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# Environment Supervision System for Chemical Industry Park Based on IOT

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Today, owing to the rising industrialization in China, the emerging industry parks has greatly benefited local development, while the safety hazards brought by them to the local environment and human cannot be ignored due to industry particularity. It is certain that the most sobering part for safety management is effective supervision on risk sources. The system is designed based on the Internet of Things (IoT) in that it can fully perceive the changes in the environment. Based on the data mining analysis, it can predict the impending accidents and hold back any of them at the initial stage. Coupled with the improvement of the emergency command system, it enables the intelligent detection on environmental changes and early warnings, which helps achieve the health, safety, and sustainable development in the chemical industry parks.

## 1. Introduction

In the chemical industry, another issue people most concern is safety and security except for operation income (Mehmood et al., 2016; Park et al., 2014; Chun et al., 2015). In general, accidents will most likely happen in the following areas of chemical industry: (1) production of chemicals. There are lots of chemical substances in the raw materials used for chemical products, which are often noxious. And worse, relatively complex composition and operation of production equipment make accident most incidental due to misuse or failure; (2) improper storage or transportation of chemical products and their raw materials; (3) force majeure factors (external environment), they could cause safety accidents (Park, 2015; Lerche et al., 2012; Li et al., 2017). Therefore, for the sake of the safety, major accidents and losses incurred in the chemical industry should be avoided. Domestic and foreign scholars have carried out extensive studies on how to contain and prevent against such accidents. The way the accidents get controlled is to intensify the supervision over external environment and improve emergency management modes. In recent years, the network information technology has been widely applied, and China have ushered the “Internet+” era. Various companies have launched the environmental supervision system with the IoT in attempt to supervise and make an early warning on safety accidents.

## 2. Key technologies

### 2.1 IoT

The IoT expands the exchange of information between tangible articles on the Internet. It can carry a huge mass of entity info., recognize different entities, perform more intelligent than Internet. It manages heterogeneous devices conjoined and uploads data to the data management center in the cloud for storage (Sevilla et al., 2014; He et al., 2018). The IoT application makes device management more efficient and simpler with intellectual transaction processing system that saves more labor cost. The framework of IoT-enabled transaction system is shown in Tab. 1.
It follows that the IoT has the following functions: (1) batch processing for different types of data in real time; (2) existing information in the smart application environment; (3) access to non-relational databases more flexibly; (4) Data storage in the cloud; (5) low storage cost, which solves the problem of low latency.

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*Table 1: The framework for the management of Internet of things data*

| the first layer | Application |
|---|---|
| the second layer | Visualization technology |
| the third layer | Data analysis and real-time event processing. |
| the fourth layer | Specialized data storage (Data mining technology) |
| the fifth layer | Data storage (Management and archives) |
| the sixth layer | Data pre-processing (Clean and disassemble) |
| the seventh layer | Data collection, production (RFID, sensor) |

### 2.2 GIS system

GIS - Geographic Information System, a computer information system for spatial structure calculations, can search for and store spatial information in real time, and display parsed and processed information available to users (Planas et al., 2018; Rømer et al., 1995; Chervin and Bodman, 2004). GIS often works with wsn technology, so that users can quickly capture the company's environmental data and its risk source monitoring figures from electronic map in real time. GIS has a strong processing capacity for geographic information at a fast speed. Data management is scientific and rigorous. It has found wider applications and is commonly used as a management system for supervision and early warning.

## 3. Demand analysis of environmental monitoring in chemical industry park

### 3.1 Chemical risk sources and explosion management

3.1.1 A diffusion model is used to calculate the concentrations of toxic chemicals leaked from hazardous sources **in the chemical industry into spaces, and divide these spatial areas into the following four types:**

(1) Lethal area; (2) Severe injury area; (3) Light injury area; (4) Inhalation reaction area (safe area).

#### 3.1.2 Enter the parameters of the impact factors:

(1) database information; (2) ambient environment; (3) climate temperature; (4) risk source.

#### 3.1.3 Output the final calculation result:

(1) Division of iso-concentration lines and the above four diffusion areas; (2) Maximum concentration at a certain point in downwind direction; (3) Full dosage at a certain point in downwind direction

#### 3.1.4 Display modes

The levels of the risk sources are identified in different colors in the GIS graph.

### 3.2 Chemical hazard sources and hidden danger management

In order to carry out secondary data retrieval and modification, the system first records hazard data and store them in the database; the hidden dangers detected by the system are called out with different block diagrams, and where the hidden dangers lie and what about their risks are identified in different colors; the system will evaluate hidden dangers as identified and then develop appropriate emergency plan. The system enables functions for hidden danger management, including: (1) hidden danger identification, analysis, reminder and retrieval; (2) closed-loop management; (3) statistical analysis of workshop layout; (6) regular preparation of hidden danger management reports issued monthly, seasonally, half-yearly and full-yearly.

### 3.3 Emergency command platform for chemical industry park

The framework of the expected emergency command platform is shown in Fig. 1:
The platform mainly integrates the following three parts:
3.3.1 Information integration:
3.3.1.1 Scientific management, maximize information sharing;
3.3.1.2 Spatial information and operational data integration;
3.3.1.3 Maximize data utility and strongest early warning capacity;
3.3.1.4 Strengthened interaction, full exchange of information between the subsystems.
3.3.2 Decision integration
3.3.2.1 Develop emergency plan;
3.3.2.2 Data analysis and processing;
3.3.2.3 Different knowledge base management.
3.3.3 Command integration

3.3.3.1 Support for various communication modes such as Web, GPRS, E-mail, 3G/4G, etc.;
3.3.3.2 On-site command and mediation;
3.3.3.3 Management standardization for emergency resource management, customer service centers and command centers.

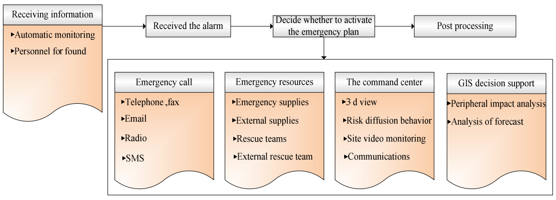


*Figure 1: Emergency command platform target system*

## 4. Environmental supervision network design in chemical industry park

### 4.1 Wireless sensor network layout in chemical industry park

The wireless sensor network layout in the chemical park is shown in Fig. 2:

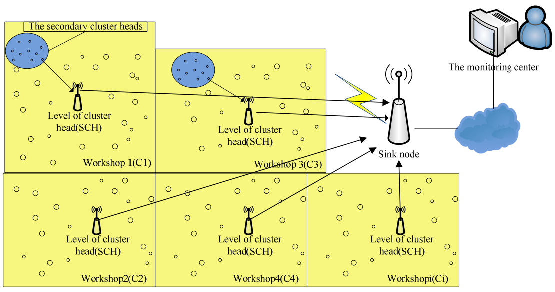


*Figure 2: Schematic diagram of network layout of chemical industrial park*

The sensor network in the chemical park is composed of multiple sensors installed in each chemical plant and used to record data in different areas. Data recorded by the sensors will be sent to the appropriate *sink* nodes which integrate environmental data in the whole plant into a super cluster and upload them to the monitoring center for supervision emergency system to process, in order to realize risk assessment, early warning and other functions.

### 4.2 Routing protocol for centralized clustering based on location and residual energy

The first routing protocol used in wireless networks in the world is the LEACH protocol, which is mainly designed to simplify data recorded by sensors and compress these data with data fusion technology to save the communication power consumption at *sink* node. The framework of this protocol technology is single-hop clustering type, and many protocols are available from its optimization, such as the development of secondary cluster heads. The protocol framework in this paper is a centralized cluster type, that is, a centralized cluster is performed on the sensors in each plant by SCH.
Under this protocol, data will be calculated by the procedure as follows:
Under this protocol, plant data is divided into *n* data domains $(C_1, C_2, C_3, \ldots, C_n)$, then the environmental data in this plant is:

$$A = C_1 + C_2 + C_3 \ldots + C_n \quad (1)$$

Remaining energy $E_{ave}(r)$ after receiving *r* rounds of data by BSH is calculated by the formula:

$$E_{ave}(r) = \sum_{i=1}^{n} E_i(r) / n \quad (2)$$

(Note: In the above formula, the remining energy at the node *i* after receiving *r* rounds of data; *n* refers to the total number of nodes)

The SCH node obtains the optional cluster head with threshold factor. Threshold factor of this system is: the sum of the remaining energies at the nodes and the distance between the node and the SCH node. Among them, the energy threshold factor ($E_{(i)}$) is:

$$E_{(i)} = \frac{E_r(i)}{\overline{E_r}} \tag{3}$$

(Note: In the above formula, $\overline{E_r}$ is the average value of the remaining energy at the nodes after receiving *r* rounds of data; $E_r(i)$ represents the remaining energy at the node *i* after receiving *r* rounds of data)
Distance threshold factor ($D_{(i)}$) is calculated:

$$D_{(i)} = 1 - \frac{d(S_i, SCH)}{d_{\max}} \tag{4}$$

(Note: $d(S_i, SCH)$denotes the distance between *i* and SCH nodes; $d_{max}$ is the maximum distance between *sink* node and SCH node)
Optimize the threshold (*T(n)*) by weighting algorithm:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times [r \bmod (1/p)]} * (w \times E_{(i)} + (1-w) D_{(i)}) n \in G \\ 0 \end{cases} \tag{5}$$

## 5. Design of environmental supervision emergency system in chemical industry park

### 5.1 System architecture

The system architecture is shown in Fig. 3:

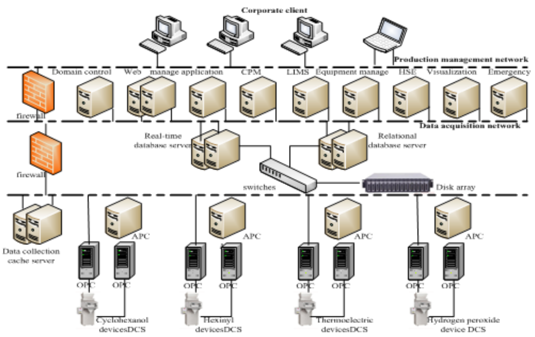


*Figure 3: Architecture of environmental monitoring system in chemical industry park*

The servers of the production management system include: (1) CPM; (2) Web; (3) Domain Control (Management System Account); (4) LIMS. The data acquisition network uses a data cache server. In addition, all device should be equipped with OPC and advanced control servers to ensure system security and timely data collection.

### 5.2 System logic design

The environmental supervision and emergency response system in the chemical industry park adopts the B/S three-tier architecture, as shown in Fig. 4:
The B/S architecture includes three levels: (1) Web presentation level, which is designed for system users to facilitate them to query system information; (2) Logical service level, which processes geospatial data and is implemented by ArcGIS software. (3) Data service level, which is used to collect and access raw data (risk sources, environment data, etc.).

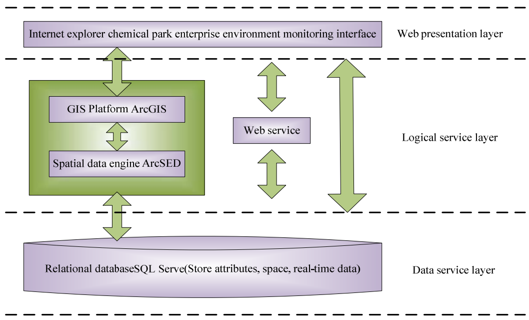


*Figure 4: Architecture diagram of environmental monitoring system of chemical industry park*

### 5.3 Design of system function

It is required for the system to restore the chemical workshop in a stereoscopic form and call out data where appropriate. For this purpose, this system needs to use 3D visualization technology and VR technology to achieve visualization effects. Beyond that, emergency action drill should be also implemented to intensify the system transaction processing and risk analysis for hidden dangers, emergency command and other functions.

The functions that system needs to design include: (1) comprehensive environment management and real-time environment data management; (2) emergency command, emergency accident supervision, early warning and pretreatment. Therefore, the functional architecture aross the system is shown in Fig. 5:

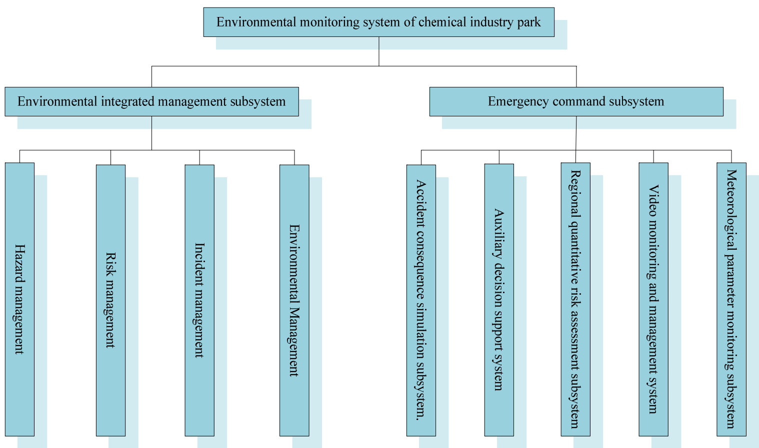


*Figure 5: System overall function structure diagram*

### 5.4 DB design

*Table 2: Basic information sheet of the risk source material properties*

| Field ID | Type | Length | Annotation |
|---|---|---|---|
| Chemical Name | VARCHAR2 | 50 | Name of hazardous chemicals |
| Chemical Type | VARCHAR2 | 50 | Type of hazardous chemicals |
| Grade | NUMBER | 20 | Hazard level |
| Chemical Quantity | VARCHAR2 | 50 | The number of dangerous chemicals |
| Chemical Properties | BLOB | 500 | Nature of hazardous chemicals |
| Control Measure | VARCHAR2 | 100 | Control measures |
| Plant Name | VARCHAR2 | 100 | The factory name |
| Plant ID | VARCHAR2 | 36 | The factory ID |
| Address | VARCHAR2 | 100 | Address |
| Telephone | NUMBER | 20 | Phone number |

The system database can be divided into the following three types by diverse information: (1) spatial information; (2) emergency resource information; (3) chemical safety production information. Here, we focus on the type (3) database:

The correlation charts of chemical safety production information database include: user information sheet, roleInfo, risk source attribute list, real-time supervision data sheet for risk sources, early warning data sheet, and emergency command information sheet. Among them, the risk source attribute list designed in this paper is shown in Tab. 2, which mainly records the basic information of the risk sources, including some attributes such as name, type, quantity, risk level, plant name, plant address, physical and chemical properties, control measures.

## 6. Implementation of major functions of the system

The system needs to authorize users access right. The operator must log in successfully to his account for setting system access. The account should be registered by user with real-name and different levels of operators should be authorized with different access rights to ensure the security of the system information and operations; the main interface of system should also include the following information: navigation of system functions, early warning of risk sources and hidden dangers, accidents and their disposal consequences. Thus, the login interface can be designed.

## 7. Conclusions

Based on environment conditions in the chemical industry park, the sensor network is designed `hierarchically, and the location of nodes and their remaining energies are calculated. A centralized-cluster-based data communication system is also built, which reduces the data traffic and energy consumption of the nodes so as to prolong service life of the sensor network.

Efficient GIS technology will enable relevant data information about the chemical park to be displayed on the electronic map more intuitively and symbolically so that the system functions can be visualized.

Plenty of emergency treatment resources are stored in the system database to facilitate the system diagnosis on the safety accidents in the park and awaken early warning function. A set of kits for emergency response is also designed to develop accident management plan.

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