DOI 10.15302/J-SSCAE-2018.02.017

Development of Multi-Perception System for “Internet Plus” Smart Environmental Protection

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Abstract: With the development of information technology and big data, the “Internet Plus” smart environmental protection era has arrived. As it is a source for all environmental data, the research and development of a multi-perception system for “Internet Plus” smart environmental protection is particularly important. China now faces some of the world’s most severe and complex environmental problems. Based on China’s present environmental issues as well as those abroad, we analyze the demands of stereoscopic monitoring technology, rapid environmental monitoring technology, and online monitoring platforms applied to multi-perception systems. Considering China’s environmental monitoring system gap, we determine the key innovative technical features and trends of multi-perception systems. By investigating the technical requirements and bottlenecks involved in atmospheric monitoring, water monitoring, and soil monitoring, we present potential targets, ideas, and suggestions for the development of multi-perception systems for “Internet Plus” smart environmental protection applicable to China.

Keywords: Internet Plus; smart environmental protection; multi-perception system

1 Introduction

The 19th National Congress of the Communist Party of China made it clear that we should accelerate the construction of an ecological system and build a beautiful China. In March 2016, the Ministry of Ecology and Environment issued the *Master Plan for the Construction of Big Data for the Ecological Environment*. Through monitoring and analysis of the ecological environment, qualitative and quantitative data are used to describe environmental quality. Thus, environmental monitoring is the basis for environmental protection work. With the public’s increasing demand for environmental quality, the quality of environmental data has shifted from the original “single data” to “environmental elements data,” and from a monitoring station to a city, an area, and the entire country. This allows the environmental multiplex perception domain a broad development space. The multi-perception aspect of environmental information requires urgent improvement. Environmental factors change rapidly, and monitoring tasks have become increasingly burdensome. Both the precision of monitoring and the types of elements monitored require enhancement. Existing automatic monitoring stations in China are mainly used to monitor the general environmental indicators of the atmosphere and water, but the monitoring range and types of indicators must be increased. It is necessary to develop a service platform with operational capability in China, and the network of automatic monitoring facilities, such as for the water and atmospheric environments, must be further improved.

2 Domestic and international development

2.1 Development and current status of multi-perception technology for a smart environment in foreign countries

Relatively complete monitoring technology exists in western developed countries. In the monitoring system, transmission,

Received date: March 13, 2018; **Revised date:** March 30, 2018

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Funding program: CAE Advisory Project “Research on Development Strategy of ‘Internet Plus’ Action Plan”(2016-ZD-03)

Chinese version: Strategic Study of CAE 2018, 20 (2): 111–119

Cited item: Liu Wenqing et al. Development of Multi-perception System for “Internet Plus” Smart Environmental Protection. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2018.02.017

processing, sharing, preservation, informatization, networking, modeling, and platforms of the monitoring information have basically been realized. Such a system provides basic environmental information for all society. They also continuously improve the comprehensive applicability of data (by developing different types of models), and conduct environmental quality evaluation based on the monitoring data (technical methods and index systems). These monitoring data play an important role in environmental management. An environmental monitoring technology system not only improves scientific decision-making, benefitting administrative departments in environmental governance, but also allows regional and national governments to formulate or modify environmental quality standards scientifically.

2.1.1 Regional environmental quality monitoring/evaluation methods have laid a technical foundation for environmental management

After decades of work, the United States and developed countries in Europe have established regional, national, and continental air quality monitoring networks for different atmospheric environmental problems. Environmental air pollution monitoring in the United States was put in place by the federal Environmental Protection Agency (EPA), which was established in 1970. There are more than 10 000 monitoring stations in the country. More sophisticated monitoring and telemetry networks have been established in cities such as New York, Chicago, Los Angeles, and St. Louis. In the 1980s, the United States launched Polar-Orbiting Environmental Satellites, and Geostationary Operational Environmental Satellites to provide quantitative data for weather and environmental conditions around the world. Canada also invested heavily in atmospheric environmental monitoring, and especially in the regular monitoring of all sources of pollution. The information obtained is released to the public via electronic bulletins on air quality. Japan's 47 prefectures have set up automated environmental air monitoring stations. Two monitoring networks have been built: a targeted monitoring network, which monitors known pollution sources, and a regional monitoring network, which monitors the air quality in different regions.

2.1.2 Application of new and advanced technologies provides technical means for regional environmental monitoring

Since the middle of the 20th century, there has been rapid development of environmental sciences around the world. The establishment of international monitoring systems has been a priority in large research projects, and new detection technologies have been actively pursued and developed. The rapid development of sensing and computer technology in recent years has increased the feasibility and stability of monitoring systems. Currently, the international networks for observing atmospheric composition mainly include: ① The European aerosol lidar network (EARLINET) established by the European Commission in 2000, with 28 ground remote sensing stations located in 15 European countries. ② The Asian Dust Network (AD-Net) established in 2001 with the main objective of obtaining a three-dimensional (3D) or 4D transmission route for monitoring dust storms through lidar stations established throughout Asia. ③ The BREDOM DOAS observation network, formed in 1991 by the University of Bremen in Germany, used primarily for testing of the Earth's atmosphere. ④ The international Network for the Detection of Atmospheric Composition Change (NDACC) organized by the NOAA and composed of more than 70 high-quality ground observation stations, this network studies the physical and chemical processes of the stratosphere and troposphere to assess the effects of changes in atmospheric composition on the global climate. ⑤ Micro-Pulse Lidar Network (MPLNET) is a ground-based micro-pulse lidar observation network established for the Earth observation system program run by the National Aeronautics and Space Administration (NASA) in the United States.

2.1.3 Application of remote sensing technology in environmental monitoring has promoted the development of comprehensive 3D environmental quality monitoring technology

The application of environmental telemetry technology has changed the research methods of traditional environmental monitoring, has provided a new research angle, and has overcome many limitations in traditional environmental research. When building a complete technical system for ground monitoring, foreign countries place great importance on the application of remote sensing in airborne and satellite platforms for environmental monitoring, and they have issued relevant plans for environmental monitoring. In 2002, the ESA Envisat satellite SCIAMACHY was able to measure the amount and distribution of air pressure, temperature, aerosols, and clouds, and more than ten types of gas components in the atmosphere, including O_3, BrO, SO_2, CH_4, NO_2, CO, and CO_2. Environmental management relies on the accumulation and analysis of long-term continuous environmental data. Since the launch of the TIROS meteorological satellite by the United States in 1960, satellite remote sensing technology has been widely used throughout the world, with applications in the fields of meteorology, agriculture, forestry, environmental protection, mining, and urban planning. In general, there has been an increase in the types of sensors used for satellite environmental monitoring, such as synthetic aperture radar and hyperspectral imagers, which have entered the practical application stage in the environmental monitoring of atmosphere, water, and oceans [1], and for specific environmental objects, such as air and ozone.

2.1.4 Research on environmental change has promoted the development of global/regional environmental monitoring systems

Changes in CO_2 in the atmosphere have been observed since

1959. To confirm and predict the changing trends of various major greenhouse gases, countries around the world have successively carried out observation and research on the concentrations of greenhouse gases in the atmosphere, and have established a gas pollutant flux observation network. A series of international cooperative studies in recent years (IGBP, WCRP, IHDP, GCTE, LUCC, etc.) have included long-term observations of terrestrial ecosystems. Environmental science research and technology have entered the stage of comprehensive integration through interdisciplinary crossover and permeation, and provided a possible means to solve the complex system problems of the environment.

2.2 Development and status of diversified perception technology for the ecological environment in China

At present, China is in a completely different stage of development than western developed countries, and the overall environmental quality of the country has degraded. The current environmental pollution situation involves a sophisticated system of mixed effects, multi-type emissions, and multi-process-coupled connections. Therefore, the existing environmental monitoring system has difficulty dealing with regional pollution, and lagging environmental monitoring technology restricts improvements in environmental protection.

2.2.1 The capability for automatic monitoring and supervision has significantly improved

In December of 2005, the State Council issued the *Decision to Strengthen the Environmental Protection of the Scientific Outlook on the Development of the Environment*, and specifically asked to build an “advanced environmental monitoring system.” It is necessary to improve the technical support capability of the environmental monitoring systems to set up a comprehensive and efficient monitoring network for environmental quality. This includes monitoring from use of traditional routines to monitoring the overall pollution process, and from monitoring urban environmental quality to fixed and mobile pollution sources to implement comprehensive and systematic monitoring of the environmental pollution in the country. We must ensure accurate, timely, and representative data. Thus far, the country has formed a basic regional network for air quality monitoring in the most typical areas: all 338 cities in China at the prefecture level and above have the ability to monitor six indicators of fine particulate matter in the atmosphere. The regional air-monitoring network covers 31 provinces and municipalities, 15 air-background monitoring networks, and an acid precipitation monitoring network made up of 440 acid precipitation monitoring stations. The sand and dust weather-monitoring network also covers 14 provinces and regions in the north. The time resolution of the automatic data is improving, and its effectiveness is increasing. New monitoring methods, such as video monitoring and remote sensor monitoring, are being continuously applied. In the area of surface water monitoring, the country has created a surface water-quality monitoring network made up of 2 703 surface-water monitoring sites, and the levels of surface water pollution have significantly improved. At the same time, 35 000 monitoring sites for soil quality have been built, representing a major step forward for automatic soil monitoring and big data collection, and laying an important foundation for the prevention and control of soil pollution.

2.2.2 High-tech means to catch up with the leading countries

In terms of monitoring instrument development, domestic environmental monitoring technology and equipment is gradually moving toward automation, applicability, intelligence, and networking. Technical indicators are developing higher precision, more components, and larger scale. Monitoring scale is becoming regional and is moving toward comprehensive 3D monitoring from surface monitoring to integrated monitoring, and from physical optical instruments to integrated application of multiple advanced high-tech instruments. In monitoring technology development, China has performed research on factors such as environmental noise, industrial pollution sources, air, surface water, soil, biology, ecology, and solid waste. A scientific monitoring technical system has been initially established, but there remains a large gap between China and other countries. Some indicators listed as priority pollutants are poorly monitored, and China lacks the means for monitoring others. In the field of automatic online monitoring for atmospheric haze, the $PM_{2.5}$ mass concentration automatic monitor, and the atmospheric fine particles and ozone laser radar system developed by Anhui Institute of Optics and Fine Mechanics, CAS (AIOFM,CAS), has reached an advanced international level for certain technical indicators [2]. In 2014, the Hong Kong Polytechnic University of China, together with Shandong University, used a thermal dissociation–chemical ionization mass spectrometry (TD-CIMS) device to measure the total NO_3 and N_2O_5 in the atmosphere in urban areas of Hong Kong. Fig. 1 shows a key technologies diagram for online monitoring of fine particulate matter in the atmosphere, and the multi-technical application provides data for more effective monitoring of and for performing genetic research involving $PM_{2.5}$.

2.2.3 Comprehensive 3D monitoring technology is constantly improving

Since the 1980s, the development of China’s satellites and sensors has improved rapidly. In 2008, China launched the HJ-1A and HJ-1B satellites for environmental and disaster monitoring, carrying wide-coverage multi-band CCD cameras, hyperspectral cameras, and infrared cameras. The Fy-3a satellite was successfully launched in 2008, carrying an ultraviolet ozone vertical detector and an ultraviolet total ozone detector. Sensors mounted on aircraft, unmanned aerial vehicles, airships, and oth-

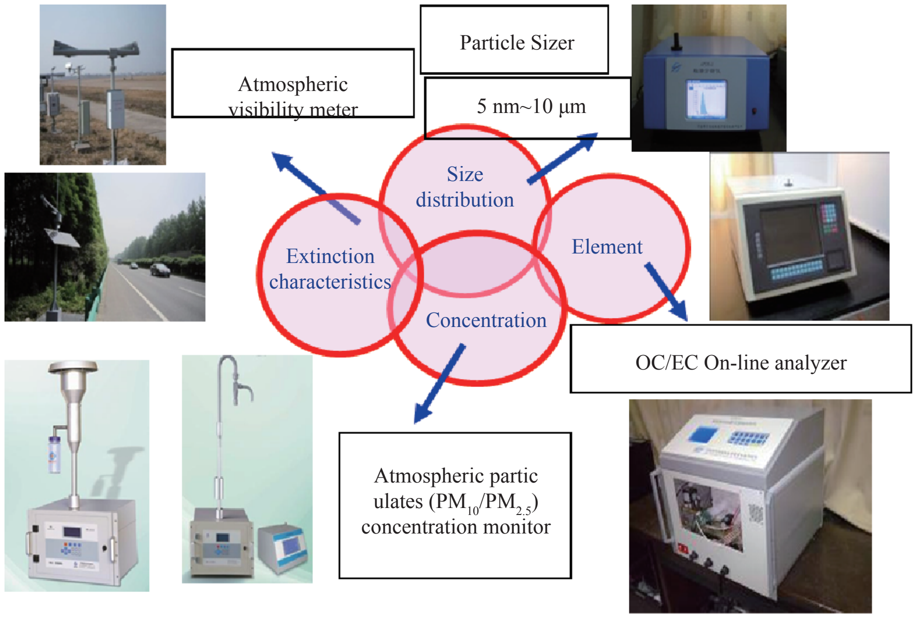

Fig. 1. Key technologies for online monitoring of fine particulate matter in the atmosphere.

er airborne remote sensing platforms have the advantages being fast and covering large areas, and can access difficult to reach areas to carry out remote sensing data acquisition. The advantages of satellites, aircraft, and ground stations complement each other, and the monitoring of air pollutants is conducive to use of 3D to visualize the distribution of air pollution for refined and comprehensive monitoring [3]. Through the use of air and water pollution spatial-temporal systems, and in-situ rapid monitoring airborne systems, high spatial and temporal resolution of regional atmospheric environment parameters (such as NO_2, SO_2, CO_2, and aerosols) and rapid telemetry of phytoplankton concentration distributions in water has been realized, and is being independently developed by AIOFM and CAS. A demonstration of these applications has been carried out for typical areas of China. Combined with an optimized selection of network sites and efficient and safe data transmission technology, the integrated 3D perception system for the atmospheric environment provides SO_2, NO_2, and O_3 column concentrations suitable for for quasi-operationalization. In conjunction with the pollution transfer model, a demonstration of the time and space distribution application for air pollution has been carried out in China [4].

3 Opportunities and challenges in the development of multi-perception technology for the ecological environment

At present, China's environmental monitoring technology and instrument industry is well developed, but there are obvious problems: the degree of domestication of monitoring equipment has increased, but some core devices still depend on imports; despite important breakthroughs in automatic on-line monitoring equipment, foreign countries still dominate high precision and analytical instruments. Compared with the rapid development of atmospheric environment monitoring equipment, the development of water environment monitoring equipment is slow, and soil environment monitoring equipment has not yet begun. The main domestic gas, water, and soil environmental monitoring instruments remain at a lower level than those in foreign countries. This does not meet the needs of China's environmental monitoring, and the main equipment is still obtained through imports. The following points embody the challenges ahead.

3.1 Research and development capability for automated and intelligent high-end monitoring technology equipment is insufficient

Most of the monitoring equipment used in China is imported, especially high-end equipment for intelligence and automation. Much of the automatic air monitoring equipment is imported, including high precision instruments for measuring O_3, fine particulate matter, and greenhouse gases. For automatic water monitoring, the main equipment for monitoring algae, microorganisms, and organic matter depends on imports. The research and development of laboratory equipment, such as inductively coupled plasma (ICP) emission spectrometers, Liquid Chromatograph Mass Spectrometer (LC-MS), and Gas Chromatography-Mass Spectrometer (GC-MS) is just beginning. For emergency monitoring equipment, portable gas chromatographs, portable GC-MS, and other foreign products are generally used. Only a few domestic companies have started to develop portable GC-MS. A gap is apparent in precision and accuracy between domestic instruments and imported equipment. In addition, China's environmental conventional pollutant monitoring system is imperfect, and the technology level of trace pollutant monitoring equipment is not high. Biological monitoring equipment is lacking, and these problems seriously restrict the development of environmental multi-perception systems in China. Therefore, it is necessary to increase investment in high-tech monitoring instruments to promote technological breakthroughs and to develop and industrialize instruments to promote development of monitoring equipment.

3.2 Lack of high-tech research on multi-pollutant detection

China's environmental pollution is becoming more and more complex, and multiple pollutants are emerging. With the frequency of sudden pollution accidents, the durability and stability of conventional monitoring equipment are insufficient, and there is not enough modern equipment for such pollutants in China. There are still major shortcomings in the research, development, and application of technology to detect special pollutants safely, rapidly, and without contact. China's current environmental monitoring technology and its standard system cannot match the necessary development speed of equipment, monitoring technology, and monitoring team technology. The update speed of technical specifications and monitoring methods cannot meet the needs for new pollutants, emergency monitoring, biological toxicity, and biological monitoring. We must accelerate our research with a new system of monitoring technologies for multiple pollution problems, establish technical standards and routes for these technologies, and meet the technical requirements for environmental management.

3.3 "Space-Air-Ground" three-dimensional monitoring technology must be strengthened

3D environmental monitoring technology has been widely used in atmospheric environmental monitoring. It has facilitated valuable advantages in understanding the regional distribution of atmospheric pollutants and multiple perceptions. The data obtained by traditional monitoring methods is not representative, the monitoring time is too short, and the methods are too simple. It is necessary to strengthen the development of remote sensor monitoring for the overall environment. Based on conventional and automatic monitoring, an integrated system for space-air-ground environmental monitoring based on airborne satellite remote sensing is needed. This would utilize a multi-element sensing system, such as basic vehicle-mounted, airborne platforms, and satellite platforms to carry out quick real-time detection of atmospheric trace gases, aerosols, greenhouse gases, atmospheric wind patterns, field moisture and temperature, etc.

3.4 Continuously promote integration of environmental monitoring technology and information construction

Although China has set up some automatic monitoring stations for water and atmosphere, the deployment, coverage areas, and management standards of these stations are not perfect and cannot meet the current need for environmental supervision. For example, we have set up approximately 600 automatic air monitoring systems to cover key cities, and 150 surface water automatic monitoring stations to cover ten major river basins in China. Data exchange, business system construction and application, and cross-border integration must be further strengthened. Through the study of multiple perception technology, the information capabilities and integration of environmental monitoring equipment can be improved to meet the needs of environmental quality supervision, and to provide more comprehensive, accurate, and detailed data.

4 Research and platform construction multiple perception technology for the ecological environment

4.1 Development strategy for "Internet plus" atmospheric environment perception system research

The Government attaches great importance to the research and development of atmospheric environmental monitoring and perception technology, and has held many special meetings to study and deploy relevant work on atmospheric environment prevention and control. To strengthen scientific research as a whole, the Government has adopted measures such as increasing investment, enhancing the promotion of popular science, promoting joint prevention and control measures and so on, to achieve a large number of successes and to promote multivariate perception technology development in the country. During the 13th five-year plan period, the development of environmental monitoring technology has been placed in a more important position with respect to scientific and technological innovation. It is necessary to first improve the multivariate perception Internet Plus system of the atmospheric environment to obtain accurate, timely, and comprehensive information to objectively reflect the quality and change trends, accurately warn about potential problems, respond quickly to emergencies, and quickly track the changes in pollution sources. We can then provide the necessary support for Internet plus smart environmental protection.

4.1.1 Improve the quality of domestic environmental air-quality monitoring technology and equipment, and accurately perceive the status of air quality

Owing to serious environmental pollution in China and the late construction of a monitoring system, system construction should be accelerated. Therefore, China is completing over 1 400 national control stations for $PM_{2.5}$ monitoring. Additional province, city, and county monitoring should be deployed in the future, building a wider environmental monitoring network, including industrial monitoring stations, rural atmospheric area networks, and road networks. This will also bring rapid growth to the monitoring industry. The equipment is in great demand, and must be constructed first [5,6].

4.1.2 Develop high-end technical equipment to monitor air oxidation and particles in the atmosphere, and implement on-line monitoring of pollution sources for ultra-low emissions

The causes of air pollution in China are complex. Compound air pollution comes from gas and particle primary pollutants discharged from various pollution sources and from a series of chemical and physical processes formed by secondary fine particles and secondary ozone pollutants. Accelerating independent research and development of high precision technology and equipment is particularly important to improve multi-sensory systems for the atmospheric environment and comprehensively monitor the atmospheric state. Fig. 2 shows an HO_x free radical measurement system for the atmosphere independently developed by AIOFM and CAS. In addition, ultra-low emissions will become the new norm in industries such as coal-fired power generation. We will develop high-end technical equipment, such as online monitoring of pollution sources with ultra-low emissions, and strengthen monitoring of pollution sources overall to test the effects of comprehensive air pollution control, implement supervision of heavy pollution enterprises, and assist in implementing a basis for assessment of local government accountability [7].

4.1.3 Accelerate the development of air quality forecasting, early warning, and emergency response technologies, and promote joint prevention and control of regional air pollution

Perfecting key technologies is urgently needed, such as a technique for spectral detection and analysis at an accident scene, or the rapid acquisition of air pollution distribution and emission flux. A 3D mobile monitoring platform for sudden air pollution accidents [8] can be integrated to provide quick and accurate information at the scene, such as the types, concentrations, range, and scope of pollutants caused by the accident. The action plan for the prevention and control of air pollution proposes to establish regional joint prevention and control mechanisms and implement responsibility assessment for each province (region and city). Heavy pollution will be added to local government emergency management plans, and according to the atmospheric pollution level, the enterprise shall take measures, such as production limits for heavy pollution processes and restrictions on the use of motor vehicles. The construction of a multi-perception platform is urgent. By accelerating the development of air quality forecasting and emergency response technologies, utilizing the regional air pollution environment three-dimensional monitoring technology in the "Internet plus" atmospheric environment multi-perception system, and by utilizing a big data comprehensive management platform, the joint prevention and control of regional air pollution can be promoted [9]. Fig. 3 shows a map of comprehensive 3D monitoring technology for the atmospheric environment.

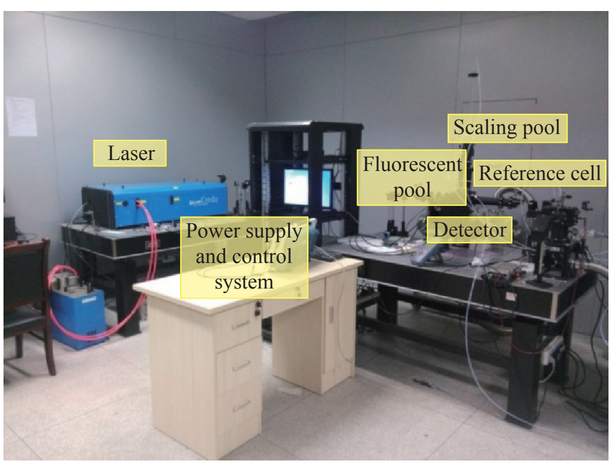

Fig. 2. Atmospheric HO_x free radical measurement system based on FAGE technology.

4.2 "Internet plus" water environment multi-perception system development strategy research

In April 2015, the state council issued the *Action Plan for the Prevention and Control of Water Pollution* ("water ten"), which put forward China's medium- and long-term water-environment governance goals. These include reducing the number of heavily polluted water bodies, continued improvement in drinking water security, strict control of groundwater, preliminary control of increasing groundwater pollution, better stability of the offshore environment, and national water environment improvement by 2020. It is necessary to improve the multivariate perception system of the Internet Plus water environment to obtain accurate, timely, and comprehensive information to reflect the current quality and change, to increase the regulation of wastewater emissions, to implement a full self-examination of online water pollutants, and to improve the overall quality of the water environment in the country. We can then provide the necessary support for Internet plus smart environmental protection.

4.2.1 Improve the environmental quality monitoring index and technical systems for drinking water sources, and realize comprehensive coverage of the water-environment perception network

Drinking water sources are closely related to healthy lives, and it is very important to monitor their environmental quality. Fig. 4 shows an online monitoring system for heavy metals in water. At present, there are a total of 61 monitoring projects for surface-water sources, and the total amount of water collected is calculated. According to the requirements, 109 items in the environmental quality standards for surface water should be collected, but the corresponding system for monitoring is not perfect. The water-quality monitoring network includes mainly routine

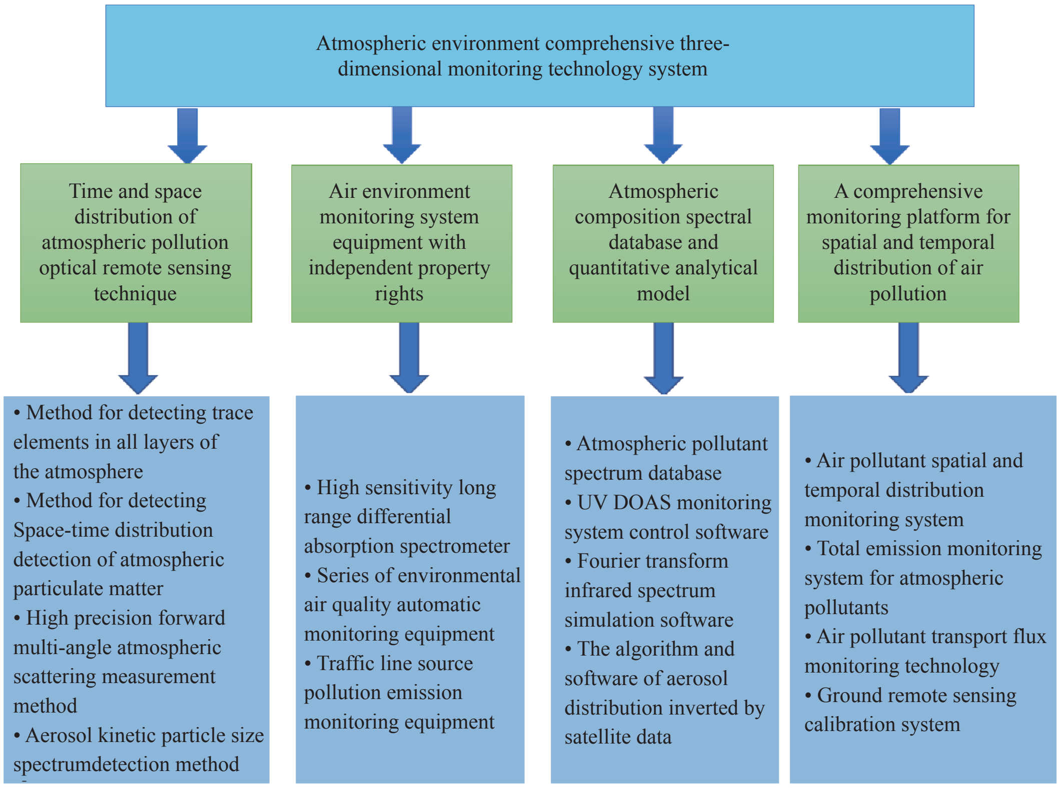

Fig. 3. Map of comprehensive three-dimensional monitoring of atmospheric environment.

indicators and lacks biological monitoring indicators. The monitoring of aquatic organisms in China still needs to be improved and currently takes place in only some areas [10].

4.2.2 Long-term automatic online monitoring capability and strengthened supervision of pollution sources

Upgrading existing wastewater treatment plants and wastewater discharge enterprises is urgent. According to the *Measures for the Licensing Management of Urban Sewage Discharge into Drainage Pipe Network* promulgated by the Ministry of Housing and Urban-Rural Development, key monitoring enterprises must install automatic detection equipment for on-line water pollutants included in the list, which began in January 2015. This is an effective monitoring and early warning method for water pollutants that can reduce or prevent the outbreak of the major water pollution events, and can protect water quality to ensure the safety of people’s lives and health.

4.2.3 Extend the tentacles of the “Internet plus” water environment multi-perception network, develop in-situ groundwater monitoring technology, and establish a complete national groundwater monitoring network

At present, China’s environmental protection system has not established a complete national groundwater environmental-quality monitoring network. The *National Plan for the Prevention and Control of Groundwater Pollution* issued by the Ministry of Environmental Protection, calls for the establishment of a state-controlled and province-controlled in-situ groundwater monitoring system. Therefore, the groundwater monitoring industry also needs to be vigorously promoted. Independent research and development of local water monitoring technology is also needed to meet the broad market demand for a complete network, and to satisfy the requirements for groundwater quality monitoring.

Fig. 4. On-line monitoring system for heavy metals in water.

4.3 Development strategy and research for “Internet plus” soil environment perception system

In May 2016, the state council issued the *Action Plan for Soil*

Pollution Prevention (hereinafter referred to as the plan). The plan proposed goals for medium- and long-term soil governance to ensure soil security for agricultural and construction land, manage and control soil environmental risks, initially curb the increasing soil pollution across the country, and stabilize overall soil quality by 2020. It is necessary to improve the Internet Plus multivariate perception system for the soil environment to obtain accurate, timely, and comprehensive soil environment information, and to objectively assess quality and change trends, strengthen the supervision of wastewater discharge, and realize a comprehensive 3D network of soil detection technology. Furthermore, improving overall soil environmental quality can be facilitated by measuring soil composition and fertilization. We can then provide important support for Internet Plus smart environmental protection.

4.3.1 Develop quick and automatic monitoring technology for heavy metals in soil using "Internet plus" soil environment multi-perception system to carry out investigations

The action plan for the prevention and control of soil pollution states that we should carry out in-depth environmental quality surveys on the basis of existing relevant surveys. Comprehensive investigation of soil pollution provides references for the formulation and implementation of laws, regulations, and policies. It is also necessary to evaluate soil environmental quality and provide governance to develop rapid on-line monitoring of heavy metals in soil. Therefore, developing portable and field monitoring instruments for heavy metals in soil is urgently needed. In 2015, the General Office of the State Council, in their opinion on accelerating agricultural development, proposed that it would be necessary to carry out formula fertilization by soil testing in depth, and improving the utilization rate of fertilizer is an important precondition to formula fertilization by soil testing. At present, the chemical reagent method is still the main method used for formula fertilization by soil testing. Thus, developing quick on-line monitoring technology and instruments for soil nutrients is urgently needed. This can effectively improve the efficiency of soil testing and fertilization, and reduce detection time and cost to promote the application of formula fertilization by soil testing and reduce the use of fertilizer [11]. Fig. 5 shows a heavy metal detection system for soil.

4.3.2 Develop soil environment zones and Internet monitoring technology to build a soil management system

Through the technological exploration of soil pollution risk-control, source prevention, and treatment and restoration, the quality of the soil environment in test areas will be improved significantly by 2020. Owing to the lack of 3D soil monitoring technology in China, the spatial and temporal distribution of pollutants in soil is not well understood; the lack of detection for heavy metals and organic pollutants in the soil makes it impossible to produce an overall assessment of soil pollution. We also lack the instruments to measure soil pollution telemetrically in China. To solve these problems, development of a comprehensive soil pollution monitoring platform and a soil environmental quality monitoring and control system are urgently needed.

4.3.3 Development strategy for "Internet plus" environmental perception system research

Through physical, biological, optical, and other avenues of cross-border integration, a multi-sensory perception system can be built. We will move toward a new environmental protection model for "environment perception and smart environmental protection," and develop fast, sensitive, continuous, and automatic monitoring technologies and equipment, We will also develop technologies for forecasting, warning, and responding to pollution-related weather and environmental emergencies, and gradually improve our operational capabilities for monitoring and emergency response to major environmental incidents. The technical and manufacturing sophistication of China's major environmental monitoring equipment and equipment management industry are comparable to those of internationally renowned enterprises. A series of environmental protection products with independent intellectual property rights have been launched, and large-scale application has been realized in practice.

4.4 Develop technologies to monitor the ecological environment, and build a comprehensive network

Monitoring is the basis of ecological environment protection, and an important support in the realization of an ecological lifestyle. Governance of rural garbage and sewage treatment is reflected in the *Guidance Notes on Rural Environmental Monitoring* (issued by the Ministry of Environmental Protection in 2010), *Guidance on Improving the Living Environment in Rural Areas* (issued by the general office of the State Council in 2014), and the action plan for the prevention and control of air pollution proposed to vigorously develop village environmen-

Fig. 5. Heavy metal detection system for soil.

tal renovation. Rural garbage contains a large number of toxic organic compounds and heavy metals, and the accumulation of garbage causes serious pollution in soil and water. Therefore, comprehensive monitoring of soil, water, and air in rural areas is required. The combined use of multiple monitoring instruments, and the comparative analysis of monitoring data are needed, but the relationship between water pollution and soil pollution in rural areas has not been determined. The farming industry in the countryside also pollutes the water supply and the air, and it is a major challenge to monitor plants [12].

4.4.1 Develop miniature and intelligent environmental monitoring sensors to realize comprehensive perception and refined management of multimedia environmental parameters

Under the guidance of the nation's "strengthen the environmental protection by information" strategy, the development of environmental management patterns has been an important tool to improve and promote environmental management. A new generation of information technology, such as the Internet of Things and cloud computing, has injected new vitality into environmental protection. The construction of China's environmental information infrastructure is progressing toward "intelligent environmental protection" from "digital environmental protection."

4.4.2 Develop equipment and platforms for low-cost environmental remote sensing technology, and form a global multi-element 3D monitoring network for the environment

Against the background of globalization, it is very important to accurately grasp the 3D distribution characteristics of global environmental elements. Fig. 6 shows an airborne atmospheric trace gas differential absorption spectrometer developed by AIOFM, CAS. It is helpful in studying the earth's space environment and its movement change law by utilizing photoelectric instruments carried by airborne platforms (satellites, stratospheric airships, and aircraft, etc.) and by various platforms on the ground.

4.4.3 Advance rapid environmental monitoring technology at the molecular level and improve understanding of the mechanisms of environmental pollution

The spatial and temporal variability of environmental pollution, the complexity of chemical components, and the lack of understanding of the mechanisms of environmental pollution have brought great uncertainty to the numerical simulation and prediction of global environmental changes. It is very important to solve environmental pollution problems at the molecular level, which greatly improves the accuracy of existing macro-environmental prediction models. It is also of great significance to promote the study of environmental science and the solutions to environmental problems.

4.4.4 Improve online monitoring technology and platforms to support environmental change

Environmental issues are becoming more and more international, and environmental protection has become inseparable from the rights and interests of the country and its diplomatic relationships. We should seize the initiative in environmental monitoring, strive for more say in safeguarding the rights and interests of our country and in our diplomatic activities, and expand our influence in the international arena to improve China's environmental diplomacy.

4.4.5 Promote the integration and sharing of scientific research and monitoring data in environmental, meteorological, and transportation fields, and fully tap the potential of big data

To promote the integration and sharing of monitoring data for scientific research in the environment, meteorology, transportation, and other fields, we need to establish operational norms and sharing mechanisms for multiple data acquisition through practice. We can then realize the interconnections and sharing of monitoring data systems at all levels, realize comprehensive informatization, and constantly improve monitoring, forecasting, warning, and security. Finally, an environmental monitoring network will be established that can be integrated as a space-air-ground network to achieve the necessary information sharing requirements.

The needs of the country's environmental quality, pollution emission control, and environmental change require monitoring technology and equipment. We need to build a high-precision, 3D multi-scale environmental pollution monitoring technology system, improve pollutant monitoring and information release,

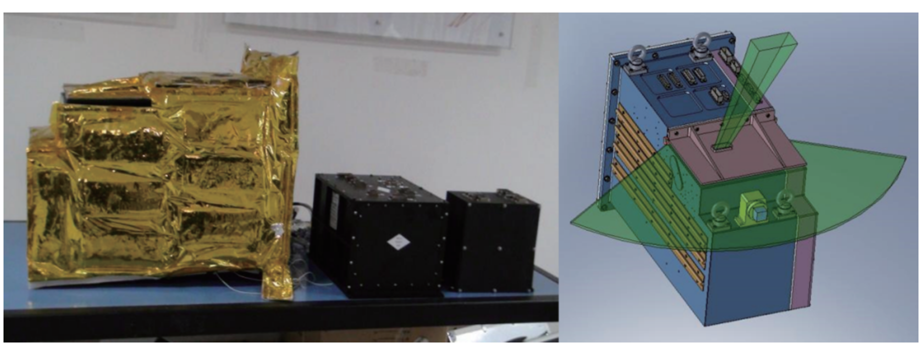

Fig. 6. Airborne atmospheric trace gas differential absorption spectrometer (left), and a photo of the model (right).

and form a multi-sensory "Internet plus smart environmental protection" ecological environment to cover major ecological elements. We will achieve connectivity and open sharing of ecological and environmental data and address major scientific and technological issues, such as the disclosure of environmental protection information resources, exploit the utilization of data, and promote innovation in environmental services. Finally, we will promote in-depth integration of information technology and environmental management services, promote system innovation, and modernize the capacity for ecological governance.

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