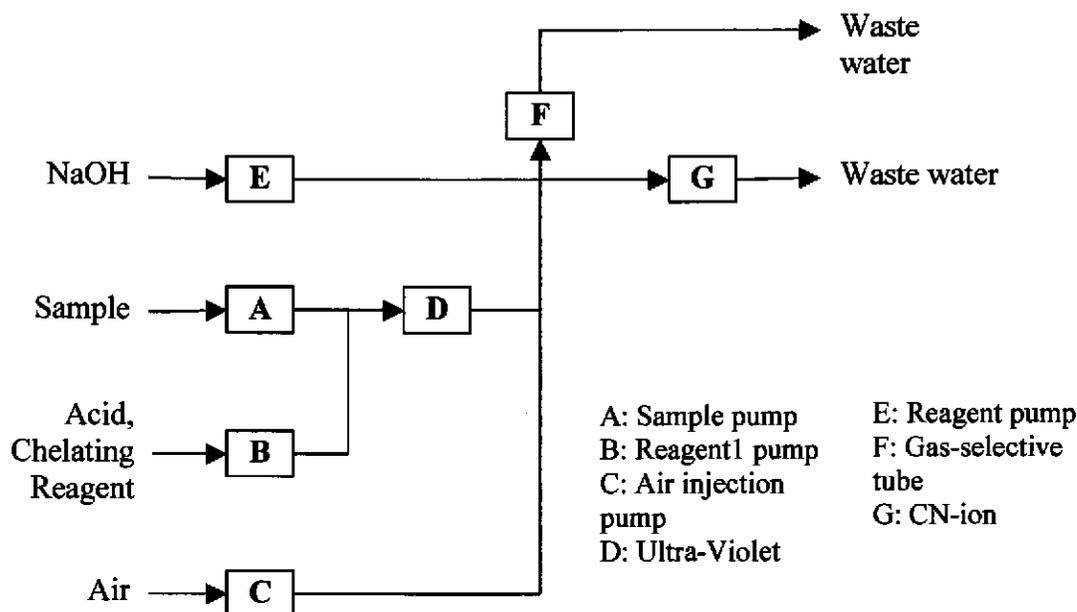
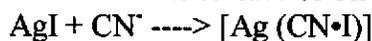


Figure 3-12 Configuration of Total Cyanide Analyzer

Principle of CN-electrode: The CN ion-selective electrode utilizes the following reaction on its surface of Silver Iodide:



The surface subjects to decay by this reaction and needs to be polished continuously for refreshment. This analyzer applies the Magnetic-Stirrer-type electrode, using an ever-polishing stirrer.

The electrode potential E (V) is derived from the following Nerunst equation: $E = E_0 - 0.059 \text{ p} [\text{CN}]$. For example, this equation reads the deference of the potentials between 0.1 and 1 mg/L [CN] is 59 mV. These potentials are not linear but obey on logarithm.

(12) *Total Phosphorus Analyzer*

Nitrogen and phosphorus are of great concern as eutrophication substances. When a closed water area or an ocean area is severely polluted with organic substances flowing into that area from a river, red tides and other abnormal phenomena occur frequently. Once the closed water area or the ocean area is polluted to such a degree, they cannot be restored in a short period of time. However, the occurrence of red tides must be prevented. Plankton takes in organic substances for its energy source. For its reproduction, plankton requires nitrogen and phosphorus, which are eutrophication substances, in addition to organic substances. Red tides occur where the necessary conditions (including temperature) exist. Therefore, if the amounts of nitrogen and phosphorus are low enough, the reproduction of plankton is suppressed. In order to prevent red tides, the concentrations of nitrogen and phosphorus must be decreased. It is thus imperative that total nitrogen and total phosphorus be measured.

Phosphoric compounds include inorganic phosphorus (orthophosphoric acid, condensed phosphorus, etc.) and organic phosphorous, and are collectively called total phosphorus.

The total phosphorus meter uses the thermal decomposition molybdate method or the photolytic decomposition molybdate method, among others.

- a. **Thermal decomposition method:** Potassium peroxodisulfate and sodium hydroxide are added to the sample, and then heated at 120⁰C for 30 minutes to decompose phosphoric compounds into phosphate ions. The decomposed sample is cooled at an appropriate temperature. Ammonium molybdate is added to the cooled sample. This sample is then reduced with L ascorbic acid to produce molybdate blue. The absorbance of this molybdate blue is obtained using a wavelength of 880 nm, and the concentration of total phosphorus is measured. This method corresponds to the official method used for manual analysis. See Figure 3-14 for an example.
- b. **Photolytic decomposition method:** Potassium peroxodisulfate is added to the sample. The sample is irradiated with ultraviolet rays are radiated to this sample at approximately 95⁰C to decompose the sample through oxidation. Phosphoric compounds are then decomposed into phosphate ions. L ascorbic acid is added to this solution, and zero calibration is performed. Sulfuric acid ammonium molybdate is added to color the solution, and then the absorbance is measured using a wavelength of 880 nm. The concentration of total phosphorus in the sample water is measured. In this method, ultraviolet rays are radiated to provide the same effect as thermal decomposition at 120⁰C. In addition, operations are performed at ordinary pressure (see below, Figure 3-13).

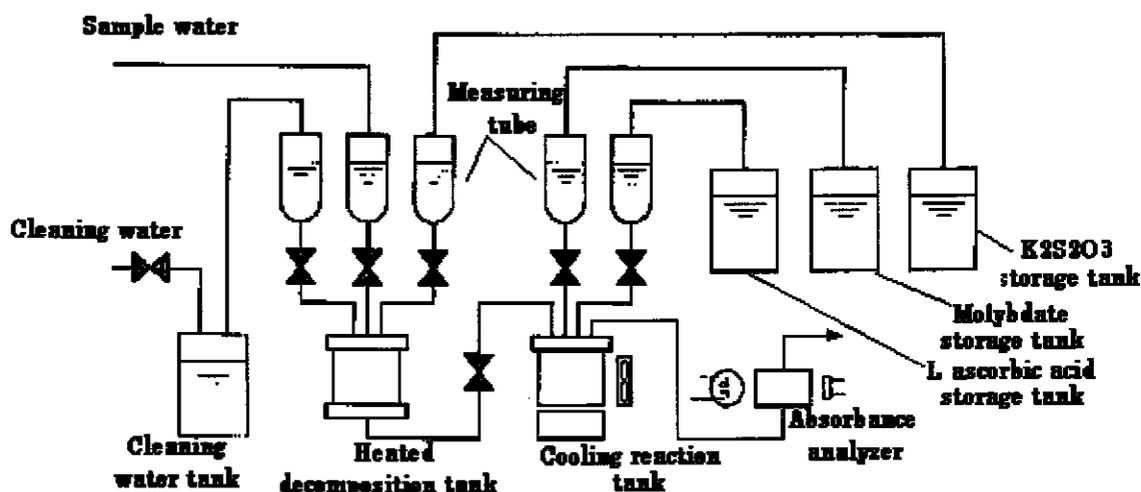


Figure 3-13 Configuration of the Thermal Decomposition Method

Therefore, the structure of the total phosphorus meter is very simple, and the maintenance is easy too. This method is characterized by its ability to provide data equivalent to that obtained by the thermal decomposition method.

(13) *Total Nitrogen Analyzer*

In water and wastewater the forms of nitrogen of great interest are, in order to decreasing oxidation state, nitrate, nitrite, ammonia, and organic nitrogen. All these forms of nitrogen, as well as nitrogen gas, are biochemically interconvertible and are components of nitrogen cycle.

Total nitrogen can be determined through oxidative digestion of all digestible nitrogen forms to nitrate, followed by quantization of the nitrate. This is done through two procedures; one using a persulfate/UV digestion, and the other using persulfate digestion. The procedures give good results for total nitrogen, compound of organic nitrogen (including some aromatic nitrogen containing compounds), ammonia, nitrite, and nitrate. Molecular nitrogen is not determined and recovery of some industrial nitrogen-containing compounds is low.

- a. **120°C Decomposition and UV Absorption Method:** Add the alkali solution of potassium persulfate to the sample and heat the mixture to approx. 120°C to transform all the nitrogen compounds to nitric acid ions. Control the pH of this solution to 2 to 3 using hydrochloric acid, and measure the absorption of nitric acid ions in UV zone to obtain the total nitrogen concentration. An example of total nitrogen analyzer using 120°C decomposition and UV absorptiometer is illustrated below. Sample is weighed and put into the sample water container. Specified amount of potassium persulfate and sodium hydroxide solutions are added to the sample and the mixture is put into the thermal decomposition chamber. In the chamber, the mixture is heated at 120°C C for 30 minutes to oxidize the

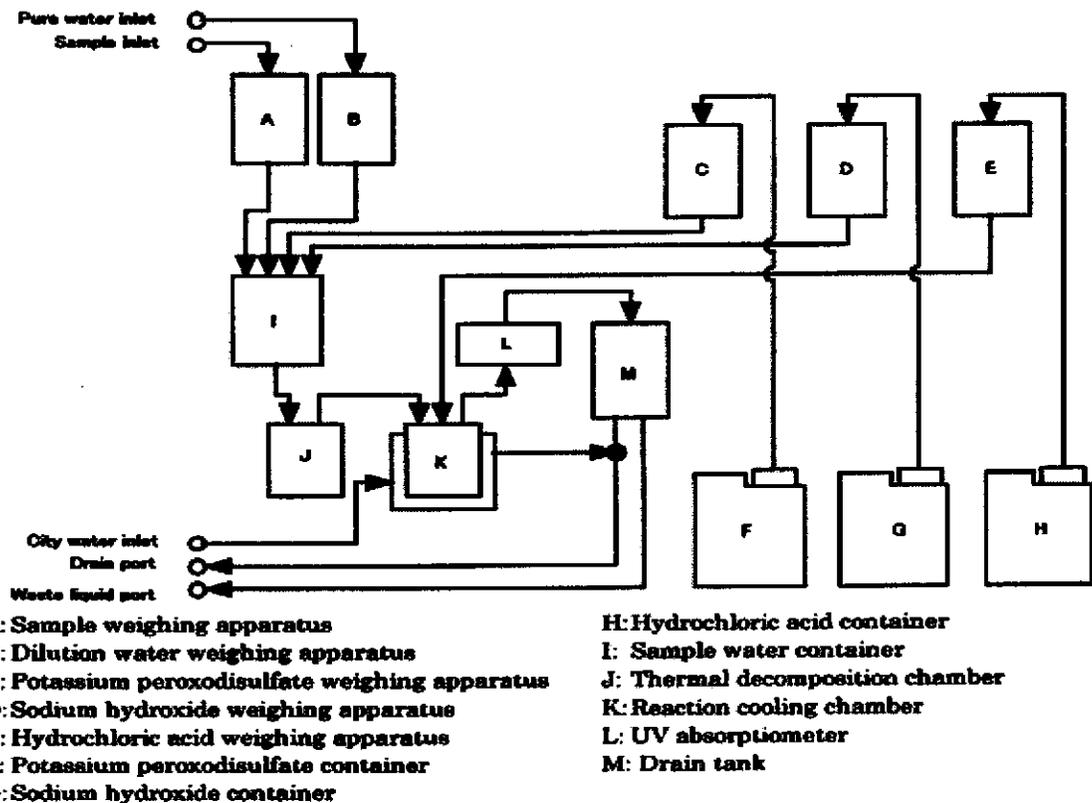
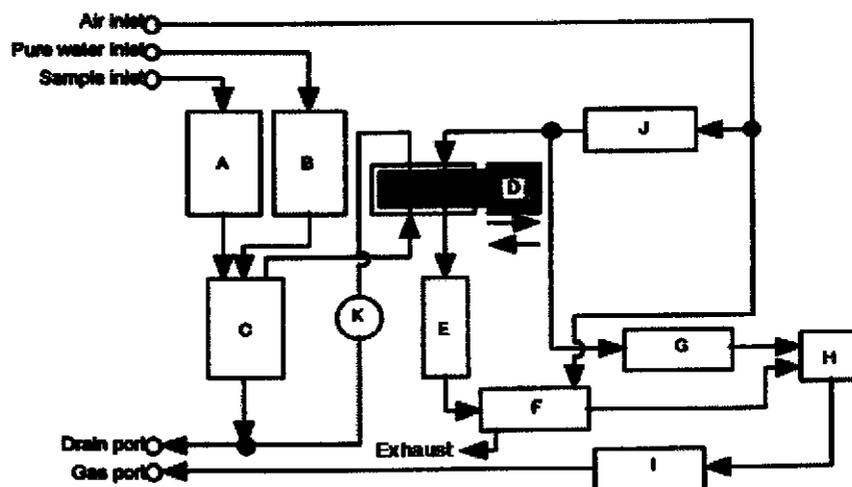


Figure 3-14 TN Analyzer of 120°C Decomposition-UV Absorptiometer

nitrogen compounds into nitric acid ions. The solution after the decomposition is put into reaction-cooling chamber to cool off. The cooled solution is then adjusted to pH 2-3 by adding hydrochloric acid. The absorbency of nitric acid ions in the solution is measured using UV absorptiometer at a wavelength of 220nm.

- b. Photo-oxidation Decomposition and UV Absorption-metric Method:** Add alkali solution of potassium peroxodisulfate to the sample and radiate ultraviolet ray to transform all the nitrogen compounds to nitric acid ions. Control the pH of this solution to 2 to 3 using hydrochloric acid, and measure the absorption of nitric acid ions in UV zone to obtain the total nitrogen concentration. An example of total nitrogen analyzer using photo-oxidation and UV absorptiometer is illustrated below (Figure 3-14). Sample is weighed and put into the mixing chamber. Specified amount of potassium peroxodisulfate and sodium hydroxide solutions are added to the sample and the mixture is put into the UV oxidation apparatus. In the chamber, the mixture is heated at 90°C and exposed to ultraviolet ray for 15 minutes to oxidize the nitrogen compounds into nitric acid ions. The solution after the decomposition is weighed and then adjusted to pH 2-3 by adding hydrochloric acid. The absorbency of nitric acid ions in the solution is measured using UV absorptiometer at a wavelength of 220nm.
- c. Catalytic Thermal Decomposition and Chemiluminescence Method:** Sample is reacted with oxygen using oxidation catalyst to transform the nitrogen compounds into nitric monoxide (nitrogen and nitrogen dioxide do not transform to nitric monoxide). When nitric monoxide is reacted with ozone, nitrogen dioxide in semi-stable status is produced. When the nitrogen



- | | |
|--------------------------------------|----------------------|
| A: Sample weighing apparatus | G: Ozone generator |
| B: Dilution water weighing apparatus | H: Detector |
| C: Mixing chamber | I: Ozone remover |
| D: Weighing valve | J: Zero gas purifier |
| E: Combustion tube | K: Pump |
| F: Dryer | |

Figure 3-15
TN Analyzer of Catalytic Thermal Decomposition – Chemiluminescence Method

dioxide in semi-stable status changes into stable nitrogen dioxide, it emits light and the strength of the light is in proportional to the concentration of nitric monoxide. Thus the total nitrogen concentration in the sample is identified by measuring the strength of the light. An example of total nitrogen analyzer using catalytic thermal decomposition and chemiluminescence method is illustrated above (Figure 3-15). Sample is weighed and then put into combustion tube, where the sample is heated to a high temperature and oxidized with oxidation catalyst into nitric monoxide. After oxidation, the sample is dehumidified with a dryer and fed into the detector, where the sample is reacted with ozone as below: $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2 + \text{hv}$. The strength of light of wavelength of 590 to 2500nm is measured.

(14) Oxidation-Reduction Potential (ORP) Meter

Oxidation and reduction reaction mediate the behavior of many chemical constituents in drinking water, process and wastewater as well as most aquatic compartments of the environment.

When metal is immersed in a solution, electric potential is detected according to that solution. This electric potential represents the oxidation or reduction force of the solution. This force (potential difference) is called the oxidation-reduction potential (ORP) of the solution, from which the oxidation or reduction ability of the solution can be obtained.

To measure the ORP, noble metals such as platinum and gold are used. Since the potential difference cannot be detected by merely using a metal electrode, a reference electrode is used in combination with the metal electrode.

Measuring Method: The ORP meter consists of a metal electrode, a reference electrode, and a potentiometer. The metal and reference electrodes are immersed in the solution to be measured, and then the electric potential between the two electrodes is measured. Thus, the ORP of the solution is measured.

The ORP meter is used for wastewater treatment. Since cyanic compound wastewater is very toxic, chlorine or a hypochlorous acid solution is generally added to decompose CN ions through oxidation. However, chlorine or a hypochlorous acid solution is minimized because it is strong oxidizing agent. It is used in the ORP meter to measure the ORP and to control the residual amount of hypochlorous acid. It is also used to monitor the reaction state of activated sludge in the activated sludge treatment process at a sewage disposal plant. In addition, chlorine or a hypochlorous acid solution may sometimes be used to measure the ORP of sedimentary sludge in rivers and other water areas so that the state of that sludge can be found.

The measurable range of the ORP meter is generally between -1200 and +1200 mV, between -1000 and +1000 mV, or between -700 and +700 mV.

(15) Chloride Ion Analyzer

Chloride is one of the major inorganic anions in water. The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. The chloride concentration is higher in wastewater than in raw water because sodium chloride is a common article in the diet and passes unchanged through the digestive system, thus, along the sea coast and river mouth, the concentration of chloride may be high.

Chloride ions to be measured in a water quality automatic monitoring station are measured by a chloride ion electrode in general. The chloride ion electrode is equipped with pressure-formed membrane mainly consisting of silver chloride as the sensor. Construction of the electrode is shown in Figure 3-16.

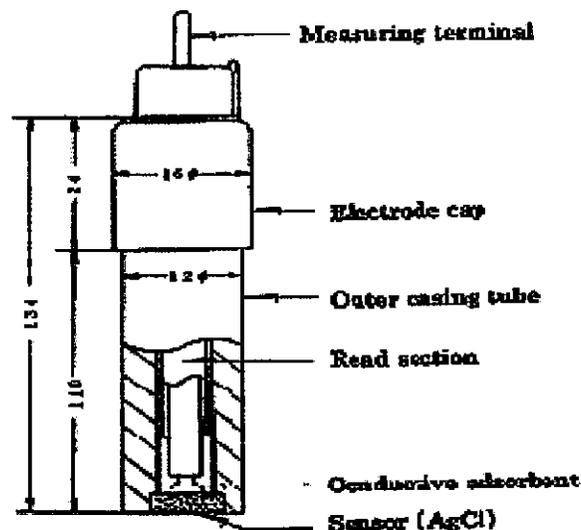


Figure 3-16 Construction of Chloride Ion Electrode

When this electrode is immersed in water containing chloride ions, electrode potential expressed by the Nernst's equation proportional to the logarithm of the chloride ion activity is generated.

$$E = E_a - 2.303 \frac{RT}{F} \log a_{Cl^-}$$

Where,

E: Generated electrode potential

E_a: Specific standard potential of chloride ion electrode

$$2.303 \frac{RT}{F} : \text{Nernst's gradient of } 59.15\text{mV at } 25^\circ\text{C}$$

a_{Cl⁻}: Chloride ion activity in the measuring solution

Accordingly, potential difference of ±59.1 mV to the concentration change of the 10-time chloride ion solution results. Chloride ions are measured by the chloride ion electrode based on this principle in combination with a reference electrode.

Determination of chloride ion by the chloride ion electrode can be determined almost free from influence by pH value of the sample. However, since it is affected by coexistence ion in the sample, special care should be taken to this effect.

(16) *Salinity Analyzer*

Salinity is an important measurement in the analysis of certain industrial wastes and seawater. It is defined as the total solids in water after all carbonates have been converted to oxides, all bromide and iodide have been replaced by chloride, and all organic matter has been oxidized. It is numerically smaller than the total dissolved solids and is usually reported as parts-per-thousand (ppt) or practical salinity units (PSUs).

Salinity is closely associated with conductivity and, in general, measured by the same sensor, with the instrument making the internal calculations converting conductivity to salinity. Salinity measurements range from 0-80 PSUs. Since some of the rivers in Jiangsu are known to be affected by tidal influence, salinity measures provide information on the extent of seawater intrusion locally.

3.4.5 **Continuous Biomonitoring**

In the States since the early seventies, chemical monitoring is supplemented with continuous biomonitoring, in which the organisms used at the beginning were fish; later a number of biomonitors were deployed in continuous monitoring either in flow-through systems or in-situ systems (*Daphnia*, algae, mussels, fishes and photo bacteria, etc.)

When evaluating water pollution with the aid of bioindicators, an understanding of an organism reaction to changes in its environment is essential. These reactions can take the form of growth and/or increased population density, modified activity, reduced growth, a decline in population, or even death. Depending on their degree of complexity, size, generation time and other factors, organisms and different species react at varying rates. Most bacteria adapt very quickly to environmental changes. Protozoa and algae take longer, and many of insects live for a year or longer as larvae in the same aquatic environment, require longer periods to react to changes in their surroundings. As a rule, organisms with longer generation times respond more quickly to negative changes, if they exceed the limits of what is tolerable, for example by migrating to zones with satisfactory living conditions or by dying. Depending upon the time which bioindicators or indicator organisms spend in a body of water, they are subjected to the prevailing environmental conditions and any changes that occur. Thus, members of a related group of organisms or a biological community integrate and reflect environmental conditions and possible changes over an extended period of time. Consequently, critical evaluation of the species compositions of a biocoenosis can yield sufficient data on the situation of a body of water and the range of fluctuations in the environment over a lengthy period of time.

The biomonitoring is an alternative to chemical test, and it is capable of rapidly detecting acutely toxic condition in water bodies. Depending on this distinctive feature they are referred to as Biological Early Warning System (BEWS). The

basic principal used is that of monitoring some functions of physiology and behavior, in a test organism which is changed when exposed to a toxic substance at a sufficient concentration. BEWS are automated continuous monitors which employ biological organisms as primary sensing elements.

Of all the biomonitoring methods that have been deployed so far, many have remained at a laboratory stage, only a few are really commercial available. In Table 3-9, some reliable continuous biomonitoring methods are shown.

Table 3-9 Methods of Continuous Biomonitoring

No.	Biomonitoring Method	Organism	Principal	Evaluation
1	Dynamic Daphnia Test	Daphnia magna	Swimming behavior by IR light sensor	Dynamic alarm thresholds
2	Luminous Bacteria Test	Photo-bacterium phosphoreum	Decline of luminescence	Comparison sample vs. control
3	Algae toximeter	Algae (various species)	Variable chlorophyll a fluorescence	Comparison sample vs. control
4	Biosens Algae Toximeter	Green algae	Spontaneous variable chlorophyll a fluorescence	Fluorescence parameter difference
5	FluOx-Algae Test	Algae (various species)	Fluorescence & oxygen production	Comparison of actual with former data
6	DF-Algae Test	Algae (various species)	Delayed fluorescence (DF)	Comparison of fading curves, sample vs. control
7	Dreissena-monitor	Bivalves (dreissena polymorpha)	Opening/ closing of valves	Comparison of activity patterns, dynamic alarm thresholds
8	Mossel-monitor	Bivalves (dreissena polymorpha)	Opening/ closing of valves, distance of valves	Comparison of activity patterns, dynamic alarm thresholds
9	Behavioral Fish Test	Golden fish	Behavioral parameters as video images	Dynamic alarm thresholds

Macrozoobenthos are good indicators of surface water quality, with reduction of pollution load, macrozoobenthos populations have reacted immediately. We suggest that Jiangsu should develop the monitoring and research on this aspect.

3.4.6 Collection and Transmission of Automatic Monitoring Data

In the remote countryside, where telephone and internet service are unavailable, the monitored data from AWMSs may be accumulated on recording paper or in a data logger, totaling the results once a day or once a week. Whereas, the communication and the internet service systems in Jiangsu Province are well

developed in comparison with most of the developing countries, which can take advantage of data transmission of the AWMSs.

As AWMSs generate large amounts of data there is a demand for advanced computer hardware and software which have to be able to handle a large number of data sets. In the States, a present practice has been made by using industrial standard software based on the Supervisory Control and Data Acquisition (SCADA). The functions of the SCADA systems for the AWMS include:

- Collection of automatic monitoring data;
- Supervision of the AWMS chain including operation and abnormal phenomena, such as power off, full scale over, pump stop, or maintenance, etc.;
- Process control and other relevant operation; and
- Generation of various easy-to-understand reports and charts.

Some of the SCADA systems installed for the AWMSs are based on the following sequence:

- The instruments located at a remote AWMS examine the parameters sending a signal to a local remote terminal unit (RTU) through an interface;
- The interface calculates the corresponding value using a device-specific function;
- The value is stored in the local database of the RTU;
- The Master Station transmits a periodic signal (usually once an hour) to the AWMS, ordering transmission of the data accumulated;
- Upon receiving the signal ordering the transmission, each of the AWMSs transmits the data and the operating situation of the measuring instruments;
- If there is a repeater, the data are transmitted from the RTU to a modem at the Master Station host, passing through the repeater;
- The data stored in the database of the Master Station are sent to an information-processing computer at the central environmental monitoring station. The computer processes data using scale transformation, abnormal codes for monitoring instruments, etc., and made ready to be displayed on easy to understand table and graphical display;
- In addition, operating conditions of measuring instruments are displayed on the monitoring screen and printed out if needed. At the same time, any abnormal condition of the monitoring instruments can be detected at any moment; then
- The values are compared against the alarm limits; the status indicator reflects the present alarm conditions.

In practice, there are various supplementary functions other than what has been mentioned above, therefore. The advantages in introducing such a teletransmission system are as follows:

- Since the teletransmission system can quickly grasp current conditions for water pollution and/or the stationary source, countermeasures for a pollution emergency can be delivered accurately;
- Since it allows collaboration with other surrounding local AWMSs, it shall enable to understand conditions for water pollution in a wide region;
- Since it is showed the operating condition of monitoring instruments, the malfunction of instruments can be responded and breaks in the reception of data can be avoided; and
- Since the data processing is automatic, it is more error-proof and faster than report data processing such as reading data from recording sheets.

We suggest that the JEPD and the JPEMC should enlarge their data sharing function for the AWMSs. The JEPD and the JPEMC should decide from beginning of the AWMS program that data would be easily accessed by the whole environmental community and other government authorities concerned to the water system. So the technical solution to disseminate data is a standard transmission of files with the TCP/IP protocol compatible with internet network. So data are available for all the entities mentioned above, with a high-speed and easy access according to modern means of communication. The JEPD and the JPEMC allow validation of measurement the day after analysis. The software includes control of access via a nominative password given to each user according to the policy.

3.4.7 Maintenance of the AWMSs

In order to collect reliable data in an AWMS, not only proper maintenance of analyzers but also smooth sampling and stable supply of sample water into analyzers is indispensable. For this purpose, various measures should be taken, including the automatic cleaning functions of sampling pipes and measurement tanks.

In this section, the Consulting Team gives some basic principals and methods for operation and maintenance of the AWMSs, which the JPEMC and the municipal monitoring labs can take as the reference for writing their own operating and maintenance manuals of the AWMSs.

As for water quality monitor including pH, dissolved oxygen (DO), conductivity and water temperature, etc. The front panel of the measurement tank is made of transparent material so that the conditions inside the tank such as sample water flow, contamination on the electrode surface and/or tank and the automatic cleaning conditions are visually confirmed.

Periodic maintenance is indispensable for collection of stable and reliable data. Periodic maintenance such as replenishment of reagents and analyzer calibration must be performed once every one or two weeks and the electrode, control tank, distribution pipes and sampling pumps should be cleaned on a weekly basis.

(1) General Matters

Contamination of the sampling pipe and control tank may affect the data quality;

they should always be kept clean. Clogging of the sampling pump prevents sample water from being properly fed into analyzers and results in measurement missing. Therefore, the sampling pump must be cleaned and checked for any abnormality at least once a week. Additional cleaning and inspection of the sampling system should be performed if the river water is significantly contaminated after a heavy rain, etc. In addition to the maintenance of analyzers and sampling system, the indoor environment of monitoring stations must be properly maintained. For example, air conditioning and ventilation are necessary in order to prevent measurement equipment from being affected by high temperature and humidity in summer.

(2) Sampling Channel

It is recommended to install two sampling channels for alternative operation, which can prevent measurement missing even when a pump trouble and/or clogging of sample water intake occur to either channel.

Sampling pipes and a pump should be equipped with automatic cleaning functions. The automatic cleaning function should be set to turn on at a proper interval according to the pollution condition of the river.

- a. **Sampling pump:** A submerged pump is often used for sample water collection due to the higher reliability, ease of repetitive operation and the availability of automatic cleaning function.

The main trouble of sampling pumps installed in a river is clogging of intake port (strainer). To prevent the clogging of strainer, automatic cleaning of strainer on a periodic basis is often used. The automatic cleaning method generally used is "Inverse flow cleaning". This method requires installation of a pump specifically used for cleaning. The cleaning pump feeds pressurized water (tap water) to the sampling pump to flush out the contaminants accumulated at the intake of the sampling pump.

In addition to the automatic cleaning, it is necessary to take the sampling pump out of water and clean the contaminants (plastic substances, weeds and algae, etc.) which were not removed by automatic cleaning, using brushes.

Placing the intake of sampling pump in a basket made of stainless steel net as shown in Figure 3-17 is effective to prevent intake port clogging.

A sampling pump with sufficient margin of capacity should be selected to avoid water quality fluctuation (water temperature, DO and turbidity, etc.) in the process of sample collection. For example, a 200V-750W pump is recommended for a case where the length of sampling pipe is less than 50m and the pump head is approximately 5m. Sampling pumps made of stainless steel is recommended due to the lightweight and anti-corrosive feature.

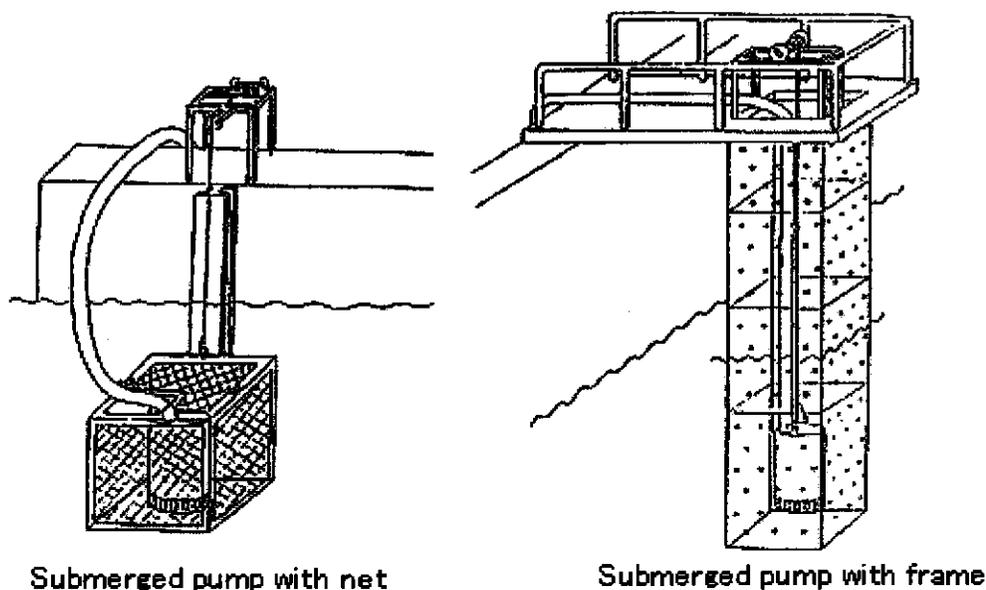


Figure 3-17 Installation Method of Submerged Pump

- b. Sampling pipe:** Steel pipes with inner surface coated with vinyl chloride or pipes made of hard vinyl chloride are generally used. Inner diameter of these pipes is normally 45 to 50mm.

Several meters of thick flexible vinyl hose is used for the connection of sampling pipe and submerged pump for ease of pump lifting for cleaning. Although sampling pipes made of steel have semi-permanent service life due to the strong endurance against corrosion, flexible tubes at the connection must be replaced once a year.

The monitoring results are affected by contamination of the sampling pipes and it is very important to keep them clean. If sampling system is not equipped with automatic cleaning function, it is necessary to disassemble and clean the pipes with a brush, etc. on a periodic basis. Therefore, sampling pipes should be designed to allow disassembling at the flange portion.

When distributing sampling pipes, the distance between the sampling pump and monitoring station must be minimized. The shorter distance allows for there to be less sample water quality fluctuation. Maintenance is also easily performed. In order to prevent sample water quality change and deterioration of pipes, the sampling pipes should be installed in a U-shaped duct and the top of the duct should be covered to prevent exposure to direct sun light.

- c. Control tank:** Sample water collected by sampling pump passes through rough and fine screens for removal of non-dissolved contaminants and is fed into analyzers. The screens are automatically flushed out with tap water once every few hours (it is normally cleaned simultaneously with the automatic cleaning of sampling pipe).

Contaminants on inner walls of control tank and screens and sediments on the bottom may not be removed by automatic cleaning and it is necessary to clean

them once every week. In particular, accumulation of a large amount of sand and dirt is expected after a heavy rain, and cleaning of each part should be carefully performed.

Automatic cleaning cannot be available for some portions of piping system. Therefore, piping distribution should be designed so that the disassembly and cleaning are easily performed. Valves in the piping should be minimized to prevent troubles due to valve clogging. If a use of valve is unavoidable, use a ball cock instead of normal valve.

d. Drain system: Waste liquid is discharged either by "natural flow" or "forcible drainage" depending on the location of the AWMS. The natural flow uses the height difference between the monitoring station and river, whereas the forcible drainage is used when the waste liquid cannot be discharged naturally.

In either case, the waste liquids from a monitoring station must be discharged to the river at the downstream of the sampling point to avoid the discharged waste liquids from being mixed with the water collected as the sample.

When waste liquids are discharged by means of natural flow, the diameter of discharge pipe should be large enough to prevent clogging due to mud, sand and/or algae. Pipes with an inner diameter of approx. 100mm are generally used.

In the case of forcible discharge, it is necessary to install a waste liquid pit of about 2 m² and a drainage pump with a capacity equivalent to or greater than that of sampling pump should be used. As the measures against pump failure, the drainage pump should be designed to automatically shut off upon receiving an alarm signal indicating that the upper water level limit of the waste liquid pit is reached.

The pump's intake port and water level sensor are easily contaminated and frequent cleaning is necessary. Periodic removal of sediment on the bottom of the drain pit is also necessary.

(3) Maintenance of Peripheral Facilities

An AWMS should be designed not only for protection of analyzers from rain and wind, but also to assure proper measurement environment and ease of maintenance. Ventilation and air conditioning equipment would be necessary. Refrigerator for storage of calibration solution and reagents, testing tables and a sink for preparation of reagents and shelves and containers for storage of chemicals and mechanical spare parts should be installed.

In order to attain smooth operation of automatic monitoring stations, maintenance of peripheral facilities such as water supply, power supply and drainage treatment is indispensable in addition to the maintenance of analyzers.

The containers for storage of chemicals and monitoring station building should be locked for security. Further security of station building and sampling location should be assured by means of locks and fences.

- a. **Tap water facility maintenance:** A tap water facility is necessary for maintenance. At the weekly inspection, the amount of water used after the previous inspection should be checked by reading the water gauge to check for leakage; faucets should be installed for ease of access to clean the analyzer tanks.
- b. **Electric facility and power consumption:** An AC power panel supplies should have circuit breakers. The power consumption by the station is checked on a weekly basis to check for any abnormality. Since automatic analyzers are easily affected by noise, power distribution to equipment with heavy load fluctuation should be separated from the line to analyzers. Each power line should be provided with a circuit breaker and must be grounded. A power panel should be provided with proper margins to cope with the increase of power needs in the future.
- c. **Management of chemicals:** Chemicals must be stored in a proper cabinet and the inventory must be checked at the time of periodic inspection. Chemicals include toxic or harmful substances and the cabinet of these chemicals must be locked for security purpose. Emptied chemical containers and bottles must be cleaned with water two (2) to three (3) times before disposal.
- d. **Waste liquid treatment:** Waste liquid after analysis and calibration should be safely stored in a drainage container and treated properly before discharge to public water area or sent to designated waste water treatment contractor for treatment.

3.4.8 Calibration and Maintenance of the Instruments for AWMSs

The correct routine calibration and maintenance of the instrument in an AWMS is an important step to collect reliable data. The specifications of analyzers may vary according to the manufactures even when they are designed for the same measurement parameters. Therefore, it is necessary to establish proper calibration and maintenance plan according to the specifications and features of each analyzer by referring to the instruction manuals. When establishing the plan, the pollution level of the target water area should be taken into account.

Generally, a calibration check using known standards is performed on cleaned monitoring sensors. If the monitor sensors are outside the range of acceptable differences, the sensor must be recalibrated. If the calibration-check sensor readings for the monitor are within the calibration criteria, the monitoring sensors are considered checked and no further adjustments are required. All sensor readings are recorded in the field notes, and all calibration information is recorded in the monitor instrument log. The calibrated monitoring sensor is then returned to the water body and allowed to equilibrate to the water temperature. The observed difference between the cleaned sensor calibration check reading and the calibrated sensor reading is a result of drift. The calibrated sensor stream

reading is the beginning observation of the new water quality record interval. If the calibrated monitoring sensor fails to agree with the calibrated field meter within the calibration criteria, the faulty sensor must be repaired or replaced after verifying that the readings of the field meter are not in error.

When a parameter cannot be calibrated with standard solutions, the maintenance personnel must determine if the problem resides with the monitoring sensor or with the monitor itself and make necessary corrections to ensure that the monitor is operational. The maintenance personnel should carry spare sensors so that troubleshooting, if necessary, can be accomplished at the time of the service visit. The troubleshooting in the field can prevent the need for extra trips and greatly reduce both lost records and time spent in processing records in the office later. Some of the more common problems that are likely to be encountered in the field when servicing monitors are generally provided in the manufacturer's equipment manuals.

The tables below (Table 3-10 to Table 3-20) list procedures and attention points for calibrations and maintenance of the widely using analyzers in the AWMSs. We recommend that the JPEMC add some of these useful items to work out its own QA/QC operation manuals.

Table 3-10 Calibration and Maintenance of pH Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Calibration reference solutions <ul style="list-style-type: none"> a) Zero calibration: pH7 reference solution (neutral phosphate solution) b) Span calibration: pH4 reference solution (phthalate acid) for samples of pH7 or less; pH9 reference solution (borate) for samples of over pH7 • Calibration: <ul style="list-style-type: none"> a) Clean electrode with pure water and dry well before placing it into calibration solution. b) An electrode is made of thin glass and easily damaged. It is recommended to use a plastic container and electrode holder to prevent damage to the electrode during calibration. c) The pH of reference solution changes according to the temperature of the solution. Keep the reference solution to the same temperature as that of the sample water. The calibration value should be confirmed based on the solution temperature. d) Calibration solution after use must not be returned into solution container, but be disposed of. e) Check the following factors if measurement stabilization took a long time: <ul style="list-style-type: none"> -Electrode contamination: Clean electrode with acidic solution. -Clogging due to crystallization of the solution contained: Replace the solution. -Deterioration of the solution contained: Replace the solution. -Clogging due to contamination on the ceramic part of reference electrode: Cleaning or replacement of the ceramic part. -Electrode is defective: Replace the electrode. 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Check the stabilizing time and response of measurement after automatic cleaning. Need of a long time before stabilization may indicate electrode contamination and/or low flow rate of sample water. • Remove the contamination on the electrode using soft and wet paper (specially prepared for cleaning). Care should be exercised to prevent damage to the electrode membrane during cleaning. Use detergent to remove oily contaminants, and hydrochloric acid (approx. 0.1mol/L) for removal of inorganic contaminants. Contamination on membrane may not always be detected by visual check and there are cases when electrode does not function correctly even if it looks clean. In such a case, measurement error may occur despite the correct calibration of the electrode. It is recommended to clean the electrode with hydrochloric acid (approx. 0.1mol/L) more than once a month. • Check the level of electrode solution and replenish or replace as necessary. • Confirm the proper function of automatic cleaning.

Table 3-11 Calibration and Maintenance of Dissolved Oxygen (DO) Meter

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Standard solutions for calibration: <ul style="list-style-type: none"> a) Zero calibration: 5% sodium sulfite (anhydrous solution); b) Span calibration: Pure water saturated with air • Clean the electrode with pure water and dry well prior to placing it in a calibration solution. In particular, the solution for zero calibration must be completely removed from the electrode before span calibration. Contamination by zero calibration solution will result in a significant error of the span value. • The pH of calibration solution changes according to the temperature of the solution. Keep the calibration solution to the same temperature as that of the sample water. The calibration value should be confirmed based on the solution temperature. • Calibration result is affected significantly by flow rate. Calibration must be performed with the flow rate correctly set. • Make sure that the membrane is free from air during calibration. It should be noted that the membrane is easily contaminated with air during span calibration. • If significant fluctuation of salt concentration is expected (e.g. tidal rivers), span calibration should be performed, taking into account the measurement error resulted from chlorine ion concentration. • A long stabilization time, difference of data from those obtained by non-automatic analysis and/or unsuccessful calibration often indicates problem of internal solution or defective membrane. • Cross check with the values measured by non-automatic analysis 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Remove contaminants on the electrode main unit and membrane using soft and wet paper, etc. (manual cleaning) • Make sure that the automatic cleaning is properly functioning.

Table 3-12 Calibration and Maintenance of Turbidity Meter

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Standard solutions for calibration: -Zero calibration: Pure water; -Span calibration: Reference calibration solution provided • When the zero calibration solution flows using the surface scattering method, adjust the solution level to the same condition as that for sample measurement. If the reading does not stabilize, there may be air trapped in the zero calibration solution. Check the water level in the water tank. The pipe joints should also be checked for looseness. • The reference calibration plate must be correctly positioned because a dislocation may result in an error of span value. • In addition to the span calibration with standard calibration solution, periodic span calibration should be performed using different reference solution. • Prepare a span solution of a known concentration using formazine or kaolin, and measure the span under the same condition as that of sample measurement. Calibrate the span based on the value measured and correct the value of standard calibration solution as necessary. It is recommended to perform an easy check of measured value of the sample during maintenance using transparency meter. • Precautions on measurement: <ul style="list-style-type: none"> -If the materials of analyzer, piping structure and/or the method of automatic cleaning are not suitable for the water quality of the target river, correct measurement cannot be achieved. Analyzers optimal for the water quality of the target water area must be selected. -When the sample water circulation rate in the tank is low, suspended substances may be produced in water and result in a measurement error when the surface scattering method is in use. -Contamination on the detector window may significantly affect the measurement results. Automatic cleaning method suitable for the water quality must be selected. -Water with high concentration of salt such as tidal rivers causes corrosion of analyzer main unit. Analyzers made of proper materials should be selected for durability and longer service life. 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Clean the measurement tank, sample and drain pipes with a brush, etc. and remove contaminants on the lens using soft paper, etc. (manual cleaning) • Make sure that the automatic cleaning is properly functioning.

Table 3-13 Calibration and Maintenance of Electrolytic Conductivity Meter

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Zero calibration: Leave the electrode in pure water or in air. • Span calibration: Use reference solution whose electric conductivity is known and the maximum range is 80 to 90%. • The electrode should be cleaned with pure water and dried prior to zero and span calibrations. • Need of a long time before stabilization or poor reproduction of measured value may indicate a change of cell constant due to contamination. Remove the contaminants using polishing powder or sandpaper. • Cross check with the values measured by manual analysis 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Remove contaminants on the electrode using wet paper, etc. (manual cleaning) • Make sure that the automatic cleaning is properly functioning.

Table 3-14 Calibration and Maintenance of Temperature Meter

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Standard Calibration: -Zero calibration: False resistor of the maximum range of 0%; -Span calibration: Set the water thermometer to the normal measurement condition and calibrate based on the value read by a glass-stick type reference mercury thermometer (50°C). • If the span calibration under normal measurement condition is difficult due to the significant fluctuation of momentary water quality (e. g. tidal rivers), put sample water into a proper container and calibrate the thermometer by placing the detector and a glass-stick type reference mercury thermometer (50°C) into the water. • Cross check with the values measured by manual analysis Measure the water temperature with the glass-stick type reference mercury thermometer and compare the data in the same manner as that for span calibration. 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Remove the contaminants on the electrode with wet paper, etc.. If the contaminant is hard to remove, clean with polishing powder and/or sandpaper.

Table 3-15 Calibration and Maintenance of COD_{KMnO4}

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • After completing the maintenance, follow the procedure below using the specified heating time for calibration: <ul style="list-style-type: none"> a) Zero calibration: Replace the sample water with distilled water and measure. Calculate mean value from 2 to 3 stable measured values. b) Span calibration: Replace the distilled water with reference solution and measure. Calculate mean value from 2 to 3 stable measured values. c) Zero and span calibration: Perform zero and span calibration using the method specified in the specification of the analyzer. • Do not replace reagents or clean the detector electrode during or after calibration. Change of reagent concentration and the sensitivity and position of electrode will cause changes of measured value. Re-calibration is necessary should reagent be replaced or electrode be cleaned. • Cross check with the values measured by non-automatic analysis • Precautions on measurements by alkali method <ul style="list-style-type: none"> a. Dissolution of glass components Thermal reaction under alkali condition will dissolve the glass container and result in a hole. • The significance of dissolution varies according to the alkali concentration and reaction temperature. Replacement of glass container may be necessary once every 3 to 4 months. At this time, glass components in contact with alkali solution, such as detector electrode, injection and measuring tubes, should also be replaced. • Titration end point setup: The titration end point of samples with high salt concentration must be determined, taking into account the fact that the ORP potential range for end point detection is narrower than that of other samples 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Check the analyzer for insufficiency of reagents. Replenish or replace the reagents as necessary to prevent measurement missing due to lack of reagents. • Sample water, dilution water and reagents are fed by air pressure or injection pump. Poor tightness and/or defective check valve will result in a failure of solution supply. Make sure that the water and reagents are properly fed. • Air trapped in titration pipe will cause fluctuation of reagent injection and result in improper measurement. Air is easily trapped in solenoid valves due to the temperature fluctuation. Do not fail to purge the air from solenoid valves. • Confirmation of operational sequence and amount of sample water and reagents, cleaning of end point detection electrode and temperature check of heating tank are all important maintenance tasks. • Waste solution after measurement is fed into neutralizing tank, where alkali solution is automatically fed to neutralize the waste solution with checking pH through pH test paper, thus the wastewater is finally discharged into public water area.

Table 3-16 Calibration and Maintenance of Ammonium Ion Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • Zero calibration: Reference solution with known ammonium ion concentration and the maximum range of approx. 10% • Span calibration: Reference solution with known ammonium ion concentration and the maximum range of approx. 50% • Adjust the reference solution to the specified pH. Use a mixer equipped with a temperature control plate and calibrate by keeping the solution temperature to that of constant temperature tank. • The membrane is easily contaminated with air. Check for air accumulation on the membrane during calibration to prevent erroneous data. • Since ammonium easily evaporates, calibration must be completed in a shortest possible time. If calibration takes a long time, the calibration solution should be replaced. • pH electrode and water thermometer should also be calibrated on a periodic basis. • (3) Cross check with the values measured by manual analysis Cross check during maintenance is impossible due to the need of equipment and time. Samples collected manually or automatically should be sent to a laboratory equipped with proper analyzers and subject to the specified manual analysis. Thus obtained data is used for cross check. 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Make sure that the temperature setup of constant temperature tank is proper, and correct if necessary (to a value higher than the sample water temp. by approx. 3°C). • Check the factors which may affect the measurement results, including the adjustment pH value, operational conditions of mixer and injection conditions of sample water. • Check the analyzer for insufficiency of reagents. Replenish or replace the reagents as necessary to prevent measurement missing due to lack of reagents. • Clean the electrode with 10%hydrochloric acid to remove the accumulating contaminants. The internal solution and membrane should be replaced on a periodic basis. The replacement frequency varies according to the water quality of the target area. Alkali constant temperature chamber, mixing rod, pH electrode, water thermometer, sample injection tube and the check valve of sample injection pump should also be carefully cleaned. • f. Waste solution after measurement is neutralized in the neutralization tank by hydrochloric acid solution that is automatically fed, and then discharged into public water area. Check the waste solution using pH test paper before discharge to make sure that the solution is properly neutralized.

Table 3-17 Calibration and Maintenance of Cyanide Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • -Zero calibration: .1mg CN/L reference solution; • -Span calibration: 1.0mg CN/L reference solution • Cross check with the values measured by manual analysis Cross check during maintenance is impossible due to the need of equipment and time. Samples collected manually or automatically should be sent to a laboratory equipped with proper analyzers and subject to the specified non-automatic analysis. Thus obtained data is used for cross check. It is recommended to perform an easy check of measured data using a water test kit. 	<ul style="list-style-type: none"> • Check the measurement data recorded after the previous maintenance to check for any measurement abnormality. • Check the analyzer for insufficiency of reagents. Replenish or replace the reagents as necessary to prevent measurement missing due to lack of reagents. The solution feed rate can be confirmed simultaneously with the checking of the remaining amount of reagents. • Check the factors which may affect the measurement results, including the operational conditions of mixer and injection conditions of sample water and reagents. • Measurement and reference electrodes should be polished once every month and the solution contained in the reference electrode should be replenished or replaced at the same time. • Pipes should be cleaned or replaced as necessary depending on the contamination condition. Gas penetration-separation pipe should be cleaned with acid or replaced as necessary. • Waste solution after measurement is neutralized in the neutralization tank by hydrochloric acid solution, which is automatically fed, and then discharged into public water area. Check the waste solution using pH test paper before discharge to make sure that the solution is properly neutralized.

Table 3-18 Calibration and Maintenance of Total Phosphorus Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • A total phosphorus analyzer using absorptiometry based on potassium peroxodisulfate decomposition and molybdenum blue (ascorbic acid) should be calibrated once every 7 to 10 days. • Measurement should be repeated more than twice in calibration mode using 1.0mg/l potassium dihydrogenphosphate standard solution and the mean value of the span voltage is entered (1-point calibration). • It is recommended to exclude the data read at the first measurement. • It should be noted that there are some analyzers requiring 2-point (zero and span) calibration. • If the measurement range is less than 1mg/l, standard solution of 1mg/l must be used. • If the measurement range is 0-0.5mg/l and 0-1.0mg/l, 1.0mg/l standard solution must be used for both measurements. (When the measurement range is set, CPU will automatically recognize it and process the data.) • For a measurement range more than 1.0mg/l, dilute the sample and set the range based on the dilution factor. This is due to the fact that the max. sensibility of any analyzer is set to 1mg/l. Therefore, the standard solution used should have the concentration equivalent to the max. value of the measurement range • Reagents should be replenished once every 7 to 10 days. Ascorbic acid and ammonium molybdate solutions will deteriorate if they are preserved; these reagents should be replaced for each measurement. 	<ul style="list-style-type: none"> • If a lamp alarm is output, replace the light source lamp. • If the necessary quantity of light cannot be recovered after the lamp replacement, replace the interference filter. It is recommended to replace them on a periodic basis (1 to 2 years). • Reagent tank should be cleaned simultaneously with the reagent replacement. The tank, measurement tube and pipe of sample water must be cleaned once every 1 to 2 months. • Disassembly and cleaning of cell block and rotor check should be performed once every 6 months.

Table 3-19 Calibration and Maintenance of Total Nitrogen Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • A total nitrogen analyzer using absorptiometry based on potassium peroxodisulfate decomposition and ultraviolet ray should be calibrated once every 7 to 10 days. • Use pure and potassium nitrate solution for zero and span calibrations, respectively. The standard solution should be of the concentration equivalent to the maximum value of the measurement range (5.0mg/L standard solution for measurement range of 0-5.0mg/L). • Measurement should be repeated more than twice in calibration mod and the mean values of the zero and span voltages are entered. • It is recommended to exclude the data read at the first measurement. • Reagents should be replenished once every 7 to 10 days. • Use highly pure reagents. In particular, potassium peroxodisulfate specially prepared for the analysis of nitrogen and phosphorus should be used. • The purity of pure water should be as high as possible. 	<ul style="list-style-type: none"> • In the case of a ceramic autoclave, there may be pin holes after 2 to 3 years of use due to the alkalinity on inner surface, resulting in solution leakage. If pin holes are found, band-heater should also be replaced. It is recommended to replace the autoclave and band-heater on a periodic basis. • If a lamp alarm is output, replace the light source lamp. If the necessary quantity of light cannot be recovered after the lamp replacement, replace the interference filter. It is recommended to replace them on a periodic. • The tank, measurement tube and pipe of sample water must be cleaned once every 1 to 2 months. • Disassembly and cleaning of autoclave, including the replacement of sealing O-ring, should be performed once every 6 to 12 months.

Table 3-20 Calibration and Maintenance of Total Organic Carbon Analyzer

CALIBRATION	MAINTENANCE
<ul style="list-style-type: none"> • The measurement range of combustion oxidation / non-dispersion type infrared ray TOC analyzer can be freely set within a range from 0-10mg/l to 1000mg/l. The proper measurement range should be set based on the concentration variation of sample water. • Calibration is performed at 3 points - zero, top span and half span due to non-linear output. Pure water and potassium hydrogen phthalate solution is used as the standard solution for zero and span calibrations, respectively. Measurement in calibration mode is repeated 3 times each (the first measurement is excluded) and the mean value of the displayed voltage values are entered (overwritten) on CPU. 	<ul style="list-style-type: none"> • Cleaning of sample water weighing tube, IC removal tube, buffer tube, sample water pipe and sample water tank, and replacement of pinch valve tune and titration pipe (injection needle) are replaced once every 1 to 2 months (titration pipe many be cleaned and reused). It is necessary to replace CO₂ absorbent (sodar lime and molecular sheave) and combustion tune (replace the quartz wool and clean the platinum catalyst with hydrochloride) once every 3 to 6 months. • If the base voltage of the non-dispersion infrared analyzer exceeds the preset level, disassemble and clean the detector (cell pipe and cell window, etc.). It is recommended to replace the dust filter at this time. The replacement frequency of the dust filter will vary according to the measurement frequency. • To maintain the measurement accuracy, visual inspection of operational conditions (pressure gauge, flow meter and water level at trap, etc.) and a pH check (litmus paper) inside the IC removal tube (pH 4.0 or under) should be performed during daily work.

3.5 Discussion and Recommendations to Mobile Water Monitoring Laboratories

Mobile water monitoring laboratories (MWML) are a convenient way to provide emergency examination and analysis in case of water contamination accidents as well as spot- check-examination for evaluation of water monitoring qualities among the AWMSs. In the States, MWMLs play an increasingly important role in the water environment monitoring.

The JEPD has a plan that calls for three MWMLs to be purchased before 2005; one for the Southern, Northern and Central parts of the province. Based on these areas, the water systems and the population of the each part, we believe that it is a reasonable decision.

Some firms in the State, such as Medicoach, Wolfcoach, American Emergency Vehicles, Ford Truck Body Builder and Canberra, etc., supply turnkey mobile laboratory, which include design, equipment selection, training and installation of the MWMLs, the custom-designed MWMLs are also commercially available in the USA. The vehicles can be light, medium or heavy duty self-propelled, and gooseneck, towed or drop-frame semi- trailers as well.

3.5.1 General Considerations and Requirements for Designing MWMLs

The laboratories based on the vehicles should be comprehensive, reliable, spacious and comfortable. The following are general considerations and basic facility needs for designing the MWMLs. We suggest that the JPEMC may add some of the following items to its bidding documents if the MWMLs are purchased through a bid.

- The vehicle body shall be insulated on its sides, ends, floor and ceiling with foamed-in-place urethane insulation. The insulation offers optimum environmental protection; added support to the side, ends and roof; prevents entrance of moisture; and acts as a sound retardant.
- Solid, anti-corrosion and shock-absorption floor, the floor shall be surfaced with Armstrong, or an equally, heavy-duty cushioned vinyl linoleum.
- Lighting system: Standard fluorescent lights shall be surface-mounted on the interior body ceiling within plastic diffuser panels or beneath cabinets above the work surface to give a minimum light density of 75 foot-candles at working distance in all parts of the vehicle. Diffusers shall be equipped with latching device to prevent falling in transit; and 12-volt dome lights shall be provided at each door entrance and within the exterior body compartment. In addition, the installation of a floodlight on the unit exterior at each door entrance; this shall be controlled by interior switches.
- Power distribution system (power panel): Unit shall be wire to receive 4-wire, 120/240 volt, 50/60Hz, AC, single phase, 60A power from a generator-on-vehicle or local power source via lead-in cable.
- Ventilation system (fume hoods) shall be installed on street sidewall of a vehicle.
- Fresh air inlet with a filter.
- Installed air conditioning.
- Refrigerator for storing water samples and reagent.
- Electric generator.
- Battery.
- Water supply system (Tank).
- Drainage system (dirty water and waste liquids tank).
- GPS and GDS locator.
- Voltage stabilizer for computer and instruments.
- Electrical service raceway.
- Mobile communication system.
- Seats for laboratory technician (provide and secure upholstered lab stool with backrest).
- Overhead cabinets.
- Anti-corrosion testing benches with drawers and cabinets.

- Data handling desk.
- Solvent cabinet with ventilation.
- Provide slide-out trays and securing devices for gas bottles.
- Travel cover and awning windows.
- First-aid appliances.
- Potable water sampler.
- Portable flow meter.



A Mobile Water Monitoring Laboratory in the USA

3.5.2 Instrumentation and Configuration in MWMLs

Numerous technologies currently exist in the US for mobile lab on-site analyses. Some of the more recent developments include X-ray fluorescence, portable gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS).

In recent years, X-ray fluorescence has found increasing acceptance as a tool of choice for rapid, nondestructive elemental analysis. X-Ray Fluorescence (XRF) technology has been in use for some time, since 1970s. Not until recent years did this technology make its way into the environmental field. Early instruments were fairly large and very heavy. Due to their bulkiness, these instruments were used only in fixed laboratories. Today's instruments (thanks to advancements in computer chip technology) are smaller, lighter and portable. The Field Portable XRF as it is referred to, be primarily a screening instrument capable of producing Screening Quality Data can be conducted in-situ in a matter of seconds or minutes. An example of a US product is the *TN 9000 Field Portable X-ray Fluorescence Analyzer*, which is manufacture by TN Spectrace. Their address is: 2555 N. INTERSTATE HWY 35, P.O. BOX 800, ROUND ROCK, TX 78680-0800. The analyzer can determine up to 25 different elements simultaneously

(some of the elements can not be determined- so far- due to the low concentration in water). The metals analyzed include the following:

- Silver (Ag)
- Barium (Ba)
- Cadmium (Cd)
- Chromium (Cr)
- Iron (Fe)
- Potassium (K)
- Molybdenum (Mo)
- Lead (Pb)
- Antimony (Sb)
- Tin (Sn)
- Thorium (Th)
- Uranium (U)
- Zirconium (Zr)
- Arsenic (As)
- Calcium (Ca)
- Cobalt (Co)
- Copper (Cu)
- Mercury (Hg)
- Manganese (Mn)
- Nickel (Ni)
- Rubidium (Rb)
- Selenium (Se)
- Strontium (St)
- Titanium (Ti)
- Zinc (Zn)

The portable high performance GC-MS system is used for on-site and/or on-vehicle examinations of pollutants in water by using the USEPA standard methods, such as EPA method 524 for monitoring volatile organic compounds (VOCs) and EPA method 525 for semi-volatile organic compounds, etc. This instrument is based on the technology of microbore capillary column chromatography and miniaturized focal plane mass spectrograph. The capability of the GC-MS has been extended for the analysis of organic compounds at low concentration (ppb to ppt range). This is accomplished by increasing the sample volume, optimizing the operating temperature of the GC column, and by the proper selection of the carrier gas. The high sensitive ion source, a lightweight and low-power-consuming pumping system and a personal computer-based data system make the GC-MS system be a reliable, powerful, popular and convenient tool for determination of organic pollutants on field.

A microtrap concentrator enables detection and identification of VOCs in the ppb to ppt range. The microtrap concentrator uses a small bed of absorbent material to trap VOCs over a minute sampling period, gas-flow through the trap is reversed as it is heated at a rate of 800⁰C/min., and then the trapped analyte are flash desorbed onto the GC column. This result is unprecedented sensitivity for fast on-site analysis, and can be helpful in water pollution problem caused by extremely low-level organic contamination.

For determination of the semi-volatile organic compounds in waters, the widely used method for pre-concentrating trace organic pollutants in water, such as polychlorinated biphenyls (PCBs), pesticides and polycyclic aromatic hydrocarbons (PAHs), is so called solid absorbent extraction.

An example of the portable GC-MS instruments is the *HAPSITE Field-Portable GC-MS System*, manufactured by the US firm of INFICON. Its headquarters is located in East Syracuse, NY 13057 USA. Table 3-21 shows the specifications of this instrument.

Table 3-21 Specifications of HAPSITE Field-Portable GC-MS

Operation Condition	5 ⁰ C to 45 ⁰ C. Cold weather insulating bag and insulation available
L × W × H	46cm × 43cm × 18cm
Weight	Approximately 16kg (35lbs) with battery
Power Supply	Rechargeable NiMH battery pack or AC INVERTER
Battery Life	Battery lasts approximately 3 hours before recharging is needed
Internal Power Consumption	24V(dc), 30 watts at normal operating conditions
Sample Introduction	Direct...internal sample pump
Carrier Gas	Nitrogen (can be customized for Helium)
Data System	Integral Intel Pentium processor & external Windows based laptop (no required for operation)
Special Features	Personal/field portable; integral concentrator; analytical/survey modes of operation; built-in National Institute of Standards and Technology (NIST) and AMDIS Mass Spectral Libraries; built to operate under adverse conditions; can be cleaned with water and bleach for field determination.
Mass Spectrometer	
Mass Range	1-300AMU
Scan Rate	1000AMU/sec. 10 points per AMU
Ionization Mode	70Ev EI
Detector	Electron multiplier
Vacuum System	Non-evaporable getler pump (NEG)
Dynamic Range	7 decades
Gas Chromatography	
Temperature	Temperature Programmable GC Column, 45 ⁰ C to 225 ⁰ C
GC Column	30m × 0.32 mm id.; Alternate phase and film thickness options available.

In the States, numerous field portable monitoring instruments and test kits are commercially available, such as Portable Colorimeters, Portable Visible & UV/Visible Spectrophotometer, Portable Turbidity Meter, and Portable Multiparameter Meter, etc. and some Portable Kits for specific parameters as well. The instruments and the kits are fast, accurate, cost-efficiency, the methods are being used are the USEPA approved standard methods. Table 3-22 lists the water monitoring parameters, the relevant USEPA methods and the vendors in the USA.

Table 3-22 Field Portable Water Monitoring Instruments/Kits in the USA

Parameter	EPA Method	Methodology	US Manufacture
Alkalinity, total	310.1	Colorimetric	Cole-Parmer Instrument Co.
Ammonia/ Nitrogen	350.2	Colorimetric	Cole-Parmer Instrument Co.
Ammonia	350.3	Electrode method	Cole-Parmer Instrument Co.
BOD	405.1	BOD incubator; BOD bottles and meters	Thermo Orion; YSI.
COD	410.4	Spectrophotometric	HACH; Thermo Orion
Chloride	325.3	Titrimetric	Cole-Parmer Instrument Co.
Chlorine DPD (free and total)	330.5	Spectrophotometric	Cole-Parmer Instrument Co.
Chlorine (free)	330.5	Spectrophotometric	LaMotte; HACH; Thermo Orion
Chlorine (total)	330.5	Spectrophotometric	LaMotte; HACH; Thermo Orion
Coliform	Note	Fermentation 9221	Cole-Parmer Instrument Co.
Coliform	Note	Filtration 9222D	Cole-Parmer Instrument Co.
Copper	Note	Colorimetric	Cole-Parmer Instrument Co.; CHEMets
Detergent (surfactants)	425.1	Colorimetric	Cole-Parmer Instrument Co.; CHEMets
Fluoride	340.2	Electrode method	Cole-Parmer Instrument Co.
Hardness	130.1	Titrimetric	Cole-Parmer Instrument Co.; CHEMets
Iron	Note	Colorimetric	Cole-Parmer Instrument Co.
Lead	Note	Voltammetry system	HACH
Nitrate	353.3	Colorimetric	Cole-Parmer Instrument Co.
Nitrate-Nitrite	353.3	Colorimetric	Cole-Parmer Instrument Co.; CHEMets
Nitrite	354.1	Colorimetric	Cole-Parmer Instrument Co.
Oil & Grease	1664	Filtration	Cole-Parmer Instrument Co.; Whatman
Oxygen	360.1	Electrode method	OAKLON; YSI; HACH
pH	150.1	Electrode method	OAKLON; YSI; HACH; Thermo Orion; Cole-Parmer
Phenol	420.2	Colorimetric	CHEMets; Cole-Parmer
Phosphorus	365.2	Colorimetric	HACH
Phosphorus, total	365.2	Colorimetric	HACH
Silica	370.1	Colorimetric	Thermo Orion; CHEMets
Sulfide	376.2	Colorimetric	Thermo Orion; CHEMets; Cole-Parmer
Sulfite	377.1	Titrimetric	CHEMets; Cole-Parmer
Turbidity	180.1	Nephelometric	HACH; OKLON;
Zinc	Note	Colorimetric (Zincon)	Cole-Parmer

Note: Several methods noted above do not have assigned methods but are referenced by their inclusion in Standard Methods for Examination of Water and Wastewater.

3.5.3 Automatic Water Sampler

An automatic water sampler is an essential tool equipped in a MWML for water sampling. As we indicated in the section 3.3.5, the sampler can take representative water samples rather than one having to use the manual grab sampling method. This will eliminate human errors in sampling and reduce labor costs as well.

There are various smart water samplers in the US market, which are computerized and programmable. Generally, sampling modes of most samplers are as follows:

- Multiple bottle time (multiple bottles per sample in programmed time intervals);
- Multiple bottle flow (multiple bottles at flow changes);
- Composite multiple bottle time (Composite samples in multiple bottles timely);
- Composite multiple bottle flow;
- Composite flow;
- Multiple samples per bottle;
- Multiple bottle per sample;
- Multiple bottle composting;
- Bottle grouping;
- Program delay based on time or flow;
- Real-time clock; and
- Sampling start by monitoring parameter changes (pH, DO, temperature, flow, etc.).

Some samplers can be equipped with optional sensors, such as pH, DO, temperature, conductivity and a flow meter, etc., a common practice of which is used for monitoring industrial wastewater discharges. In case of a waster water source begins discharging, or flow of the discharging suddenly increases or quality of the discharging water is getting worse, the values of flow, pH or other parameters may change, the sensors will send the changed signals to the sampler, the sampler will automatically begin sampling after receiving the signals.

Some of the samplers are used for volatile organic compounds sampling (VOC) which closely follow the USEPA protocols. The sampler collects representative VOC samples in sealed glass vials, and preserves them in the ice-cooled carousel to assure accurate and defensible results. Because the pump is pneumatic, it can operate in hazardous locations where VOCs may be present, while the sampler is located in a safe atmosphere.

The specifications of the several typical US autosamplers are shown in Table 3-23, and the contact information of the vendors is listed in Table 3-26.

Table 3-23 Specifications of Several Typical US Automatic Water Samplers

Parameter	ISCO 6712	ISCO 6712FR	ISCO 6100 VOC Special VOC	Manning VST	Sigma 900 (Portable)	Sigma 900 max (Portable)	Sigma 900 Max (All weather, Refrigerated)
Dimensions	68.6 x 50.7 cm		72.4 x 45.7 cm	70.5 x 45.08 cm	50.5 cm x 69.4 cm	61 cm x 44.1 cm	112 cm x 61 cm x 61 cm
Weight	32lbs/15kg		44lbs/19.8kg	24.5lbs / 11.1kg	32.6 lbs/14.8 kg	28.3lbs / 12.9 kg	140 lbs / 63 kg
Sampling Pump Type	Diaphragm Vac Comp	Diaphragm Vac Comp	Bladder pump	Diaphragm Vac Comp	Peristaltic Dual Roller	Peristaltic Dual Roller	Peristaltic Dual Roller
Refrigerator/Ice Chamber			Ice Chamber		Ice Chamber	Ice Chamber	Refrigerator
Material	Fiberglass			Fiberglass	Delrin	Delrin	Delrin
Power Requirements	12vDC	230vAC	12vDC	12vDC	12vDC	12vDC	115/230 vAC
Power Backup				6 Amp hr Bat	6 Amp hr Bat	6 Amp hr Bat	6 Amp hr Bat
Internal Battery			5 year Lithium	5 year Lithium	5 year Lithium	2 C-cell alkaline	2 C-cell alkaline
Intake Strainers					Tef & 316	Tef & 316	Tef & 316
Intake Purge	Adj air bef/aft	Adj air bef/aft			Air bef/aft	Air bef/aft	Air bef/aft
Tubing Life Indicator	Warning	Warning					
Intake Suction Tubing	Vin or Tef	Vin or Tef		PVC/Tef	Vin/Tef	Vin/Tef	Vin/Tef
Maximum Lift	28ft/(8.5m)	28ft/(8.5m)	80ft/24m	28ft/8.5m	27ft/8.2m	27ft/8.2m	27ft/8.2m
Repeatability	Typical 5ml	Typical 5ml		.5ml		5%	5%

Parameter	ISCO 6712	ISCO 6712FR	ISCO 6100 VOC Special VOC	Manning VST	Sigma 900 (Portable)	Sigma 900 max (Portable)	Sigma 900 Max (All weather, Refrigerated)
Typical Line Velocity	3ft/sec @ 3ft	3ft/sec @ 3ft		5ft/sec @ 3ft	2ft/sec @ 15ft.	2ft/sec @ 15ft.	2ft/sec @ 15ft.
Pump Flow Rate					60ml/sec @ 3 ft.	60ml/sec @ 3 ft.	60ml/sec @ 3 ft.
Liquid Presence Detector	Yes	Yes			single sensor	single sensor	single sensor
Controller Weight	13lbs./5.9kg	13lbs./5.9kg					
Temp Oper Range	0-49 C	0-49 C	0-50 C	0-50 C	0-49 C	0-49 C	0-49 C
Enclosure Rating	Nema 4X, 6IP67	Nema 4X, 6IP67	NEMA 4X, 6	NEMA 4X, 6	NEMA 4X, 6	NEMA 4X, 6	NEMA 4X, 6
Program Memory	Non Volatile ROM	Non Volatile ROM					
Flow Meter Signal Output	5-15vDC	5-15vDC	5-15vDC				
NO. of Compos Sample	1-999	1-999					
Clock Accuracy	1 Min/Month	1 Min/Month	1 Min/Month	1 Min/Month	.007% time	.007% time	.007% time
Sample Cooling	Ice Chamber	Ice Chamber		Refrigeration	Ice Chamber	Ice Chamber	Refrigeration
Sample Frequency	1 Min to 99 hrs	1 Min to 99 hrs		1-2000ml			
Sampling Modes	Time, flow, event	Time, flow, event		512 events			
Programmable Sample Volume	10-9,990ml	10-9,990ml					10-9,999 ml

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Parameter	ISCO 6712	ISCO 6712FR	ISCO 6100 VOC Special VOC	Manning VST	Sigma 900 (Portable)	Sigma 900 max (Portable)	Sigma 900 Max (All weather, Refrigerated)
Sample Retries	3	3			auto 1-3	auto 1-3	auto 1-3
Rinse Cycle	Auto 3	Auto 3	Auto 3		auto 1-3	auto 1-3	auto 1-3
Program Storage	5 Programs	5 Programs				5 programs	
Serial Interface	SDI 12	SDI 12					
Data Logging				512 events	400 events	116,000 events	116,000 events
Memory	4 MB Memory	4 MB Memory					
Input/Output				4-20 mA in and/or RS-232 out		RS-232 serial port	RS-232 serial port
Sampling Stop/Resume	24 commands	24 commands					
Bottle Configurations	11 24x 1L	11 24x 1L					
Base Price for Sampler					\$2,671.00	\$3,245.00	\$5,735.00

3.5.4 **Quality Assurance/Quality Control of MWMLs**

Before a new MWML is ready for operation, the QA/QC activities associated with the verification test focus primarily on reference analysis, sample preparation and handling, and data recording and analysis (the procedures are similar to that in regular laboratory QA/QC). This is a critical step to reach the objective of the monitoring quality for the MWMLs; we suggest that an independent audit covering each of these areas shall be performed before any MWML going into operation by the QA/QC Department of the JEPD and the Jiangsu Provincial Technology Inspection Administration (JTIA).

(1) QC Samples

Prepared QC samples include both laboratory reagent blank (RB) and laboratory-fortified matrix (LFM) samples. In the States, the RB samples are prepared from American Society for Testing and Materials (ASTM) Type II deionized water and exposed to identical handling and analysis procedures as other prepared samples, including the addition of all reagents. These samples are used to help ensure that no sources of contamination are introduced in the sample handling and analysis procedure. The LFM samples are prepared as aliquots of water samples and spiked in the field to increase to increase the analyte concentration. The spike solution used to prepare the LFM is prepared in the laboratory and brought to the MWML and the field sites. These samples are used to help identify whether matrix effects have an influence on the analytical results. At least 10% of all the prepared samples to be analyzed will be RBs, and at least one sample taken from each sampling site will be an LFM.

Quality control standards (QCS) are used as a calibration check to verify that the analyzers/kits being verified and the reference instruments are properly calibrated and reading within defined control limits. These standards shall be purchased from an approved commercial supplier and shall be subject only to dilution as a appropriate. The calibration of all instruments/kits shall be verified using a QCS before and after each testing day, as well as after every tenth sample. Additional standards shall also be purchased from an approved independent supplier for use in a performance evaluation audit.

(2) QC of Reference Method

Analysis of QC samples throughout the verification test shall be used to document the performance of the reference methods. If the analysis of an RB sample indicates a concentration above the Minimum Detection Limit (MDL) for the reference instrument, contamination will be suspected. Any contamination source(s) shall be corrected, and proper blank readings shall be achieved before proceeding with the verification.

The accuracy of the reference methods shall be verified before and after each testing day, as well as after every tenth sample. The instruments to be used for reference are calibrated initially according to the procedures specified in the reference method. The instrument calibration is verified using an appropriate

QCS. If the QCS analysis differs by more than $\pm 10\%$ from the true value of the standard, the instrument is recalibrated before continuing the test.

LFM samples are analyzed to determine whether matrix effects influence the results of the reference methods. The percent recovery (R) of the spiked solution is calculated from the following equation:

$$R = \frac{C_s - C}{s} \times 100$$

Where C_s is the analyzed concentration of the spiked sample, C is the analyzed concentration of the unspiked sample, and s is the concentration equivalent of the analyzed spike. If the percent recovery of an LRM falls outside the range of 85% to 115%, a matrix effect will be suspected.

(3) Performance Evaluation Audits

A performance evaluation (PE) audit will be conducted to assess the quality of the reference measurements made in the verification test. A PE audit involves challenging the field portable instruments used for reference methods with standards that are independent of those used to calibrate the instruments for the test. For the PE audit, an independent standard will be obtained from an approved vendor other than the one that supplied the QCS. The QCS and the PE standards will be compared once during the verification test. Agreement of the standards within 10% is required for the measurement to be considered acceptable. Failure to achieve this agreement will trigger recalibration of the instruments with the original QCS and a repeat of the PE comparison. Failure in the second comparison requires obtaining another set of standards and repeating the performance audit.

(4) Audits for Technical System and Data Quality

QA/QC personnel from the JEPD and JTIA shall perform a Technical System Audit (TSA) during the course of the verification test. The purpose of the audit is to ensure that verification test is being performed in accordance with the protocol and that all procedures described in the protocol are being followed. During this audit, the QA/QC personnel reviews reference standards and methods used, compares actual test procedure to those specified in the protocol, and review data acquisition and handling procedures. An independent TSA may also be performed by QA/QC personnel from the Chinese NEPA.

The QA/QC personnel from the JEPD and the JTIA shall audit at least 10% of the data acquired during the verification test. The data from the initial acquisition shall be traced, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results. All calculations performed on the data undergoing the audit are checked.

3.6 American On-Line Instrument Vendors - An Introduction

There are numerous companies in the USA that manufactures various state-of-the-art on-line water monitoring instruments. Based on the Consulting Team member's experiences in the field as well as current application literature in the environmental journals and the internet websites, the following American vendors are identified for manufacturing on-line water quality monitoring equipment:

- Hach Company
- Cole Parmer Co.
- Yellow Spring Instruments, Inc. (YSI)
- ISCO, Inc.
- HydroLab (now part of the Hach Company)
- In-Situ, Inc.
- Biospherical Instruments, Inc.
- Royce Technology, Inc.
- Turner Designs, Inc.
- Analytical Technology, Inc. (ATI)
- Sutron Co.
- Sentex systems, Inc.
- Waltron Ltd.

3.6.1 Overview of Instruments and Vendors

Table 3-24 shows several US vendors and the monitoring parameters that their products can examine on-line. The firms, we believe, are famous in the US environmental monitoring society.

Table 3-24 On-line Water Monitoring Parameters & US Instrument Vendors

Parameter	Vendors in the USA					
	HACH	YSI	ISCO	In-Situ	HydroLab	ROYCE
pH	✓	✓		✓	✓	✓
Temperature	✓	✓		✓	✓	✓
DO	✓	✓		✓	✓	✓
ORP	✓	✓		✓	✓	✓
Conductivity	✓	✓		✓	✓	
Turbidity	✓	✓		✓	✓	
COD	✓		✓			
BOD			✓			
NH ₃ -N	✓	✓				
TOC	✓		✓			
Nitrate	✓	✓	✓	✓		
Total N	✓	✓				
Total P	✓		✓			
Chlorine	✓					
Ammonia	✓	✓	✓	✓		
Chlorophyll		✓				
Salinity		✓			✓	

In addition, the US firm of Biospherical Instrument, Inc. manufactures the water monitoring system designed to continuously monitor nuisance algae pollution in reservoirs and lakes; monitor color distribution to calculate turbidity, organic and inorganic solids, and photosynthesis. Turner Designs, Inc. produces the on-line fluorometer that monitors chlorophyll in water. The contact information for the both companies is listed in the Table 3-26.

3.6.2 Consideration for Selecting Instrument for the AWMSs

Since thousands of on-line water monitoring instruments are available in the international market, comprehensive consideration for selecting suitable instruments before designing and purchasing is a critical step for reaching the monitoring objectives. Factors for consideration include the specifications and stability of the instruments, the costs for both initial capital and routine operation/maintenance, history records of the manufacture's production and sales, as well as user services after sales and another user's responses for the qualities and applications of the instruments. The following are key factors for consideration.

(1) Specifications and System Stability

- Monitoring range (Maximum Detection Limit and Minimum Detection Limit);
- Repeatability;
- Accuracy;

- The other specifications of parameter(s) measured;
- Sensitivity to surrounding environmental conditions, such as temperature, pH, humidity, salinity, solids content, flow fluctuation, and bioaccumulation of algae or bacteria on sensor, etc.;
- Body material (enclosure integrity);
- Resistant to corrosion; and
- Sensitivity of the system's response to external factors, such as hostile environmental conditions and unstable power and water supply, etc.

(2) *Costs for Purchasing and Operation*

- Quotations for completed instrument and accessories including installation and initial calibration;
- Cost for assembling to an AWMS;
- Civil construction cost for building an AWMS;
- Cost for routine calibration;
- Cost for routine maintenance (by the JPEMC);
- Cost of scheduled parts maintenance (by a vendor); and
- Cost for initial training required.

(3) *System Characteristics*

- Instrument life;
- Memory capacity;
- Remote download capability; and
- Power requirement (220 volt) and backup power availability.

(4) *End User Service*

- Technical and Repair Support from the Manufacturer;
- Application and technical support location;
- Technical support response time;
- Order turnaround time; and
- Product warranty.

(5) *Records of Manufacturer's Production & Sales history/ Experience*

- Product endorsement;
- Locations and duration of production and sales experience;
- Distributor location especially in China including Hong Kong, Macau, and the mainland; and

- Market history.

(6) Rugged and Robust

- Integrity of the equipment housing structure and operating components;
- Weight and dimensions; and
- Weather proof.

3.6.3 Estimated Investment for the AWMSs

Based on the current quotations from the American vendors and the monitoring parameter and instrumentation requirements from the JP EMC, Table 3-25 gives an estimated investment budget for the establishment of the AWMSs. These figures do not include the costs for civil constructions.

Table 3-25 Cost Estimation for Establishment of the AWMSs

Category for Equipment	Estimated Unit Cost (USD)	Pieces of Equip. to be Purchased	Estimated Total Cost (USD)
Five (six) -parameter Analyzer (DO, Conductivity, pH, Temperature, Turbidity, ORP)	12,000	17	204,000
NH ₃ -N Analyzer	9,000	17	153,000
Potassium Permanganate Index Analyzer	12,000	17	204,000
TOC Analyzer	15,000	7	105,000
Total Phosphorus Analyzer	15,500	7	108,500
Spare parts and accessories	10,000	17	170,000
Sampling facilities including pump, monitoring tank, pipe distribution, and backwash system	9,000	17	153,000
Data transmission system including software	10,000	17	170,000
Total	92,500		1,267,500

The cost estimation above does not include import duties, shipping and training costs. Although in most of the cases, technical training is provided as a part of the instrument quotations.

3.6.4 Contact Information for Some of the US Vendors

In this section, the Consulting Team lists the contact information for some of the US vendors (Table 3-26), for the client's convenience, the contact information for

the vendor's representatives and the branches in China are also listed, which were obtained from the headquarters of the vendors in the States.

Table 3-26 Contact Information for the US Vendors

Vendor	Contact Information in USA	Contact Information in China
<p>HACH Company. http://www.hach.com</p>	<p>U.S. contact person: Danny Hutcherson (Director of Global Key Account) Add.: P.O. Box 389 Loveland, CO 80539-0389 Tel: (970) 6693050, ext. 2249 Fax: (970) 6692392 E-mail: dhutcherson@hach.com</p>	<p>HACH (Beijing China) Room 2308, SCITE Tower 22 Jianguomenwai Street Beijing 100004 China Tel: (86-10) 65150290 Fax: (86-10) 65150399 Email: jiye.huang@fluke.com.cn</p> <p>HACH (Shanghai, China) Room 1204, Tower 1 Kerry Everbright City No. 218 Tianmu Road Shanghai 200070 China Tel: (86-21) 63543218 ext. 121 Fax: (86-21) 63543215 Email: yang.xiang@fluke.com.cn</p>
<p>HydroLab Co. http://www.hydrolab.com</p>	<p>U.S. contact person Victor Pena (International Sales Manager) HydroLab Corporation 8700 Caneron Road, Suite 100 Austin, Texas 78754 Tel: (512) 832-8832 Fax: (512) 832-8839 E-mail: vpena@hydrolab.com</p>	<p>HydroLab (Hong Kong, China) 1703, 17/F, Tamson Plaza 161 WAI YIP Street Kwun Tong, Kowloon Hong Kong Tel: (85) 221912936 Email: sales@hydrolabasia.com.hk</p>
<p>IN-SITU, INC. http://www.in-situ.com</p>	<p>U.S. contact person Craig McKee (Vice President) 210 S. 3rd Street Laramie, WY 82070 Tel: (307) 721-7576 Fax: (307) 721-7598 E-mail: craig@in-situ.com</p>	
<p>YSI, INC. http://www.ysi.com</p>	<p>U.S. contact person David Lee (Western Regional Manager) Yellow Springs, Ohio Tel: (916) 2891-8154 E-mail: Dlee@ysi.com</p>	<p>YSI (Beijing, China) Room 618 South Office Tower No. 3A Chongmenwenwai Street Beijing 100062 China Tel: (86-10) 67092652/53 Fax: (86-10) 6709-2651</p> <p>YSI (Shanghai, China) 58 Kang Ping Road Shanghai 200030 China Tel: (86-21) 64662108 Fax: (86-21) 6415-7692</p>
<p>GLI INTERNATIONAL, INC.</p>	<p>U.S. contact person Marc Sanches (International Sales</p>	

Vendor	Contact Information in USA	Contact Information in China
<p>http://www.gliint.com</p>	<p>Manager) Jensen Instrument Company 345 Littlefield Ave. South San Francisco, CA 94080 Tel: (650) 867-8257 Fax: (512) 856-3645 E-mail: MARC@jenseninstrument.com</p>	
<p>ISCO, INC. http://www.isco.com</p>	<p>U.S. contact person Dr. Vikas Padhye (Director of Marketing) ISCO, INC 4700 Superior St. PO Box 82531 Lincoln, NE 68504 Tel: (402) 464-0231 Fax: (402) 465-3064 E-mail: vikasp@isco.com</p>	<p>North America Instrument Co. (Distributor in China) Room 1025 Yishang Building No. 11 Malian Road Guanganman Wai Beijing 100055 China Tel: (86-10) 63852897 Fax: (86-10) 63855922 Email: Info@naicc.net</p>
<p>Cole Parmer, Instrument Co. http://www.coleparm.com</p>	<p>625 East Bunker Court Vernon Hills, IL 60061-1844 Tel: 800-323-4340 Fax: 847-247-2929 E-mail: info@coleparmer.com</p>	<p>Cole-Parmer (Beijing, China) Room E-7F, Majestic Garden No. 6 Middle Beisihuan Road Beijing 100029 China Tel: (86-10) 82847772/73 Fax: (86-10) 82847771 Email: cpchina@email.com.cn</p> <p>Cole-Parmer (Shanghai, China) Room 202, Building 8 No. 305 Fenglin Road Shanghai 200032 China Tel: (86-21) 34160809/64042553 Fax: (86-21) 64042553 Email: cpshi@online.sh.cn</p>
<p>Biospherical Instrument, Inc. http://www.biospherical.com</p>	<p>U.S. contact person Dr. John Morrow 5340 Riley Street San Diego, CA 92110-2621 Tel: (619) 6861888 Fax: (619) 6861887</p>	
<p>Turner Designs, Inc. http://www.turnerdesigns.com</p>	<p>845 W Maude Avenue Sunnyvale, CA 94085 Tel: (408) 2124017 Fax: (408) 7490998 Email: psanders@turnerdesigns.com</p>	
<p>American Sigma http://www.americansigma.com</p>	<p>P.O. Box 389 5600 Lindbergh Drive Loveland CO 80539-0389 USA Tel: 001-800-6354567 Fax: 001-970-4613914</p>	

Vendor	Contact Information in USA	Contact Information in China
	E-mail: signa@americansigma.com	
ROYCE TECHNOLOGIES http://www.royceinst.com	U.S. contact person Jim Dartes (President) Royce Technologies 13555 Gentilly Road New Orleans, LA 70129 Tel: (800) 347-3505/(504) 254-8888 Fax: (504) 254-8855 E-mail: Jam.dartes@sanitaire.itt.com	

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Chapter IV

CHAPTER IV CONCLUSIONS AND FUTURE CONSIDERATION

4.1 Conclusions

Since high economic growth in China's Jiangsu Province during the past two decades has caused serious impact to the air and water environment, sufficient, automatic and reliable monitoring of the ambient air and surface waters is a critical step to reach air and water protection and restoration objectives.

Funded by the USTDA, to help the JEPD to establish and enhance its AAMS and AWMS networks, the Consulting Team from the U.S. firms of H&J, Inc. and E&E, Inc. has prepared this Feasibility Study after studying the situation of air monitoring and water monitoring in the province.

AAMS

Jiangsu Province has experienced significant population growth expansion of its industrial sector during the last decade. This growth is not expected to slow down anytime in the near future. With the growth, ambient air pollution has also increased due to the infrastructure needs to support the population, and the expansion of the industrial sector. There is also a high demand for automobiles; therefore, mobile source emissions have increased dramatically. All of these factors have led to the air quality in the province to exceed Level II standards for PM₁₀ throughout the province and for both NO_x and SO₂ in many of the cities. There is also a significant amount of haze in most urban areas.

The assessment and suggestions for the province's existing air quality monitoring system are as follows:

- The ambient pollution monitoring methods currently used throughout the province meet international criteria (US EPA and European Standards) and are sufficient for characterizing air quality in the province.
- The AAMS currently has 87 monitoring stations.
- Eight (8) of the 13 key cities are under-monitored based on SEPA recommended guidance for the number of monitoring sites per urban area based on population size.
- An additional 24 monitoring stations should be added to adequately characterize the air quality in the key cities throughout the province.
- Three (3) to four (4) mobile monitoring units should be purchase and placed at different locations throughout the province (Nanjing, Wuxi, & Xuzhou) to allow the province to adequately monitor emergency situations and conduct special monitoring studies.
- Funding for the additional stations in each of the key cities is critical due to the overall cost of the systems.
- Estimated cost to complete the monitoring stations expansion is U.S. \$3.96 million.
- Estimated cost for the purchase of three (3) mobile monitoring laboratories is U.S. \$0.57 million.

The FS discusses and recommends the parameters to be monitored and monitoring devices needed to complete the monitoring network. Expanded criteria for operating, maintaining and QA/QC of the monitoring equipment is included.

The FS recommends that the existing data management system which collates the data from each of the automated stations be upgraded or replaced with a system that standardizes the network and station data loggers/DAS to allow JPEMC to concentrate on presenting and using the data rather than continually fixing problems because of inconsistent information being transmitted.

A full list of current certified instrument manufacturers and vendors and contact information for them is included for reference purposes at the end of Chapter II of this FS. All of the listed vendors currently have systems operating in China. Prices are available on request of each vendor.

AWMS

The assessment and suggestions for the province's existing water monitoring system are as follows:

- A detailed QA/QC manual for operating the AWMSs should be formulated.
- The current frequencies of sampling and monitoring are insufficient.
- In-situ monitoring method should be used for determination of DO and temperature.
- Recommendation of using automatic water samplers (the current manual grab sampling is deficient in representativeness).
- Recommendation of using instruments with multiparameter combined water electrodes (Sonde).
- Coordination and cooperation among the government entities.
- Establishing more AWMSs at the drinking water sources.
- Sediment samples should be collected.

Selection and optimization of AWMS sites are very important, but both are costly and time intensive. Establishing a model for the work would require the acquirement of great amounts of data and information on hydrology, meteorology, water quality, tide, hydrophytes; as well as data regarding amounts, points and frequencies of wastewater discharge. In addition, methods such as statistics, empirical formula, water quality modeling, fuzzy-analogy and combined analysis, etc. would have to be adopted to establish the model. The model should also be verified in practice and be revisable as changes to hydrological conditions and water qualities happen in the future. Since the modeling work was not included in the TOR for this TDA project, the Consultants have obtained limited data and information, thus, a detailed introduction and discussion is not included in this report. However, a brief introduction about selection and optimization for AWMS locations using modern RS technologies has been included.

The FS discusses and recommends the factors for designing and establishing new AWMSs, which includes site selection, building construction, auxiliary facilities,

sampling facilities, as well as monitoring configuration, instrumentation and methodologies.

Based on the requirements of the JPEMC, the Consulting Team introduces the development on continuous biomonitoring technologies in the USA (the method is to monitor water pollution through organism reaction changes in a polluted water). And the data transmission system for the AWMSs by using SCADA technology is also mentioned in the FS.

For accuracy and reliability when operating the AWMSs, the FS presents the methods and the procedures for calibration and maintenance of the instruments and the auxiliary facilities. The team suggests that the JPEMC should take it as a reference to work out a proper QA/QC operation manual for the AWMSs.

The recommendations for purchasing mobile water monitoring labs (MWML) are given at the end of Chapter III in this FS, which covers the considerations and requirements for designing and purchasing on-vehicle facilities and the instruments in the MWMLs. The FS lists some of the US commercial portable instruments/ monitoring kits and the relevant vendors, including a portable GC/MS system, a 16kg instrument for determination of organic pollutants in water, and a portable X-ray fluorescence (XRF) analyzer for analysis of trace metals in water. The sampling modes of the typical US automatic water samplers and their detailed specifications are also introduced in the FS. A series of QA/QC activities including a verification test before putting a MWML into operation are also recommended.

The FS repeatedly emphasizes the importance of the QA/QC for AWMSs and MWMLs rather than only purchase and operation of advanced equipment. The team suggests the JPEMC to enhance its capacities for QA/QC.

4.2 Uncertainties and Potential Problems for Further Consideration

The most significant uncertainty and/or potential problems have to do with QA/QC. With the kind of equipment that has been recommended for the ambient air monitoring stations and the water monitoring stations, JEPD and JPEMC should recognize the fact that QA/QC is an essential part of any air or water monitoring system. Therefore, the JEPD and JPEMC should enhance their capacities by implementing a rigorous QA/QC.

Secondly, the consistency in managing and performing the ongoing maintenance and QA/QC at each of the monitoring stations is at least, uncertain. There does not appear to be a provincial-wide standard for how these QA/QC functions are handled, therefore, it is up to each of the individual EPD's to ensure their equipment is operating correctly and being maintained consistently. Most of this is done according to manufacturer recommendations, which is good operating practice. However, it is uncertain how much interaction the individual EPD's have with each other, and without a formal procedure in place, this could lead to under-maintained equipment and inadequate data being sent to JPEPD.

Another potential problem has to do with the slow/lack of free flowing information between the various monitoring stations and the agencies that own/run them. The result from this slowness/lack of is that it inhibits the

effectiveness and accuracy of real-time information to be utilized for the betterment of the air or water quality for the province. Similar equipment and computers that are able to "talk" to each other must be implemented to deal with this problem. The various stations and agencies must think of the betterment of air and water quality for the province.

Lastly, the recognition that air monitoring programs can not comprehensively quantify patterns of air pollution in both space and time. At best, monitoring provides an incomplete – but useful – picture of current environmental quality. Therefore, monitoring should be used in conjunction with other objective assessment techniques, including modeling, emission measurement and inventories, interpolation and mapping. Thus, one way to eliminate potential problems in air monitoring is to recognize that it is essential that monitoring, modeling and emission assessments should be regarded as complementary components in any integrated approach to determining compliance against air quality criteria.

4.3 Potential Future Work

Potential future work could be in the area of training. Quality training could be provided regarding the QA/QC procedures for the equipment (i.e. calibration) as well as in procedures (i.e. implementation), etc.

Based on the recommendations and uncertainties, several areas of potential future work are available:

- Full-scale monitoring station siting studies for each of the eight (8) cities which do not currently have enough monitoring sites. The studies would need to evaluate not only the existing monitoring station locations, but also incorporate a full area-wide air pollutant emissions inventory (both stationary sources and mobile sources) and urban airshed modeling to determine the most appropriate locations for the stations.
- Upgrading the DMS system to a fully integrated system with minimum standards for each existing and new facility to meet.
- Development of a province-wide training program to establish consistent procedures for operating, maintaining and performing QA/QC on the monitoring system. This would include development of a training manual and development of baseline standards for the monitoring network.
- Focused study on reducing haze throughout the province and upgrading emission controls systems at existing facilities throughout the province to meet the 2007 nationwide regulatory mandates (primarily applies to coal burning facilities).

Appendix

APPENDIX A

ACRONYMS

Chapter I

COD _{Mn}	Chemical Oxygen Demand on Manganese
DO	Dissolved Oxygen
E&E, Inc.	Ecology & Environment, Inc.
FDI	Foreign-direct Investment
FIEs	Foreign-invested Enterprises
GDP	Gross Domestic Product
H&J, Inc.	H & J, Inc.
JPEMC	Jiangsu Provincial Environmental Monitoring Center
JEPD	Jiangsu Environmental Protection Department
NEMC	Nanjing Municipal Environment Monitoring Center
NO _x	Nitrogen Oxides
PM ₅	Particulate Matter 5 (PM size of less than 5 Microns)
PM ₁₀	Particulate Matter 10 (PM size of less than 10 Microns)
SO ₂	Sulfur Dioxide
TSP	Total Suspended Particulates
USTDA	United States Trade and Development Agency
YEMC	Yangzhou Municipal Environment Monitoring Center

Chapter II

AAMS	Automatic Ambient Air Monitoring System
AAMSS	Automatic Ambient Air Monitoring Systems
API	Advanced Pollution Instruments
EPBs	Environmental Protection Bureaus
JPEMC	Jiangsu Provincial Environment Monitoring Center
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
DAS	Data Acquisition System
DMS	Data Management System
DQOs	Data Quality Objectives
EMS	Environmental Monitoring System
ESPs	Electrostatic Precipitators
GPS	Global Positioning System
IPS	Information Processing Systems
LEADS	Leading Environmental Analysis and Display System
MAP	Mobile Real-time Air Monitoring Platform
NO ₂	Nitrogen Dioxide

NO _x	Nitrogen Oxides
NWS	National Weather Service
O&M	Operations and Maintenance
O ₃	Ozone
PDCS	Point Data Collection System
PM	Particulate Matter
PM ₁₀	Particulate Matter 10 (PM size of less than 10 Microns)
PM _{2.5}	Particulate Matter 2.5 (PM size of less than 2.5 Microns)
PSD	Prevention of Significant Deterioration
QA	Quality Assurance
QC	Quality Control
RP	Rupperecht and Patashnick
SEPA	State Environmental Protection Administration
SO ₂	Sulfur dioxide
SO _x	Sulfur Oxide Gases
TEOM	Tapered Element Oscillating Microbalance
TCEQ	Texas Commission on Environmental Quality
TIG	Transpositional Infrared Gas
TSP	Total Suspended Particulate
UVF	Ultraviolet Fluorescence
UPS	Uninterruptible Power Supply
VOCs	Volatile Organic Compounds
WAN	Wide-Area-Network
WHO	World Health Organization
WMO	World Meteorological Organization

CHAPTER III

ASTM	American Society for Testing and Materials
AWMS	Automatic Water Monitoring Station
BEWS	Biological Early Warning System
BOD ₅	Five-day Biological Oxygen Demand
COD	Chemical Oxygen Demand
COD _{Mn}	Potassium Permanganate Index
DO	Dissolved Oxygen
FDI	Foreign Direct Investment
FIE	Foreign-Invested Enterprise
GC/MS	Gas Chromatography/Mass Spectrometry
GDP	Gross Domestic Product
IC	Inorganic Carbon
JPEMC	Jiangsu Provincial Environmental Monitoring Center

JEPD	Jiangsu Environmental Protection Department
JTIA	Jiangsu Provincial Technology Inspection Administration
LED	Light Emitting Diode
LFM	Laboratory Fortified Matrix
MDL	Minimum Detection Limit
MWML	Mobile Water Monitoring Laboratory
NDIR	Non-Dispersive Infrared
NEMC	Nanjing Municipal Environment Monitoring Center
NH ₃ -N	Ammonia-nitrogen
NO ₃ -N	Nitrate-nitrogen
NPOC	Non-purgeable Organic Carbon
ORP	Oxidation-reduction Potential
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinate Biphenyls
PE	Performance Evaluation
POC	Purgeable Organic Carbon
ppb. (µg/L)	Part per billion (microgram per liter)
ppm. (µg/L)	Part per million (milligram per liter)
ppt.	Part per trillion
QA/QC	Quality Assurance/Quality Control
QCS	Quality Control Standards
RB	Reagent Blank
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SEPA	State Environmental Protection Administration
TC	Total Carbon
TDS	Total Dissolved Solids
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSA	Technical System Audit
USEPA	United States Environmental Protection Agency
USTDA	United States Trade and Development Agency
UV	Ultraviolet
VOCs	Volatile Organic Compounds
XRF	X-ray Florescence
YEMC	Yangzhou Municipal Environmental Monitoring Center

APPENDIX B

Figure 2-6 Changzhou Air Monitoring Stations

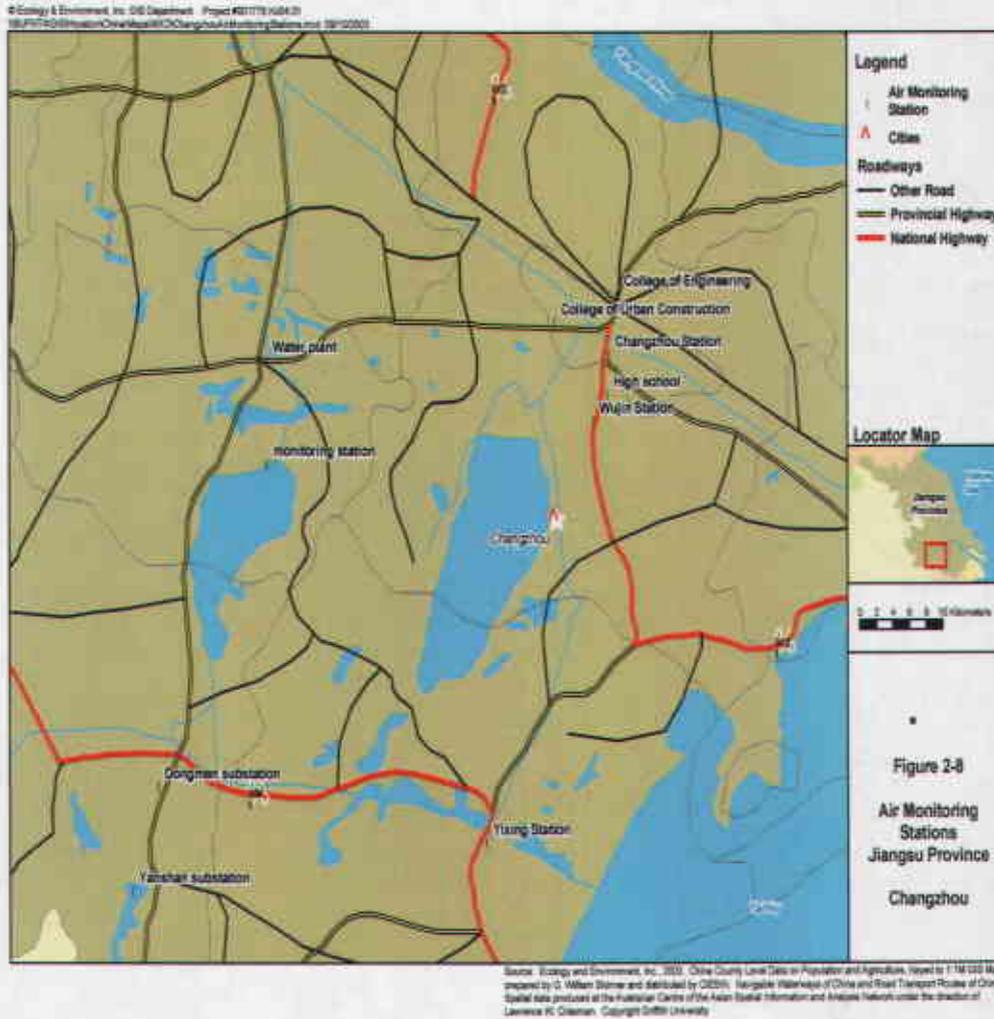
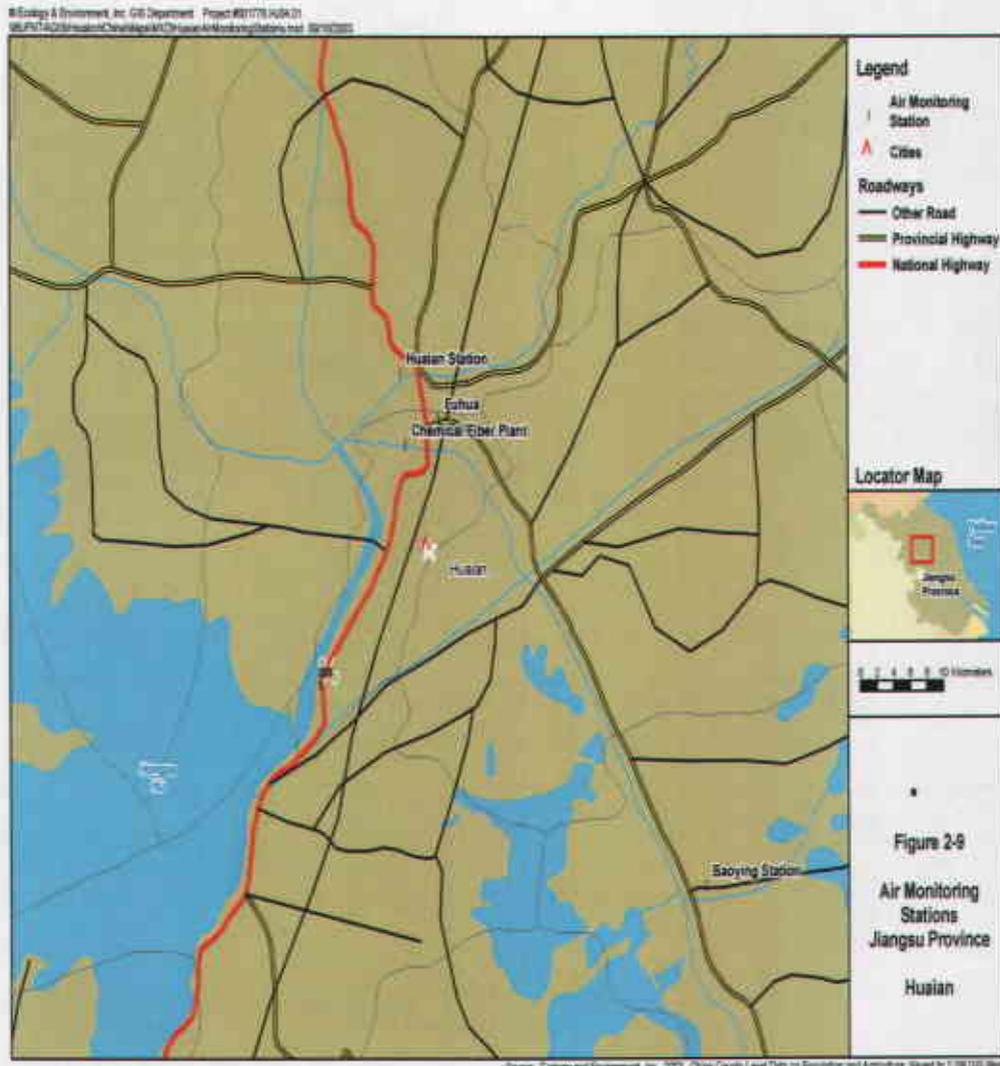
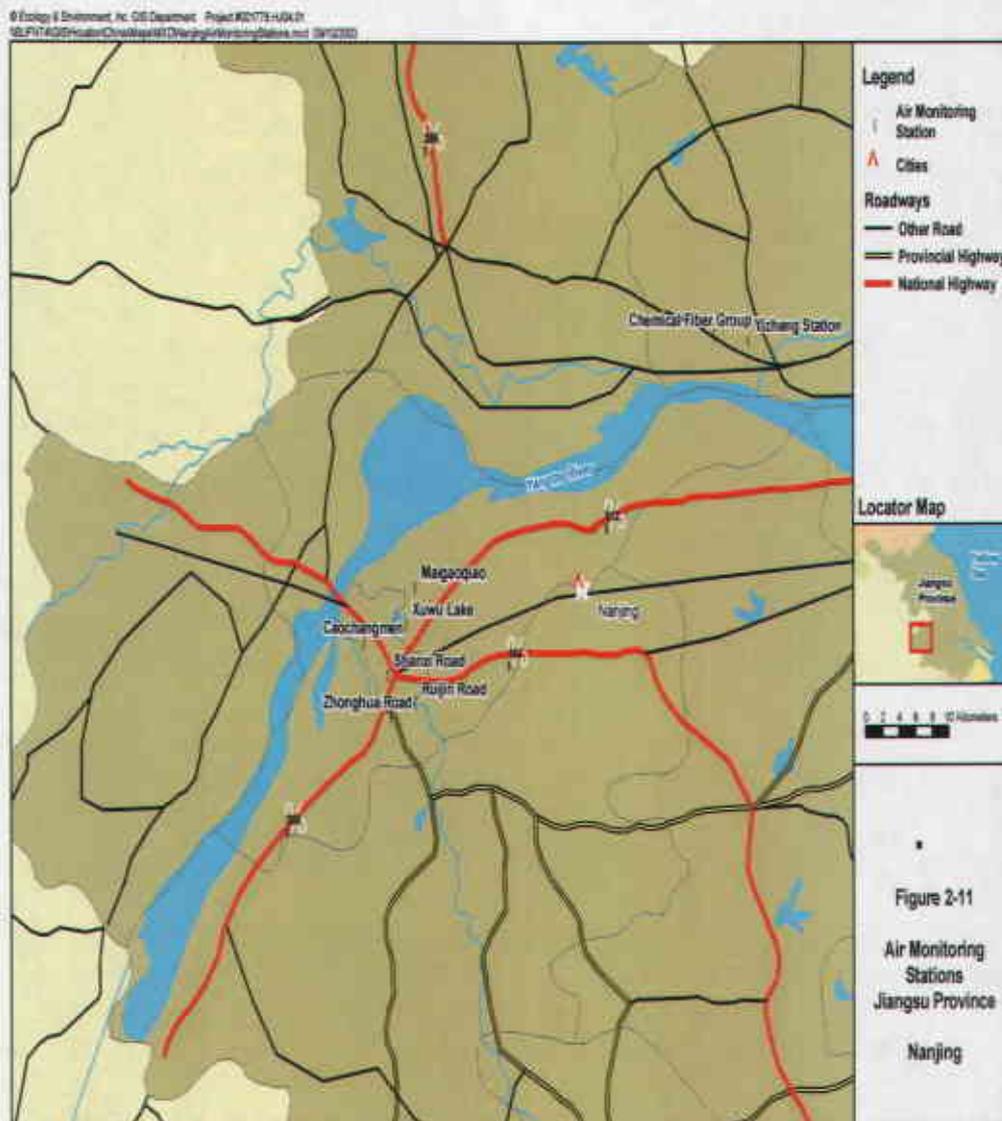


Figure 2-7 Huai'an Air Monitoring Stations



Source: Ecology and Environment, Inc. 2003. China County Level Data on Population and Agriculture, based on 1:100,000 maps prepared by G. William Skinner and distributed by CEDRI. Geographic Names of China and Road Transport Routes of China Spatial data produced at the National Centre of Geographical Information and Analysis Network under the direction of Lawrence W. Osborne. Copyright Griffith University.

Figure 2-9 Nanjing Air Monitoring Stations



Source: Ecology and Environment, Inc., 2002. China County Level Data on Population and Agriculture, scaled to 1:50,000 Map, prepared by G. Wilson Skinner and distributed by CEISRI. Navigable Waterways of China and Road Transport Routes of China. Spatial data produced at the Russian Centre of the Earth Spatial Information and Analysis Network under the direction of Lawrence W. Ottensm. Copyright Griffith University.

Figure 2-11
Air Monitoring
Stations
Jiangsu Province
Nanjing

Figure 2-10 Nantong Air Monitoring Stations

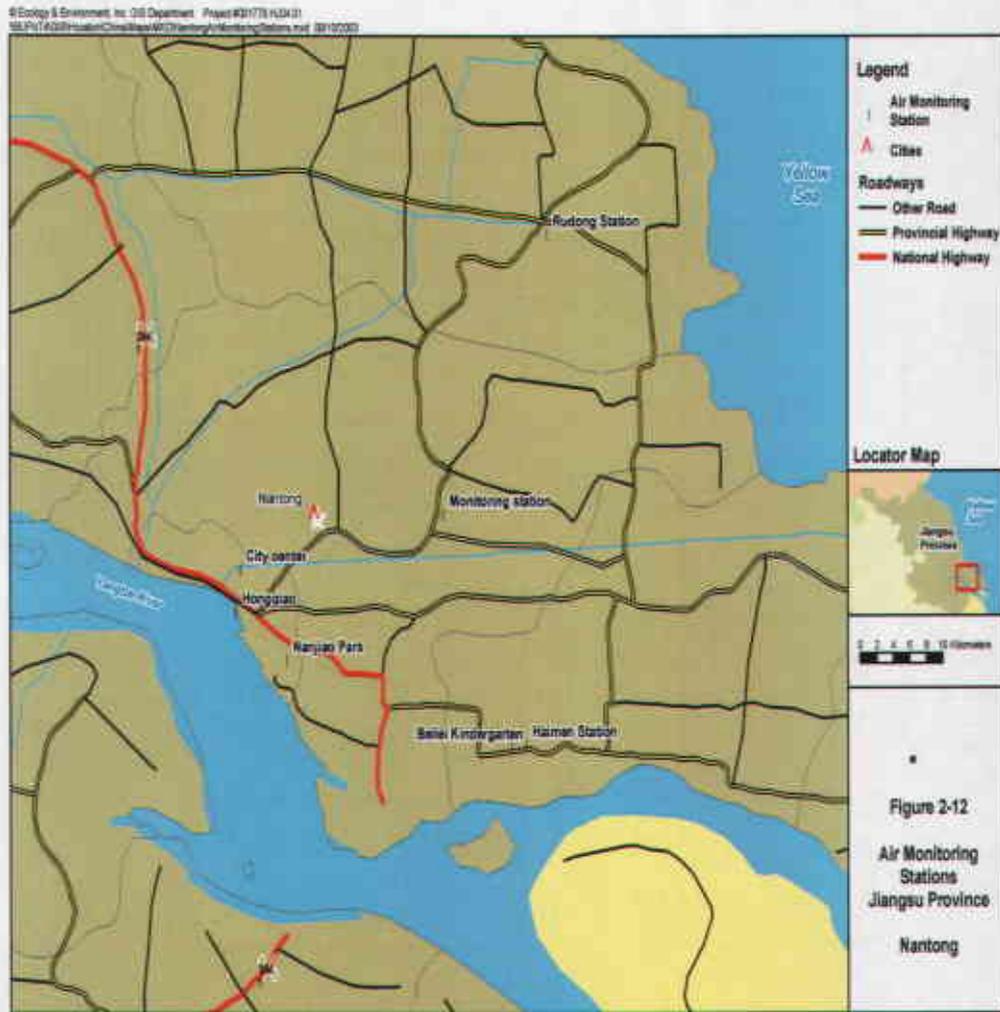
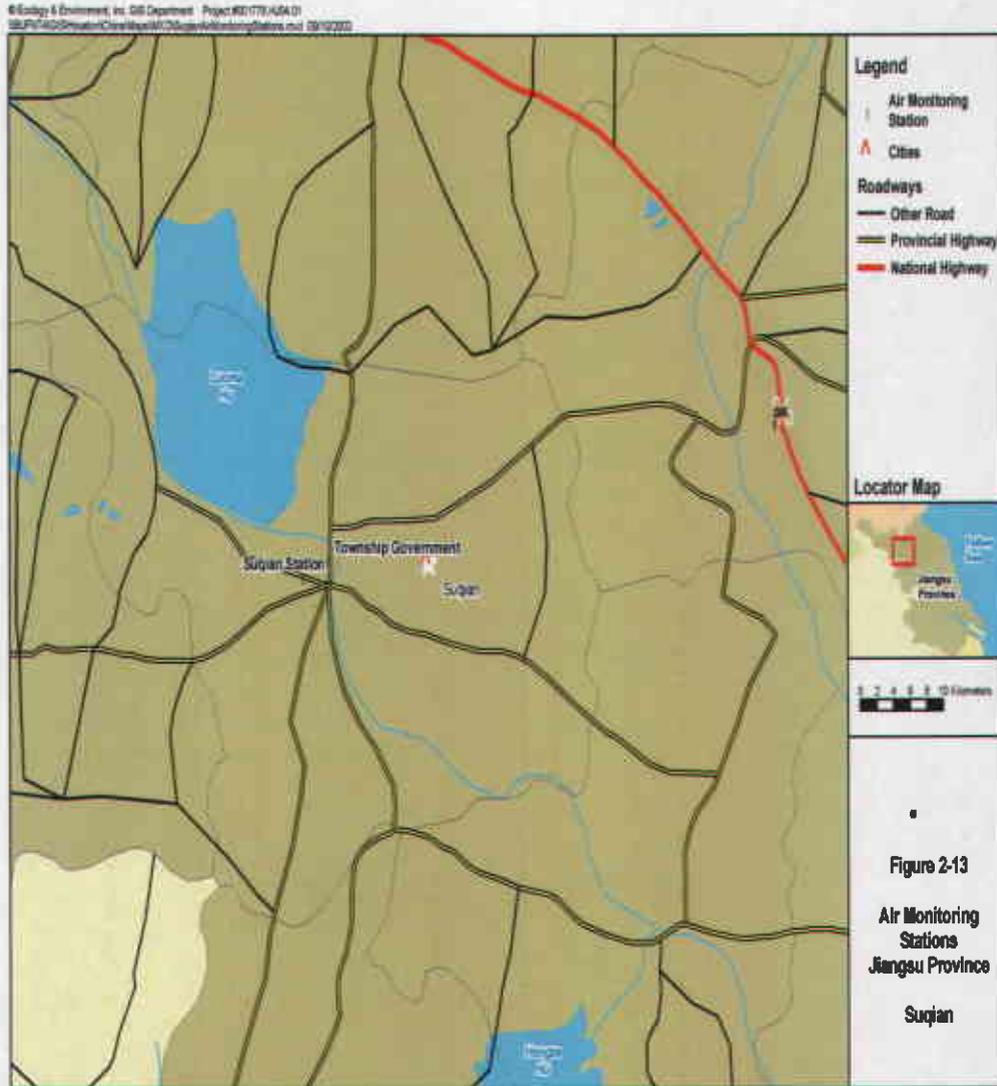
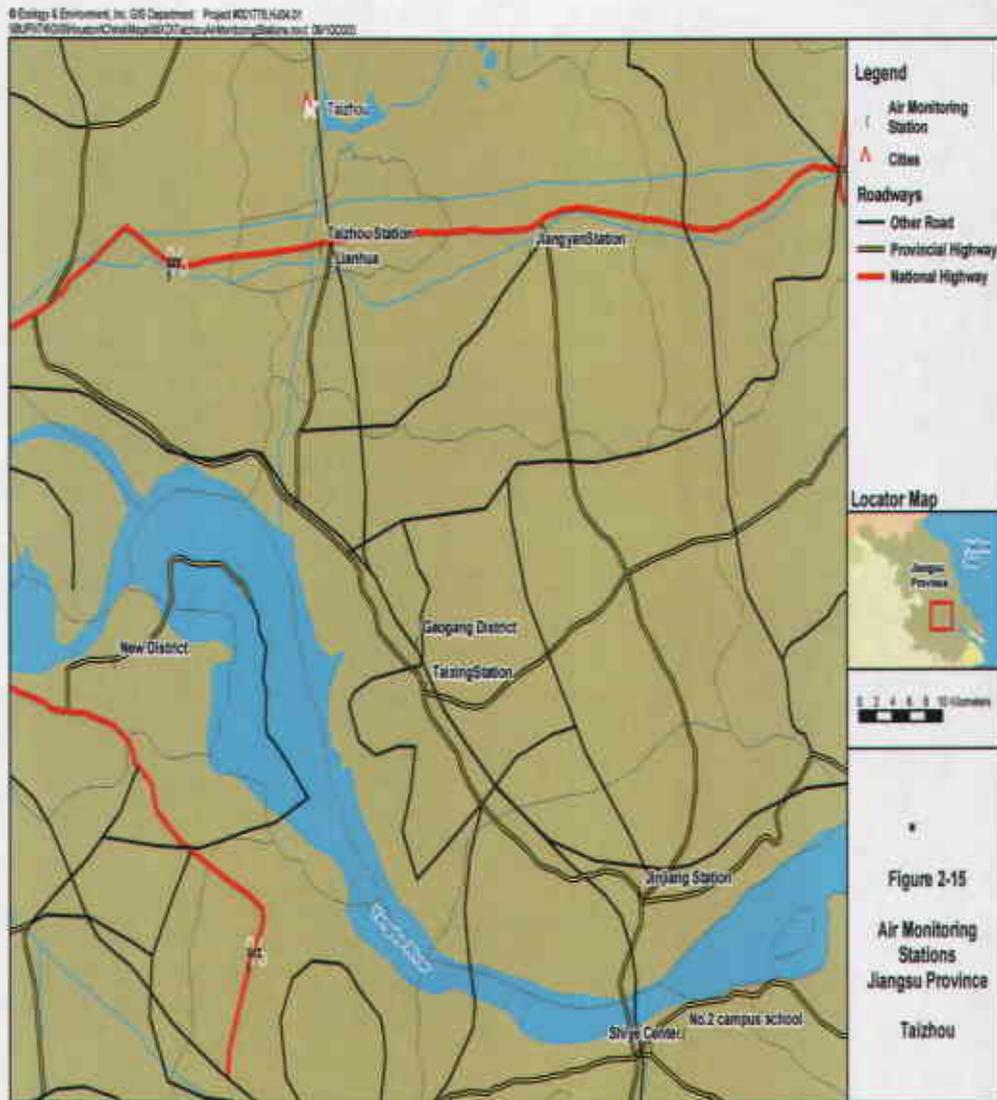


Figure 2-11 Suqian Air Monitoring Stations



Source: Ecology and Environment, Inc., 2011. China County Level Data on Population and Agriculture, based on 1:100,000 Map, prepared by G. Wilson Brown and distributed by CIESIN. Navigable Waterways of China and Road Transport Routes of China Spatial Data produced at the Australian Centre of the Asian Spatial Information and Analysis Network under the direction of Lawrence W. Clemons. Copyright 2010 University

Figure 2-13 Taizhou Air Monitoring Stations



Source: Ecotop 4 Environment, Inc. 2005. China County Level Data on Population and Agriculture, based on 1:100,000 maps prepared by G. William Skinner and distributed by CIESIN. Navigable Waterways of China and Road Transport Routes of China Spatial data processed at the Australian Centre of the Asian Spatial Information and Analysis Network under the direction of Lawrence W. Cassman. Copyright Griffith University.

Figure 2-16 Yancheng Air Monitoring Stations



Source: Ecology and Environment, Inc., 2007. China County Level Data in Population and Agriculture, based on 1:100,000 Map, prepared by G. Wilson Barker and distributed by CEIS. Jiangsu Waterways of China and Road Transport Routes of China Spatial data produced at the Auditor Center of the Asian Spatial Information and Analysis Network under the direction of Lawrence W. Deamant. Copyright © 1996 University

Figure 2-17 Yangzhou Air Monitoring Stations

