Environment Assessment Technology

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Abstract

The wide range of environmental problems that require solutions includes global warming, ozone layer depletion, acid rain, increase in waste materials, hormones in the environment, dioxin, and pollution of our air and water. We have developed environment monitoring and assessment technology to provide tools for predicting future air quality, beginning with an investigation of our immediate ambient air.

1. Aiming for street-corner environmental assessment

Our air quality monitoring system uses small sensors connected via a network to measure the nitrogen dioxide (NO_2), suspended particulate matter (SPM), ozone, and other components of automobile exhaust gases that damage the environment. It can collect environmental data in fine detail on the street-corner scale (i.e., distances of a few hundred meters). Experiments to verify the effectiveness of the sensors were conducted using an atmospheric environment simulator that makes fluid dynamics computations on the basis of weather data, taking into consideration the effects of traffic, buildings, land features, heat, road surfaces, and other such factors. The successful measurement of the street canyon effect*1 and other such phenomena in those experiments demonstrates the feasibility of analyzing street-corner-scale environment data. A combination of monitoring and simulation makes it possible to estimate air pollution at the street-corner level.

To improve the atmospheric environment in urban areas, the Japanese Ministry of the Environment has chosen to set new standards, aiming for the summer of this year, and enact the world's strongest emission gas regulations. The regulations concerning diesel vehicles in the central areas of Tokyo will also be strengthened. The three substances from diesel exhaust gases that pollute the roadside air—NO_2, SPM, and ozone—also cause acid rain, photochemical smog, and asthma. The types of pollutants and their concentration levels vary greatly from place to place. Considering the serious effects of local conditions on the health of traffic police officers and other persons, more detailed monitoring is needed. At present, the air quality measuring equipment used by local governments is both large and expensive, so the number of air quality monitoring sites is limited. Consequently, those systems do not measure pollutant concentrations close to individuals, which would let us assess the effects on a person's health.

NTT Energy and Environment Systems Laboratories is developing simulation technology for evaluating the three-dimensional (3D) distribution of atmospheric pollutants on the street-corner scale by networking compact portable sensors that operate on independent power supplies. The fusion of these technologies will allow realtime monitoring and estimation of air-polluting substances by local governments and application to public health assessment.

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*1 Street canyon effect: A phenomenon in which regions of high concentrations of atmospheric pollutants appear along the buildings on the windward side of a street due to eddies that form over streets that are lined with buildings.

2. Local air quality monitoring

Measuring the concentration of pollutants from exhaust gas sources such as automobiles at the low levels found in the environment (e.g., a few parts per billion (ppb) for a gas) requires highly sensitive sensors. In our work, we assume high sensitivity and aim for a more compact and energy-efficient system. The objectives are first to establish technology for low-power-consumption sensing of the air pollutants that are increasing in importance as monitored items (NO_2, SPM, and ozone) and then to establish technology for realtime collection of data on multiple items, i.e., a multi-monitoring system.

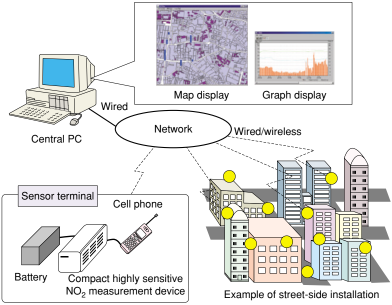

Fig. 1. Compact and highly sensitive NO_2 monitoring system.

2.1 Compact, highly sensitive NO_2 monitoring system

NTT Energy and Environment Systems Laboratories has developed a sensor that employs a sensor element that detects NO_2 with a reagent contained in porous glass that reacts chemically only with a particular gas. The amount of reaction in the sensor element is measured at fixed intervals and the differences are calculated. This achieves highly sensitive and highly selective measurement of the change in atmospheric gas concentration over time. We have developed a compact and highly sensitive NO_2 monitoring system that is capable of multi-point remote measurements when a number of these small lightweight sensor terminals are connected via a network to a central personal computer (PC) that collects, analyzes, and displays the data (**Fig. 1**) [1], [2]. The sensor terminal is equipped with two batteries and the entire unit is simply placed in a louvered box and installed at the outdoor location where measurement is desired. No power cables or communication wires are needed (**Fig. 2**).

The NO_2 concentration data collected by the central PC can be displayed as a graph showing the change over time or as a map showing the distribution of concentration at multiple measurement locations.

(a) on a wall (b) on a utility pole

Fig. 2. Examples of NO_2 sensor installation.

Detailed monitoring of the road-side air environment can be accomplished by installing the sensor on a road-side utility pole. Air environment measurement experiments conducted with this system in the cities of Sapporo and Kawasaki confirmed the street canyon effect, in which road-side atmospheric pollutants are locally distributed.

2.2 Networked multi-sensing air environment monitoring system

The networked multi-sensing air environment monitoring system [3] is an expansion of the NO_2 measurement system described above. It also measures SPM and photochemical oxidant (ozone), thus achieving a system of autonomous measurement terminals that can make dynamic measurements of the three traffic pollutants that cause the most damage (**Fig. 3**). This new terminal incorporates an NO_2 sensor (developed by NTT), an SPM sensor, a semiconductor ozone sensor, and temperature and humidity sensors. It is designed to be much smaller than the public measurement stations. Together with a data communication logger for control and communication (wired or wireless), it will fit within a $30 \times 25 \times 60$ cm^3 louvered enclosure.

The small size of this terminal means it can be moved easily to sites where it is required. Therefore, a system constructed of multiple measurement terminals can enable realtime mobile measurements of the traffic pollutants mentioned above, which we believe will be useful in the assessment of the road-side environment. In the future, we intend to install an SPM sensor that can cope with high concentrations of SPM to allow use in areas where traffic pollution is particularly high and develop more kinds of sensors to expand the functional range of the system.

3. Local air environment simulation

We believe that the analysis, evaluation, and prediction of pollutant distributions in which buildings and geographic topology are taken into account are essential to local environmental assessment on the street-corner scale. We are therefore developing a 3D data input and display system using GIS[*2].

*2 GIS (Geographical Information System): A map information system that includes maps and types.

3.1 3D local air environment simulation

In recent years, the focus on the problem of air pollution has been shifting away from regional pollution towards the residential environment and public health. Accordingly, we have developed a 3D local atmospheric simulator for evaluating air environments ranging in size from 100 to 1000 m for the purpose of assessing street-corner-level air environments. Because air advection diffusion can be calculated in 3D using fluid dynamics methods, the effects of building structure and arrangement can also be included, which is not possible with conventional 2D techniques. That makes it possible to calculate various factors such as heat and coolness, the distribution of automobile exhaust gases, and building heat exhaust in urban environments where the wind flow is complex.

The simulator involves developing application programs for a GIS file input function and simulating the advection diffusion of heat, humidity, air pollutants, etc., with a wind simulator serving as the basis for numerical calculations (**Table 1**). For analysis based on fluid dynamics, we are increasing the computation accuracy of the wind flow field. Also, the GIS file reading function developed in this work allows markedly faster input of the structure data for the evaluation area compared with the previous manual entry of data. The automobile exhaust gas distributions, the building heat exhaust distribution, the distribution of humidity on a river surface, and other such data can be calculated easily using the 3D city model obtained from the file input (**Fig. 4**). Up to ten types of pollutants can be evaluated at the same time.

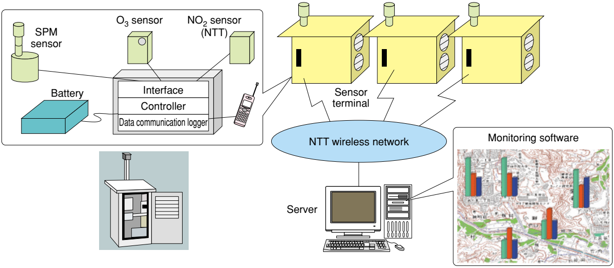

Fig. 3. Networked multi-sensing air environment monitoring system.

Table 1. Issues in the development of the 3D local air environment simulator.

Location		Specific problem	Solution
Interface	Input	• GIS data input function (maps, elevation, land use information)	New
	Output	3D display	Existing
Computational element	Wind	• Fluid dynamics computation	• Requires a special solver • Building design tool exists
	• Gas • Precipitates • Temperature and humidity	• Advection • Diffusion, precipitation, rinsing	Modification of existing function
	Effects of structures	• Thermal characteristics of building and the ground surface, exhaust settings processing • Processing for semi-transparency of wind in trees	New

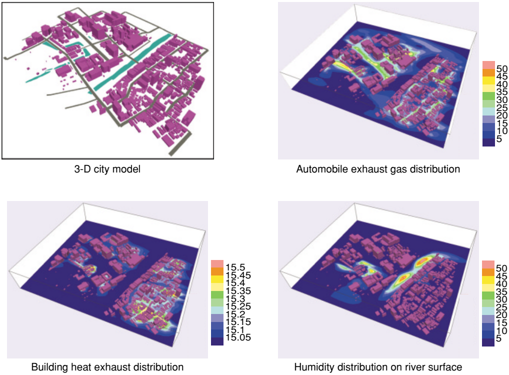

Fig. 4. Example of 3D local air simulation.

The system runs on a single PC rather than on a supercomputer, so it is easily managed, although the computation time can range from 30 minutes to about one day, depending on the number of spatial divisions (10^4 to 10^6 cells).

We believe the application field of this system extends beyond analysis for evaluating urban environment comfort, local pollution problems, and traffic pollution to, for example, the assessment of the effluence of highly toxic substances such as dioxin[*3]. We are considering offering the system to local governments, research organizations, companies involved in building construction, and environment assessment enterprises. In future work, we intend to add chemical reaction models, improve computational accuracy, and study the simulation of secondary products such as oxidants.

*3 Dioxin is a toxic material that is created when substances containing chlorine are burned in an incinerator. Dioxin accumulates in human and animal bodies causing health problems.

4. Development toward environment data estimation technology

With the goal of establishing technology for high-density, realtime air environment evaluation on the scale of the local environment in which people live, we are proceeding with the development of more compact and energy-efficient multi-sensing technology and the development of highly accurate simulation technology based on 3D computation to which atmospheric chemical reaction models have been added. By combining that with air monitoring and assessment technology, we are proceeding with the research and development of technology for estimating photo-chemical oxidant systems and other pollutants.

References

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He received the M.S. and Ph.D. degrees in chemistry from Osaka University, Osaka in 1982 and 1991, respectively. In 1982, he joined NTT Electrical Communications Laboratories, Musashino where he engaged in research on trace analysis of compound semiconductors for LSI circuits by secondary ion mass spectrometry. He received the Young Authors' Award from the Electrochemical Society (ECS) in 1987. Since 2001 he has been researching systems for environmental assessment using monitoring and simulation technology. He is a member of ECS, the Japan Society of Applied Physics (JSAP), the Japan Society for Analytical Chemistry, the Japan Society for Atmospheric Environment (JSAE), and the Japan Society of Waste Management Experts.

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