Study on the information chain of sudden pollution accident

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Abstract. The sudden pollution accident in a river basin is combined with accident cause, cause factor (pollutants) and the receptive environment all together, this study brings up the method to establish the information chain of sudden pollution accidents in a river basin which can describe the causality of all information. Take the sudden oil pollution accident in a river basin as an example, the information system of sudden pollution accidents in a river basin is established from five aspects: pollution source characteristics, pollution characteristics, regional environment characteristics, lash-up treatment technology status and pollution impact characteristics. Through index abstraction and structure representation for the above information, and connect the interactive relationship of the node variables with directed edge line segments, based on which the expert knowledge analysis synthesis method is applied to achieve the optimal causal direction relationship, and the information chain of sudden oil pollution accident in the river basin is ultimately established. This information chain can sufficiently show the causal relationship of each information elements in the sudden pollution accident and can supply decision making basis for examining and distinguishing the status of a sudden water pollution accident in a river basin and determining the precise lash-up treatment technology.

Keywords: Pollution Accidents in A Drainage Area; Information Chain; Factor Set; Responding Relation; Expert Knowledge Analysis Synthesis Method

1. Introduction

Each key link in the whole genesis and development process of a pollution accident in a river basin decides the development trend of the accident, there are certain penetration and interference relationship amount the pollution source information, pollutant information, regional environment information and pollution development. The status quo of the study on environmental pollution information system [1-6] is only to achieve electronization and partial visualization from the information’s structure and format, and the study on sudden pollution accidents in a river basin is merely focused on coordination between departments, compiling technology for lash-up plan, lash-up monitoring technology, statistics technology for hazardous articles [7-13]. Since the current study lacks deep analysis of the cause of the sudden pollution accidents and the impact of the exterior environment, a complete logical reasoning can hardly be achieved, therefore, the determination of the lash-up treatment scheme is restrained, and when the accident occurs, it cannot be disposed timely and effectively [14-16]. Based on the above, this study brings up the knowledge requirement according to
the lash-up treatment technology, to start with the evolution mechanism of the sudden pollution accident in a river basin, the connection of the information is drawn out, and the pollution status of sudden pollution accident is distinguished, which is also the key problem in China that needs urgently to be solved.

2. Establish the system of sudden pollution accident in a river basin

According to system theory, the sudden pollution accident in a river basin shall be a system that combines with the accident cause, cause factors (pollutants) and the receptive environment, and the pollution is a result output from the interplay and interaction of each factor in the system. Therefore, the sudden pollution accident in a river basin can be seen as a system, of which the related input, status, output factor set is drawn out, and the interplay and interaction of the above three factors together decides the development trend of the sudden pollution accident. The system factors composition of a sudden pollution accident in a river basin is shown in Figure 1.

3. Method for establishing the information chain of sudden pollution accident

3.1. Definition of information chain

The information chain of sudden pollution accidents in a river basin is a graphic model that describes the causal relationship of all information. It is a structure composed by nodes stating for information index and the directed edge line connecting these nodes, the directed edge line is directing from father node to son node in the form of “→”, as shown in Figure 2. The directional and acyclic diagram can be established according to the accident’s regularity or characteristics, and also the expert’s knowledge.

3.2. Type of the information chain structure

There are correlative relations between nodes in the information chain for sudden pollution accident in a river basin, and the structural relationship of the chain is complex. According to the shape and connecting mode difference of the information chain, it can be divided into: sequential connection, divergent connection and convergence connection, as shown in Figure 3.

Figure 1. System factors composition of a sudden pollution accident.

Figure 2. Example of information chain.

Figure 3. Type of information chain structure.
3.3. The determination method of information chain structure

The above-mentioned causal relationships of the nodes are distinguished by experts. There are differences of the each expert’s knowledge structure and perception, so each expert will endow different credibility to each causal relationship. It is necessary to analyze and synthesize different credibility to determine the final structure of information chain. The analysis and synthesis method for experts’ knowledge is shown below:

Let a expert endow the credibility to a certain causal relationship , in which , which satisfies:

\[
\sum_{j=1}^{n} m_i(A_j) = 1
\]

Suppose the number of experts is , then shows the credibility to the causal relationship endowed by each expert. Therefore, the synthetic credibility of the causal relationship is:

\[
\sum_{j=1}^{n} m_i(A_j) = 1, \sum_{j=1}^{n} m_L(A_j) = 1
\]

In which

\[
K = m_1(A_1)m_2(A_1)\cdots m_L(A_1) + \cdots + m_1(A_n)m_2(A_n)\cdots m_L(A_n) = \sum_{j=1}^{n} \prod_{i=1}^{L} m_i(A_j)
\] (1)

4. A case study

4.1. Determination of the information variables for a sudden oil pollution accident in a river basin

From the case statistic analysis of more than 40 sudden oil pollution accidents in different river basins in the near 30 years, abstract analysis is applied to the whole process of the sudden oil pollution accidents, and the three-composing factor set of sudden oil pollution accidents are drawn out: input factor , status factor and output factor , as shown in Table 1. In the design of input factor it is considered that pollution input, pollution control and other factors. The thickness of oil film, the days of oil film coverage, the current stock of oil pollutants and the distribution of oil pollutants in water all describe the damage intensity of oil accidents in the basin, so they are the variables of state factor S. Changes in the internal state elements of the accident system will lead to changes in the environmental state of the system basin. Therefore, the monitoring value of the water quality index “Dissolved Oxygen” (DO) in the basin, whether the downstream water body functions a re polluted, and the remaining quantity of oil pollutants in the water are taken as the variables of output factor O of the accident.

| Set of input variables factor (I) | Variables of accident source characteristics | Cause of accident; Leakage amount of pollutants; Way of pollutant entering into river; Leakage position of pollutant |
|----------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------|
|                                  | Variables of pollutant characteristics         | Viscosity; Pour point                                                                               |
|                                  | Variables of regional environment characteristics | Initial water quality Class of the river basin; Hydrological runoff; Wind speed of the wind field; Water flow speed |
|                                  | Variables of lash-up management characteristics | Source control; Control of the controlling path; Pollution treatment technology control            |

| Set of status variables factor (S) | Thickness of oil film; Covering date of oil film; Distribution of oil pollutants; Residual amount of oil pollutant |
|------------------------------------|------------------------------------------------------------------------------------------------------------------|

| Set of output variables factor (O) | Monitored value of DO; Residual quantity of oil pollutant; Pollution status of the water body                      |
|------------------------------------|------------------------------------------------------------------------------------------------------------------|

These three factors can describe the whole genesis and developing process of sudden pollution accident in different river basins, combining with the lash-up treatment technology and working condition for the oil pollution, certain values are assigned to the above factors set. For example, based
on that different mechanical retrieving technology fits for different oil viscosity, the assigned value of the factor set is divided into three types: “γ < 2000 cst”, “6000 cst ≤ γ”, “2000 cst ≤ γ < 6000 cst”. Value range of each information variable in the information chain of a sudden oil pollution accident in a river basin is shown in Table 2.

**Table 2.** Value range of each information variable in the information chain of a sudden oil pollution accident.

| Variable Information variable types | Value range |
|-------------------------------------|-------------|
| I₁ Accident cause                   | Artificial / accident / transportation |
| I₂ Way of oil entering river        | One time / continuous            |
| I₃ Oil leakage amount (t)            | M < 50, 50 ≤ M < 100, 100 ≤ M |
| I₄ Oil leakage position             | Earth surface / river side / center of the river basin |
| I₅ Viscosity (cst)                   | γ < 2000, 2000 ≤ γ < 6000, 6000 ≤ γ |
| I₆ Pour point                       | T < t₀ (Environment temperature) |
| I₇ Scale of river basin (°C)        | Big river, middle river, small river, big lake (reservoir), middle lake (reservoir), small lake (reservoir) |
| I₈ Initial water quality class of river basin | I/II/III/IV/V |
| I₉ Hydrological runoff               | Wet season / normal season / dry season |
| I₁₀ Wind speed of the wind field (m/s) | f ≤ 3.3, 3.3 < f ≤ 8.0, 8.0 < f ≤ 10.7, 10.7 < f ≤ 13.9, 13.9 ≤ f |
| I₁₁ Water flow speed (m/s),         | v ≤ 0.2, 0.2 < v ≤ 0.8, 0.8 < v ≤ 1.2, 1.2 < v ≤ 1.8, 1.8 ≤ v |
| I₁₂ Source control                  | Adopted / not adopted          |
| I₁₃ Control of the controlling path  | Adopted / not adopted          |
| I₁₄ Pollution treatment technology control | Adopted / not adopted |
| S₁ Thickness of oil film (mm)        | H ≤ 0.025, 0.025 ≤ H < 1.1, 1 ≤ H < 10, 10 ≤ H |
| (S)                                 |                         |
| S₂ Covering date of oil film        | /                         |
| S₃ Distribution of oil pollutants    | /                         |
| S₄ Residual amount of oil pollutant  | /                         |
| O₁ Monitored value of DO (mg/L)     | DO ≤ 2, 2 < DO ≤ 3, 3 < DO ≤ 5, 5 < DO ≤ 6.6, 6.6 < DO ≤ 7.5 |
| O₂ Residual quantity of oil pollutant| /                         |
| O₃ Pollution status of the water body function | /                         |

### 4.2. Design of the information chain for sudden pollution accidents in different river basins

The causal relationship between each node forms a special topological structure with three layers: (a) The exterior environment and the accident’s lash-up decision making (the control input) will co-affect the change of the system’s status (the status factor), which is labelled as the subsidiary information chain structure of input factor $I →$ status factor $S$. (b) The system status factors is labelled as the subsidiary information chain structure of status factor $S →$ status factor $S$. (c) The change of the internal system factor’s status will cause certain impact to the exterior environment, which is labelled as the subsidiary information chain structure of status factor $S →$ output factor $O$. By analysing the case data of oil accidents in the basin in the past 30 years, the causal relationship between each node and the interaction among nodes in the Bayesian network is preliminarily established, and then the causal relationship between the nodes is identified and screened with equation (1) according to the research knowledge of several experts in this field.

Based on the above structure, the composition of the information chain for sudden oil pollution accident in a river basin is confirmed with the branch of oil film thickness, the branch of oil film covering date, the branch of monitored DO density information, the branch of pollutants’ distribution information and the branch of pollutants’ residual amount information. Take the branch structure of oil film thickness information as an example, main variables of which are: oil leakage amount ($I₁$), oil leakage position ($I₃$), viscosity ($I₅$), pour point ($I₆$), source control ($Iₙ$), control of the controlling path ($I₉$), control of the pollution treatment technology ($I₁₀$), oil thickness ($S₁$), monitored DO density ($O₁$). Table 3 below shows the experts’ knowledge base of oil film thickness subsidiary information chain.
formed according to anticipated causal relationship and the credit assigned by the experts. In the above table, the experts’ credit is synthesized with equation (1), and a synthesis credit of each causal relationship is achieved, detailed shows in Table 4.

**Table 3.** The experts’ knowledge base of oil film thickness subsidiary information chain.

| Expert | Cause | Result | Credit | Expert | Cause | Result | Credit |
|--------|-------|--------|--------|--------|-------|--------|--------|
| $E_1$  | $I_3$ | $S_1$  | 0.91   | $E_2$  | $I_3$ | $S_1$  | 0.82   |
| $E_1$  | $I_4$ | $S_1$  | 0.91   | $E_2$  | $I_4$ | $S_1$  | 0.82   |
| $E_1$  | $I_3$ | $S_1$  | 0.91   | $E_2$  | $I_3$ | $S_1$  | 0.82   |
| $E_1$  | $I_6$ | $S_1$  | 0.91   | $E_2$  | $I_6$ | $S_1$  | 0.82   |
| $E_1$  | $I_{12}$ | $S_1$ | 0.92   | $E_2$  | $I_{13}$ | $S_1$ | 0.78   |
| $E_1$  | $I_{13}$ | $S_1$ | 0.92   | $E_2$  | $I_{14}$ | $S_1$ | 0.78   |
| $E_1$  | $I_{14}$ | $S_1$ | 0.92   | $E_2$  | $I_{15}$ | $S_1$ | 0.78   |
| $E_1$  | $I_1$ | $O_1$  | 0.01   | $E_2$  | $I_1$ | $O_1$  | 0.05   |
| $E_1$  | $I_4$ | $O_1$  | 0.01   | $E_2$  | $I_4$ | $O_1$  | 0.05   |
| $E_1$  | $I_3$ | $O_1$  | 0.01   | $E_2$  | $I_3$ | $O_1$  | 0.05   |
| $E_1$  | $I_6$ | $O_1$  | 0.01   | $E_2$  | $I_6$ | $O_1$  | 0.05   |
| $E_1$  | $I_{12}$ | $O_1$ | 0.02   | $E_2$  | $I_{12}$ | $O_1$ | 0.01   |
| $E_1$  | $I_{13}$ | $O_1$ | 0.02   | $E_2$  | $I_{13}$ | $O_1$ | 0.01   |
| $E_1$  | $I_{14}$ | $O_1$ | 0.02   | $E_2$  | $I_{14}$ | $O_1$ | 0.01   |
| $E_1$  | $S_1$ | $O_1$  | 0.97   | $E_2$  | $S_1$ | $O_1$  | 0.95   |

**Table 4.** Synthetic table of experts’ knowledge credit for oil film thickness subsidiary information chain.

| Expert | $I_7$→$S_1$ | $I_8$→$S_1$ | $I_2$→$S_1$ | $I_4$→$S_1$ | $I_{12}$→$S_1$ | $I_{13}$→$S_1$ | $I_{14}$→$S_1$ | $S_1$→$O_1$ |
|--------|-------------|-------------|-------------|-------------|----------------|----------------|----------------|-------------|
| $E_1$  | 0.91        | 0.91        | 0.91        | 0.91        | 0.92           | 0.92           | 0.92           | 0.97        |
| $E_2$  | 0.82        | 0.82        | 0.82        | 0.82        | 0.78           | 0.78           | 0.78           | 0.95        |
| Result | 0.9972      | 0.9972      | 0.9972      | 0.9972      | 0.9967         | 0.9967         | 0.9967         | 1           |

The calculated result in Table 3 shows: the synthetic result of credit of $I_7$→$S_1$, $I_8$→$S_1$, $I_2$→$S_1$, $I_4$→$S_1$, $I_{12}$→$S_1$, $I_{13}$→$S_1$, $I_{14}$→$S_1$, $S_1$→$O_1$ is close to 1, which proves the causal relationship exists between them. The synthetic result of credit of $I_7$→$O_1$, $I_8$→$O_1$, $I_2$→$O_1$, $I_4$→$O_1$, $I_{12}$→$O_1$, $I_{13}$→$O_1$, $I_{14}$→$O_1$, $S_1$→$O_1$ is close to 0, which proves there is very small possibility of causal relationship existing between them. Therefore, Figure 4(a) below the branch information chain structure of oil film thickness is formed. Similarly, other branch information chain structure can be confirmed, as shown in Figure 4(b-e).
4.3. Establish the complete information chain for sudden pollution accident

Through logical synthesis of the above-mentioned branch information chains of each factor of sudden oil pollution accident in different river basins, below complete information chain model is established for the sudden oil pollution accidents. Based on the above mentioned information chain structure, value range of the factor set is brought in, and information chain of sudden oil pollution accidents in different river basins is achieved, as shown in Figure 5. It reveals the correlation between the pollutant properties, pollutant inventory, oil overflow, regional meteorological and hydrological conditions, water pollution status and other indicators in oil pollution accidents, enabling various emergency management bodies to understand various emergencies from a unified perspective. Therefore, the screening index of oil pollution emergency treatment technology is simplified into a set of index elements with objective range, which can simplify the case search and matching and the identification of emergency treatment technology.

Figure 5. Information chain of sudden oil pollution accidents in different river basins.
5. Conclusion
Based on that the sudden pollution accident in a river basin has rich information, and the information has interplay and interaction relationship between each other, this paper sees the sudden pollution accident in a river basin as a system, and draws out the input, status and output factors, and then seeks for the interaction relationship between each factor, and finally establishes an information chain for sudden pollution accidents in a river basin. This information chain can sufficiently show the causal relationship between each information factor of a sudden pollution accident in a river basin. It changes the limitation of the pure electronization of current environment pollution accident information.

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