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Dynamic Surveillance System for Contamination Accidents in Chemical Industry Park Based on Internet of Things

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In recent years, the frequently occurring contamination accidents in the chemical industry parks in China has posed great threats to the healthy development of the national economy and social stability. For this purpose, this paper conceives a set of dynamic surveillance system against such accidents, which, on the premise of rapidity, simplicity, and reliability principles, revamps and redesign the HYSPLIT air pollution model for the interface, architecture, and functions, wholly integrates with air pollution diffusion model, numerical meteorology forecasting model, and the Geographic Information System (GIS). With the business operation mode, this system can effectively warn against the "uncertainty" of atmospheric pollution events in the chemical industry park, timely access the information about whether any pollutant exceeds allowable limits when an accident occurs. In the response to the emergency accident, it enables quantitative analysis and visual expression on chemical pollutant concentration limits, development trends and health risks, so as to provide an effective business and information support for decision commanders.

1. Introduction

In our country, with the development of economy, serious environmental and security risks in the chemical industry parks also arise. Most of the commodities and raw materials contain awful lots of toxic chemicals with high masses which may trigger off hidden perils on the environmental security (Ball and Bernard, 1978; Banach et al., 2016; Broding et al., 2011). In addition to this, many chemicals are extremely toxic and unsteady, they are scavenged out of the parks in a highly intensive mode, maybe mix and react. In this sense, the leakage of chemicals often leads to grave consequences. In order to effectively hush up hidden dangers of chemical products, China has already taken tremendous efforts in some ways, for example, to build assessments on hidden dangers in the project environment, environmental emergencies, distinguish the level of environmental hazards in key areas, and review hidden risks of companies in key areas (Chen et al., 1997; Chen et al., 2006; Dixon and Dixon, 1981). The IoT based on the integration of the most advanced technologies in multiple industries has unique application effect in the category of the environmental since it features strong information access, delivery and solution capacities. It is therefore bound to explore a new channel for the surveillance over environmental hazards (Grigalunas et al., 1988; Gunster et al., 1993; Hart et al., 2008).

2. Framework of pollution event surveillance system in chemical industry park

2.1 Concept of IoT

The IoTs (Internet of Things) originated from the Massachusetts Institute of Technology in the United States in 1999 (HPrzewozny, 1996; James, 1997; Lennox et al., 1998). Specifically, the previous IoTs refer to a uniquely expanded Internet built "based on Radio Frequency Identification (RFID) technology and infrastructure, which associates the established communication protocol with the network to allow intelligent recognition and supervision, intercommunication, interchangeability, and sharing of product information" (Tan et al., 2015; Tanabe, 2001; Zoeteman et al., 1981). From the perspectives of the industry chain and technology development, the theoretical community generally believes that the IoT framework comprises the network layer, the perception layer, and the application layer, see Fig.1 for details:

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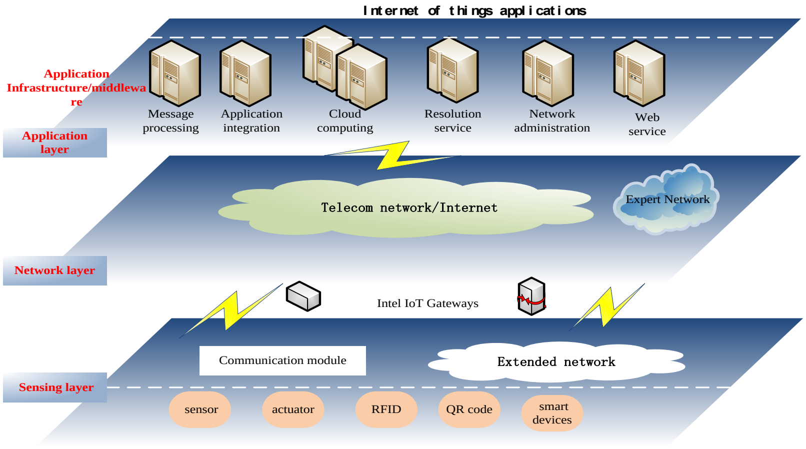


Figure 1: Application effect diagram of Internet of things

2.2 Analysis of system requirements

(1) Environmental data acquisition: timely monitoring information about particular pollutants in atmosphere; pollutants in normal atmosphere; daily meteorology data in the local area; information database for chemicals with hidden hazards. (2) Environmental data to be transmitted at any time. (3) Overall application of environmental data.

2.3 Management object and model

In accordance with the identification of risk sources in the chemical industry park, it is clarified that there are the natural risks arising from extreme climate and overfalls, as well as the human risks from explosions, oil spills above the sea, leakage of toxic chemicals, fires, discharge of waste residues, waste water and exhaust. For natural disasters, the focus turns on warnings; while for human risks, the focus should be taken on prevention against these and that urgent treatment is required once occurred.

2.4 Framework design

2.4.1 Design principle

(1) Holistic coverage; (2) Social collaboration and division of labor; (3) Relaxation and standardization.

2.4.2 Application models of IoT in environmental management

In virtue of the application cases of the IoT in the environmental industry at home and abroad, the application models of the IoT in environmental supervision are screened and concluded, see Tab. 1 for details.
Perception layer covers weather testing system, atmospheric monitor station, supervision over particular pollutants, emergency surveillance; as for transmission layer, in view of the fact that there are too many outdoor supervision nodes, scalability, and mobility, the wireless network should be chosen to achieve the information transmission. Application layer involves information treatment, storage and requisition, as well as information investigation.

2.4.3 Framework description

Based on atmospheric risk sources, natural risks and atmospheric quality in a chemical industry park, the system uses environmental and meteorological sensors to build a purposeful surveillance system which allows holistic supervision for atmospheric pollutants and actual pollutant concentrations, climate conditions, and current service information. Some classified information collected can be sent to the information agencies whenever needed, with the help of consistency processing, to serve for various types of later supervision project after storing.

3. Design and development of early warning system against abrupt air pollution accidents in chemical industry park

3.1 Framework of early warning system

An early warning system for abrupt air pollution accidents is built using the following procedure: associate dynamic data of the risk source supervision system on the premise of initiative and manual assistance supervision on the current situation of environment in order to identify the omen of potential hazards in the environment in the early days; use the meteorological data to develop the warning model for atmospheric environment quality assessment, explore pollution trends, predict the constraints and damage that the environmental issues may lead to, and issue the classification warnings; simulate different measures against environmental hazards, assess the treatment situation, and provide the clues to improvement measures. An architecture of the abruptness air pollution warning system is shown in Fig. 2.

Table 1: Summary of application patterns of Internet of things in environmental management

Application field	Water environment	Atmospheric environment	Solid waste	Sound environment	Radiation management
Perception form	Water quality monitoring station	Atmospheric monitoring station	RFID		Radioactive source monitoring station
	Water quality sensor	Atmospheric monitoring probe	Video camera	Noise environment monitoring	
	Hydrological monitoring information	RFID	GPS		Radioactive moving monitor
Perceived object	Surface water	air pollution source	hazardous chemical		Fixed source
	]industrial wastewater	ambient air quality	solid waste		radioactive source effluents
Sensing parameters	DO, Temp, Tur, phyllo-, CODCr	NO_x, SO_2, CO, et.	Position status information	noise decibel	intensity of the radioactive material
The application layer	Pollution control Control total of COD Water source protection Emergency response	Air pollution control Control total of SO_2 pollution prediction Emission reduction	Track hazardous chemicals, waste status and location, efficient management and preparation for emergencies	Monitor city noise sources Draw city noise map	Track and manage sources of radiation

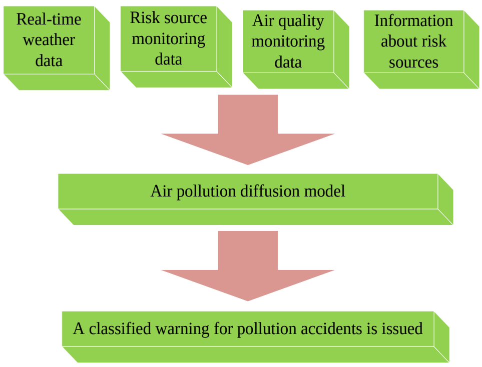


Figure 2: The framework of the air pollution monitoring system in chemical industry park

3.2 Detail design of early warning system

3.2.1 Perception layer

According to the hazards from key chemicals and pollutants in the chemical industry park, the five types of toxic gases, i.e. hydrogen sulfide, styrene, benzene, vinyl chloride, and chlorine, are supervised as key particular pollutants.

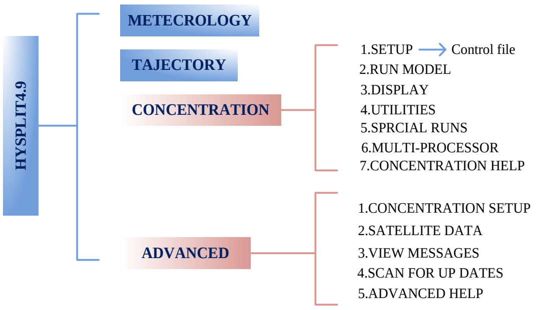
In light of study, it is believed that the open optical circuit infrared spectrometer as the subjective and photoion tester applies to the supervision of the demonstration industry park. On this premise, an integrated, expanded, and mobile pollutant test model is built. Take such an integrated model as an example to explain it in detail:
Key facilities: Contaminant probes (chlorine, VOCs, etc.) with warning functions, mobile emergency test vehicles, and photo ion tester.
Measures: Contaminant probe stabilized at the periphery of a chemical company is taken as the subject, assisted with the PID of the chlorine tester and the movable VOCs. The warning probes only measure up certain type or several types of gases, and do not depend on the roaring type but remote warning by transmitting information. In virtue of special pollutant-matched alarms installed at different chemical plants, it is possible to detect pollution scientifically. If the pollutant in a certain area exceeds the standard, the alarm emergency supervision vehicle can rush to the scene in the first place after receiving the message.
By contrast, this paper picks up a holistic one from three types of test measures, and there are qualitative and quantitative tests associated with stability and mobility, mainly on particular pollutant alarms, assisted with mobile emergency surveillance vehicles.

3.2.2 Design of transport layer

As the particular pollutant supervision system operates in a small scope, and much closer to the emergency supervision sectors in the chemical industry park, roughly 1.5km. Therefore, the wireless network established by wifi can timely transmit data back to the information agencies.

3.2.3 Design of application layer

Model utility correction: In order to estimate the transmission trends and dates of hazardous and toxic products (risk sources), as well as the substantial results from the environmental improvement simulation, it is required to quantitatively simulate the diffusion model of a certain type of atmospheric pollution. With the help of the integrated measurement model, it is definite that the Lagrangian trajectory diffusion model (simply called HYSPLIT) is taken as a precondition to check, pick and reconstruct the model and develop its interface using parameters in order to achieve the regional operation of the model.
As the original function and operation procedure of HYSPLIT model are more complicated, that is, in the English interface, and with higher professional requirements, this paper streamlines the model composition and improve its functions.
(1) Select model function components, the composition of HYSPLIT model function modules and their relationship are shown in Fig. 3:



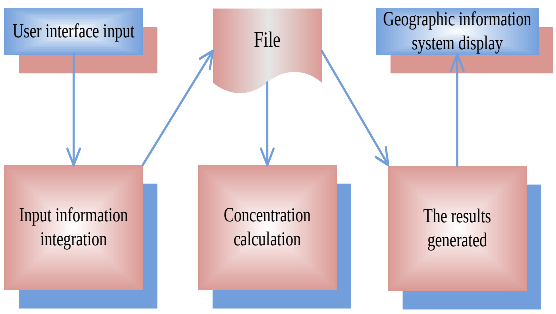


Figure 3: HYSPLIT mode function module composition and relationship

Figure 4: Batch file design logic diagram

(2) Write a batch file with design logic shown in Fig.4:
(3) The conversion result outputs file format.
1) Construction of information base for particular pollutant parameters: After surveying all devices in chemical plant area, particular pollutants from the hazard sources and their positions are measured; the parameters required by the model operations such as the Henry's constant of chemical substances are defined with reference to the document literature, and an information library for pollutant parameters is also constructed. The backstage of pollutants and parameters can be reached, which further greatly reduces the inward transmission of external source data when the system operates. The parameters involving particular pollutants are shown in Table 2:

Table 2: Particular pollutant parameters

Material name and code name	Molar mass($g\cdot mol^{-2}$)	Henry coefficient ($Pa\cdot m^3/mol$)	Surface reaction ratio	Diffusion ratio
Benzene01	78.11	556	0.0	1.6
Styrene02	104.151	267	0.0	1.6
Hydrogen sulfide03	34.076	533.54	0.0	1.6
Chlorine04	70.906	16.36	0.0	1.6
A vinyl chloride051	62.5	2685	0.0	1.6
The vinyl chloride052	96.94	2649	0.0	1.6

2) Integration of model with numerical meteorology warning system: The HYSPLIT model uses the meteorological information at the grid to calculate the concentration of air mass or particles. The pollutant propagation rate can be available based on the operations of vertical expansion profile, the horizontal deformation of the wind field, and the wind shear. HYSPLIT model information format is converted into unit compilation and assembled on the high-performance computer in the institute. Every time the TJ-WRF information is determined, it is integrated to form the "ARL" format data required by the HYSPLIT model. Meteorological information will be updated once every 8 hours and timely transferred to the high-performance computer in Harbor Economic Zone.

3.3 System operation

The paper conducts trial operation for supervision system in a chemical industry park, which now operates with an excellent project. The system returns monitoring information once every dozens of seconds, and sets an alarm for excessive pollutants, so that the concentration of VOCs is read as zero under normal conditions (less than 1ppm), as shown in the figure; if there is any pollutant which exceeds the standard, the system will highlight the red alarm information. As shown in Fig. 5:

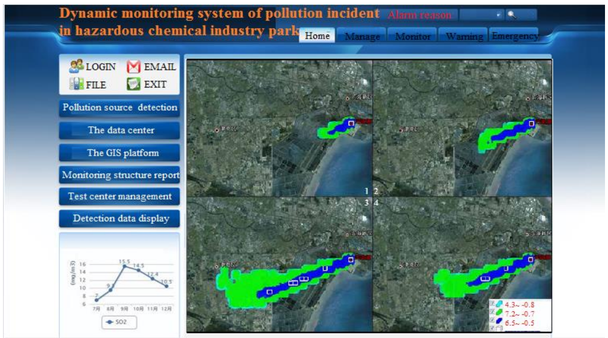


Figure 5: The interface diagram of the dynamic monitoring system of pollution incident in hazardous chemicals park

The air pollution warning system can be inspected for its operation conditions comprehensively by means of trial operation. It is confirmed that the system can warn against any pollutant in the first time, achieve a precise surveillance on any pollutant and its concentration, and timely return relevant data. Beyond that, it will be able to quantitatively estimate the contagious concentration of pollutants, contamination development trend with the help of air pollution model so as to provide an all-round support for emergency treatment, decision and rescue work.

4. Conclusions

(1) This paper uses the advantages of the IoT integrated with sensing, communication, and information technologies to explicitly define the supervision subject, model and program aiming at the “uncertainty” that occurs in the supervision process over environmental hazards in chemical industry parks, in virtue of identified risk receptors and risk sources.

(2) The system architecture is constructed with systematic survey measures, and the framework and functions of the system are meticulously conceived from three dimensions, perception, transport and application layers to achieve the goal of prevention against contamination accidents and emergency supervision system development, as well as effective operation in the chemical industry park.

(3) This system enables a daily real-time supervision on pollutants based on atmospheric characteristics, and makes a timely alert for excessive standard information; if data alerted is proved to be an accident, it immediately accesses the emergency response to pollutant concentration, diffusion scope and development trend for computation with the atmospheric model, so as to provide reasonable decision support materials for full command of chemical companies.

References

Ball D.J., Bernard R.E., 1978, An analysis of photochemical pollution incidents in the greater london area with particular reference to the summer of 1976, Atmospheric environment, 12(6), 1391-1401, DOI: 10.1016/0004-6981(78)90081-1.

Banach J.L., Stratakou I., Fels-Klerx H.J.V.D., Besten, H.M.W.D., Zwietering, M.H., 2016, European alerting and monitoring data as inputs for the risk assessment of microbiological and chemical hazards in spices and herbs, Food Control, 69, 237-249, DOI: 10.1016/j.foodcont.2016.04.010

Broding H.C., AndrÉ V.D.P., De Sterke J., Monsé C., Fartasch M., Brüning T., 2011, In vivo monitoring of epidermal absorption of hazardous substances by confocal raman micro‐spectroscopy, Journal der deutschen dermatologischen gesellschaft, 9(8), 618-627, DOI: 10.1111/j.1610-0387.2011.07657.x

Chen L., Jiang D., Xia J., Chen L., Jiang D., Xia J., 1997, A scheme of hazardous chemical identification for transportation incidents, Journal of hazardous materials, 56(1-2), 117-136, DOI: 10.1016/s0304-3894(97)00033-2

Chen Q.F., Milburn, R.K., Karellas, N.S., 2006, Real time monitoring of hazardous airborne chemicals: a styrene investigation, Journal of hazardous materials, 132(2), 261-268, DOI: 10.1016/j.jhazmat.2005.09.050

Dixon T.R., Dixon T.J., 1981, Aeolian sky packaged chemicals pollution incident. Marine Pollution Bulletin, 12(2), 53-56, DOI: 10.1016/0025-326x(81)90260-5

Gao Y.Q., 2018, Application of Computer Surveillance Technology in Industrial Ethanol Fermentation, Chemical Engineering Transactions, 65, 565-570, DOI: 10.3303/CET1865095

Grigalunas T.A., Opaluch J.J., French D., Reed M., 1988, Measuring damages to marine natural resources from pollution incidents under cercla: applications of an integrated ocean systems/economic model, Marine resource economics, 5(1), 1-21, DOI: 10.1086/mre.5.1.42871962

Gunster D.G., Gillis C.A., Bonnevie N.L., Abel T.B., Wenning R.J., 1993, Petroleum and hazardous chemical spills in newark bay, new jersey, usa from 1982 to 1991, Environmental pollution, 82(3), 245-53, DOI: 10.1016/0269-7491(93)90126-9

Hart J.E., Bertrand K.A., Dupre N., James P., Vieira V.M., Vopham T., 2018, Exposure to hazardous air pollutants and risk of incident breast cancer in the nurses' health study ii, Environmental health, 17(1), 28, DOI: 10.1186/s12940-018-0372-3

HPrzewozny B.J., 1996, Opportunities and constraints in monitoring chemical hazards by religious organizations, Science of the total environment, 188(2), 113-6, DOI: 10.1016/0048-9697(96)05284-9

James W.H., 1997, Offspring sex ratio as a potential monitor of reproductive disorders in communities near hazardous chemical sites. Reproductive toxicology, 11(6), 893, DOI: 10.1016/s0890-6238(97)00073-7

Lennox S.D., Foy R.H., Smith R.V., Unsworth E.F., Smyth D.R., 1998, A comparison of agricultural water pollution incidents in northern ireland with those in england and wales, Water research, 32(3), 649-656, DOI: 10.1016/s0043-1354(97)00264-9

Tan Q., Zhang Y., Zhang X., Pei X., Xiong J., Xue C., 2015, A hazardous chemical-oriented monitoring and tracking system based on sensor network, International journal of distributed sensor networks, 2014(1–3), 1-8, DOI: 10.1155/2014/410476

Tanabe A., 2001, Development of simultaneous analytical methods for hazardous chemicals and their applications to environmental monitoring, Bunseki kagaku, 50(12), 915-916, DOI: 10.2116/bunsekikagaku.50.915

Zoeteman B.C.J., Greef E.D., Brinkmann F.J.J., 1981, Persistency of organic contaminants in groundwater, lessons from soil pollution incidents in the Netherlands, Science of the total environment, 21(81), 187-202, DOI: 10.1016/s0166-1116(08)71938-1