ABSTRACT
To prevent illegal dumping of waste, Taiwan established the “Industrial Waste Control Report System,” in 2000. This online reporting system is aimed at waste flow tracking (auditing), and investigation of violations. It is part of an effort to control the waste flow from cradle to grave. Different from other systems run by other countries, it requires the waste generators and transporters, as well as the treatment, storage, and disposal facilities (TSDFs) to report online the movement of industrial waste within 24 hours after it has been shipped, received or completely treated. The designated generators also need to report the monthly rate of waste generation. The reported data is checked on a daily basis. On-site investigation is conducted if any violation is suspected. This system also provides On-Line Analytical Processing (OLAP) for reporters to analyze all their data, so as to encourage self-management of waste.
Currently there are 18,126 generators, 3,766 transporters, and 833 TSDFs that are required to make online reports. The reported amount of waste is about 15 million tonnes per year, which is about 80% of the waste generated in Taiwan. About 20,000 people visit the website daily either to report the waste flow or view the web information. It serves as a “single portal” for industrial waste management. This system also succeeded in monitoring the disposal of medical wastes from Severe Acute Respiratory Syndrome (SARS) patients to ensure the wastes were properly treated in 2003.
Starting from the year 2002, 1,600 vehicles that transport hazardous waste were required to install a Global Positioning System (GPS) and transmit their position data every 30 seconds to the same website. Along with the manifests being reported online, the routes can be traced and verified. Illegal dumping cases have been reduced tremendously since then. Another 4,000 GPSs will be installed to the remaining shipping vehicles in the next three years.

INTRODUCTION
The purpose of this article is to explain waste management tools employed by the government of Taiwan. This method uses online reporting by parties related to waste activities in order to establish a comprehensive waste activity tracing system. This system serves as a single portal form of public service, known as the Industrial Waste Control Center Report System (http://waste.epa.gov.tw). Currently there are 90,000 factories, nearly 20,000 medical institutions, and at least 20,000 new demolition sites acting as waste generators, generating 26 million metric tons each year. This is, indeed, a huge burden for an island with an area of 36,000 square meters. There are 170 illegal dumping sites classified as severely polluted sites. A large quantity of the budget is spent on soil and groundwater remediation. These sites came into being as a result of economic development and difficulties of management. Paper manifests were used in waste tracking in the past; this method was time-consuming and very inefficient to monitor the waste flow. The governmental waste management in Taiwan involved at least five ministries. The communication between these ministries such as Environmental Protection Administration (Taiwan EPA), the central industry competent authorities, and local enforcement authorities was indeed inefficient and costly.
The Taiwan EPA initiated the online system in 1998 to better manage tracking. After three years of testing, the Industrial Waste Control Center was officially established in 2000. It offers functions like online integration, mobilization, and OLAP analysis. The reporting system is improved to not only trace the waste flow but also to monitor the actual amount of waste generated.

METHODS
The goal of the Industrial Waste Control Center is to establish a management system for waste disposal from cradle to grave. This management system includes baseline information management, waste disposal and treatment facility permit management, and waste flow
activities management. They are now completely in electronic form and online. The Center relies on the Industrial Waste Control Report System, which designated 40,000 generators to manage baseline information such as their production capacity and raw material input, and requires 20,000 of these designated generators who generate large quantities of industrial and hazardous waste to report waste generation and flow online. Waste disposal facilities must report the arrival of waste after they have received it in order to double check the amount. Global Positioning Systems (GPS) are installed on disposal vehicles to transmit their whereabouts back to the Center. That way the inspectors are able to trace the disposal route and waste flow, as well as verify the information with the manifests reported.

This system mechanism is shown in Figure 1. It is the first system that employs online reporting by various parties associated with waste flow activities to trace the flow of waste and its disposal. Due to the satisfactory performance of the tracking system, the scope has been gradually enlarged by designating more waste generators or waste disposal facilities. The growing trend of designated generators trend is demonstrated in Figure 2. There are around 20,000 generators who make online reports, representing 22% of the total generation sources. Their reported waste quantity makes up 80% of the total quantity of waste generated nationwide. The other 20% of waste generation is from disposal facilities that make monthly reports on waste generation without manifest reporting.

The system is designed for reporting the designed waste activities, e-government service, and regularly auditing and carrying out daily QA/QC to ensure the data gathered is correct. Most applications and permit issuance are handled online. The report data is audited to find out illegal activities like waste disposal exceeding permitted quantity, or waste materials not corresponding to categories waste permitted by the government. There are around several hundred cases investigated each year. Indeed, this system achieves the goal of promoting environmental protection. Figure 3 explains the control management and application items. The system framework is explained as follows:

**Figure 1** Waste Disposal Tracking and Management Mechanism Flowchart

**Figure 2** Growing Trend of Designated Business

**Figure 3** Waste Management Single Portal Diagram

### Generators Management

This system promotes designated generators to report online waste generation categories and quantities, raw materials used, and products
produced in order to establish the waste generation baseline information. It also uses an online auditing system to manage baseline information from around 40,000 generators. Since 2002, there have been around 20,000 generators designated as major targets. They must report production capacity, raw material usage, or generation quantity monthly in order to update their baseline information. These businesses are also required to report temporary waste storage quantity, and the mass balance concept is used to instantaneously calculate all the disposal quantities reported. Waste properties and reported waste quantities are compared together with generators using the same production process to ensure the reported amounts are correct.

To reinforce the self-management of each business, this system offers rapid self-auditing functions for waste generation, statistical analysis to balance temporary storage quantity and disposal quantity, reported data as compared with permitted quantity, disposal quantity trend changes over the years, and GPS tracking inquiries. Businesses do not need to construct their own systems. Using this system will assist businesses in following regulations and raising self-management efficiency and competitiveness. Businesses are able to participate in government policy and have more confidence in the government.

**Waste Flow Tracking Management**

According to the Taiwan EPA regulations, waste disposal facilities must report waste reception information and waste reception quantities online as waste arrives in their facilities. Meanwhile, waste generation quantities and condition after treatment or reuse must be reported online as well. This ensures all waste generated is properly treated.

An important aspect of waste management is to establish correct disposal or treatment information. This system audits waste manifests against disposal, treatment, and recycling permits to determine violations in terms of disposal quantity exceeding the permitted quantity, disposal of waste categories not listed in the permit, and waste disposal vehicles simultaneously registered under two or more transporters. These cases were investigated and citations made accordingly.

Since 2002, the Taiwan EPA has required industrial waste disposal vehicles to be installed with real time tracking systems. Vehicle specifications and maintenance were also regulated. Wireless technology allowed disposal vehicles shipping hazardous waste or wastes that are easy to dump to be installed with a real time tracking system. There were 1,645 vehicles that passed the system test. In the next three years, another 4,000 disposal vehicles will be installed with the tracking system and will be monitored. The disposal route and waste generator report data will be compared against each other, and barcode scanning will replace the manual reading of manifests. The UTM axis is joined with internet auditing to easily track the route of hazardous waste liquid. If a suspicious vehicle enters an important water source protection area, the alarm system will be triggered. Inspection officers can inspect suspicious cases at anytime. This system offers a PDA inquiry function. A designated vehicle route is tracked and random inspection is conducted. A PDA is also used to report back the inspection result.

To achieve the goal of controlling the trans-boundary movement of waste, beginning in 2002, this system required that exporters must report online the manifest describing the route, amount, and categories from the storage area to the port, and a corresponding English version manifest. Foreign treatment facilities must make online reports to confirm waste received. The exporter and the foreign treatment facilities have been following the regulation to make online reporting. This is the first online management system in the world that traces waste trans-boundary movement.

**On Site Inspection and Auditing**

To control the accuracy of the reported data, the Taiwan EPA has mandated inspection offices or entrusts professionals to conduct onsite inspections of more than 10,000 cases each year. Frequent inspection of waste generation, and storage, and comparing the reporting data with onsite inspection results in over 90% reliability of reported data.

**Statistical Analysis and Strategy Support**

To overcome the difficulties of prompt inquiry into 30 million records, this system uses On Line
Analysis Processing (OLAP), which calculates large quantities of historical data into a multi-dimensional cube (Figure 4). The cube can be up to more than five categories. Data conversion into a multi-dimensional cube allows for rapid inquiry, statistical analysis, and auditing functions. Competent authorities can use this information when formulating waste management strategies.

Dimension and Level Analysis

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**Figure 4** OLAP System Dimensional Analysis and Application

**RESULTS**

This system was constructed by the Taiwan EPA and shared with each local enforcement authority and other industry competent authorities; it saves more than 30 million NT dollars (one million US dollars) in administrative costs annually. After this system was established, there were only a few cases of illegal dumping of demolition waste in these past two years. Our environment has profusely benefited from this system and the benefits it has brought include: 1. Barriers to communication obstacles with other industry competent authorities are removed; 2. Self-management and competitiveness of businesses are increased. Businesses are able to participate in policy making and have greater confidence in our government; 3. Policy makers utilize analytical reports, database storage, and data mining to promptly make correct policy; 4. Waste generation and treatment capacity information is offered for businesses that are interested in setting up treatment facilities. In 2003, during the SARS epidemic, Taiwan was designated as a severely affected region. This system promptly analyzed medical waste generation and the remaining available treatment capacity on a daily basis and offered the sanitation department a valuable source of information for decision making. The environmental management staff was able to use this system to work at home, without interruption from the threat of SARS infection. This was a successful application of executing environmental management without limitation of work location and time.

**DISCUSSION**

Waste disposal flow tracking involves cross boundary movement. Without using modern technology, it is difficult to monitor transportation and therefore also difficult to reach the goal of “managing waste from cradle to grave.” Currently, we have established a complete database, but we will have to continue to upgrade this system by adopting the latest information technology. We will employ Radio Frequency Identification (RFID) and image transferring technology to reinforce the efficiency and accuracy of waste disposal monitoring. Employment of such technology will raise the reporting efficiency and offer better public service. We will then integrate all the permit and baseline information from different departments (air, water, waste, and toxic substances). Such a system will be a good tool to reach the goals of controlled flow of materials and sustainable development of resource. This type of management system is currently not employed in many countries, and we wish to share our successful experience with others.

**SUMMARY**

Industrial waste management in Taiwan takes advantage of the e-revolution and wireless technology to establish a complete industrial waste tracking system and single portal, even with limited manpower. Over 40,000 waste generators are designated in this system and more than 30 million records have been gathered. Online management enables the Taiwan EPA to promptly understand waste generation and flow. This is the first and largest system to date to use Internet reporting to manage cross boundary waste movement. It is also one of the best systems that exists worldwide to manage waste online.
There are around 20,000 hits on the site each day and more than three million visitors visit the web site annually. The web site has become the most visited site among Taiwan’s government web sites. The environmental central competent authority, local enforcement authority, and central industry competent authority have more than 300,000 visitors who log into the management system annually. This system offers the environmental competent authority a sound basis for inspecting illegal activities. This system also offers businesses a chance to conduct self-management. The system achieves the dual goals of convenient service and environmental management.

REFERENCES
3. “Enterprises Designated as Mandatory Online Reporting on Waste Generation, Storage, Disposal, Treatment, Reuse, Export, and Import”, promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, April 1, 2005.
4. “Reporting Format, Items, Contents, and Reporting Frequency for Online Reporting of Waste Generation, Storage, Disposal, Treatment, Reuse, Export, and Import”, promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, June 29, 2004.
5. “Enterprises Designated as Mandatory Submitted Waste Disposal Plan”, promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, on August 30, 2005.
6. “Waste Disposal Plan Format and Data Items Required to be Submitted”, promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, January 24, 2003.
7. “Specifications and Maintenance Requirements for Real Time Tracking System Installed on Industrial Waste Disposal Vehicle” promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, February 6, 2006.
8. “Industrial Waste Disposal Vehicle Types Required to Install Real Time Tracking System”, promulgated by Environmental Protection Administration, Executive Yuan, Taiwan, May 11, 2006.

BIBLIOGRAPHIES