APPLICATION OF FUZZY ANALOGICAL REASONING IN INFERRING OF MAXIMUM ALLOWABLE CONCENTRATION OF INDUSTRIAL TOXICANT

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In this paper we shall use the fuzzy analogical reasoning to infer the standards of maximum allowable concentration of industrial toxicant vinvlbenzene styrene. Three different fuzzy analogical reasoning operations are suggested for inferring the standard. They are Near degree operation, Addition power comprehensive method and fuzzy the biggest path calculation.

Keywords: Fuzzy analogical reasoning, Near degree operation, Addition power comprehensive method, Fuzzy the biggest path calculation.

1. Introduction

There are about five-handred thousands of toxic substances in the would. How are obtained exactly the standards of maximum allowable concentration (MAC) of toxicant in modern production? How are the standards set up fast? The fuzzy analgical reasoning method is a good one. It is a fuzzy reasoning which compares tow objects of different universes.

Given two objects X and Y that belong to different universes, now we investigate to find that there are n qualities $q_1, q_2, \ldots, q_n$ in X and Y such that for each $1 \leq i \leq n$, X and Y possess qualities q_i in degree a_i and b_i, respectively. If there is another quality, i.e. X possesses quality q_{n+1}, we want to ask in what degree does Y possess quality q_{n+1}? Such a inference is a fuzzy analogical reasoning and can be denoted as:

$$\frac{\begin{array}{lll} X & \text{possesses} & a_1, a_2, \ldots, a_n \text{ and } a_{n+1} \\ Y & \text{possesses} & b_1, b_2, \ldots, b_n \end{array}}{\begin{array}{lll} Y & \text{possesses} & b_{n+1} \end{array}}$$

Fuzzy analogical reasoning was discussed quantitatively in [1]. The [1] suggested three methods which are Near degree, Addition power comprehensive method and Fuzzy maximum path method.

In this paper, we shall use these methods to infer the standard of MAC of industrial toxicant vinylbenzene styrene.

2. Establishing the analogical reasoning model between vinylbenzene styrene (VS) and vinyl chloride (VC)

VC and VS are very resemblance on many qualities. We investigate their qualities from three hands which are properties of physics and chemistry, toxicity experiment and clinical manifestation. The seven qualities which are colour, excretory quantity, disolve, slow toxicity, acute toxicity, slow toxicosis and acute toxicosis are compared, respectively. They can be listed as follows:[2]

According to Table 1, we can give the corresponding fuzzy vectors $\tilde{A}$, $\tilde{B}$, which are the qualities in degree a_i and b_i $i=1,2,\ldots,7.$, respectively, representing VS and VC.

$$\tilde{A} = (1, 0.4, 1, 0.6, 0.6, 0.6, 0.6) \qquad (VS)$$

$$\tilde{B} = (1, 0.7, 1, 0.9, 0.8, 0.9, 0.8) \qquad (VC)$$

		vinylbenzene styrene (VS)	vinyl chloride (VC)
physical and chemical properties	color	colorless	colorless
	excretory quantity	40%	69.4%
	dissolution	dissolve in organic solvent but dissolve little in water	idem
toxicity experiment	slow toxicity	breathe with difficulty blurred consciousness	muscle tic short of breath
	acute toxicity	weak stimulation in respiratory tract	lose weight react slowly
clinical manifestation	slow toxicosis	headache sickness	headache coma
	acute toxicosis	abdominal distension cough	abdominal distension dry skin

Table 1

Then we use the formule (2) in [1] to calculate the result.

$$N(\tilde{A},\tilde{B}) = 1-\frac{1}{n}\sum_{i=1}^{n}\left|\tilde{A}_{a_i} - \tilde{B}_{b_i}\right| \qquad i=1,2,\ldots,n. \tag{2}$$

When $\tilde{A},\tilde{B}$ are substituted into (2), we hare

$$N(\tilde{A},\tilde{B}) = 1 - \frac{1}{7}(0.3+0.3+0.2+0.3+0.2)\approx 0.814$$

Because MAC of VC is $30mg/m^3$, we can infer that the possibility of MAC of VS being $30mg/m^3$ has 0.814.

3. Using addition power comprehensive method

The seven qualities all be treated without distinction of importance in above operation. In fact, the slow toxicity, acute toxicity, slow toxicosis and acute toxicosis are important, the disolve is secondary, the colour and excretory quantity are insignificant among them. We use the addition power comprehensive method so that stick out these significant qualities and obtain conclusion better than near degree operation.

The seven qualities of VS and VC can be added power in turns as follows:

$$D = (0.05,\ 0.05,\ 0.1,\ 0.2,\ 0.2,\ 0.2,\ 0.2)$$

To make D, $\tilde{A}$, $\tilde{B}$ are instituted into the (3) of [1],

$$1 - \left|(D\circ\tilde{A}^T) - (D\circ\tilde{B}^T)\right| \tag{3}$$

have

$$1 - \left|(0.05,0.05,0.1,0.2,0.2,0.2,0.2)\circ\begin{pmatrix}1\\0.4\\1\\0.6\\0.6\\0.6\\0.6\end{pmatrix} - (0.05,0.05,0.1,0.2,0.2,0.2,0.2)\circ\begin{pmatrix}1\\0.7\\1\\0.9\\0.8\\0.9\\0.8\end{pmatrix}\right| = 1 - \left|0.66-0.865\right|$$

= 0.795

The composition operation of fuzzy matrices ∘ can have many formulas,[3] where we use the operation of arithmetic X,+.

We may infer that the possibility of MAC of VS being 30mg/m^3 has 0.795.

4. Using the fuzzy maximum calculation inferring MAC of VS

The seven qualities of VS and VC are considered separably by the two above mentional methods. If we consider not noly the degree of qualities themselves, but also the relation one another among these qualities, the reliable standard of reasoning will be greatly raised.

So we can use the fuzzy maximum path method of [1] to repersent the relation one another among seven qualities and to infer conclusion.

The interrelationships among the seven qualities of VS can be listed table as follows:[4]

	color	excretory quantity	disso-lution	slow toxi-city	acute toxi-city	slow toxi-cosis	acute toxi-cosis
color	1	0.1	0.3	0.2	0.15	0.2	0.15
excretory quantity	0.1	1	0.4	0.35	0.38	0.3	0.34
disso-lution	0.3	0.4	1	0.55	0.58	0.5	0.6
slow toxicity	0.2	0.35	0.55	1	0.45	0.6	0.36
acute toxicity	0.15	0.38	0.58	0.45	1	0.42	0.6
slow toxicosis	0.2	0.3	0.5	0.6	0.42	1	0.52
acute toxicosis	0.15	0.34	0.6	0.36	0.6	0.52	1

Table 2

First we have matrix 1 according to the (i), part 4,[1].

$$\begin{bmatrix} 0 & 0.1 & 0.3 & 0.2 & 0.15 & 0.2 & 0.15 \\ 0.1 & 0 & 0.4 & 0.35 & 0.38 & 0.3 & 0.34 \\ 0.3 & 0.4 & 0 & 0.55 & 0.58 & 0.5 & 0.6 \\ 0.2 & 0.35 & 0.55 & 0 & 0.45 & 0.6 & 0.36 \\ 0.15 & 0.38 & 0.58 & 0.45 & 0 & 0.42 & 0.6 \\ 0.2 & 0.3 & 0.5 & 0.6 & 0.42 & 0 & 0.52 \\ 0.15 & 0.34 & 0.6 & 0.36 & 0.6 & 0.52 & 0 \end{bmatrix}$$

matrix 1

Then according to the (ii) and (iii), part 4, [1], when k=1, the $C_1 = (x_1, x_2, \ldots, x_7)$.

$$x_1 = e_{i_1 1} = \max\left\{ e_{i1} \,\middle|\, i=1,2,\ldots,7 \right\}$$

$$= \max\{0,\ 0.1,\ 0.3,\ 0.2,\ 0.15,\ 0.2,\ 0.15\}$$

$$= 0.3$$

Let $e_{3j}=0$, $(j=1,\ j=2,3,\ldots,7)$ and $e_{13}=0$, then we have matrix 2 as follows:

$$\begin{bmatrix} 0 & 0.1 & 0 & 0.2 & 0.15 & 0.2 & 0.15 \\ 0.1 & 0 & 0.4 & 0.35 & 0.38 & 0.3 & 0.34 \\ 0.3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.2 & 0.35 & 0.55 & 0 & 0.45 & 0.6 & 0.36 \\ 0.15 & 0.38 & 0.58 & 0.45 & 0 & 0.42 & 0.6 \\ 0.2 & 0.3 & 0.5 & 0.6 & 0.42 & 0 & 0.52 \\ 0.15 & 0.34 & 0.6 & 0.36 & 0.6 & 0.52 & 0 \end{bmatrix}$$

matrix 2

$$x_2 = e_{i_2 3} = \max\{0,\ o.4,\ 0,\ 0.55,\ 0.58,\ 0.5,\ 0.6\}$$

$$= 0.6$$

Let $e_{7j}=0$, $(j=3,\ j=1,2,4,\ldots,7)$ and $e_{37}=0$, then have matrix 3 as follows:

$$\begin{bmatrix} 0 & 0.1 & 0 & 0.2 & 0.15 & 0.2 & 0.15 \\ 0.1 & 0 & 0.4 & 0.35 & 0.38 & 0.3 & 0.34 \\ 0.3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.2 & 0.35 & 0.55 & 0 & 0.45 & 0.6 & 0.36 \\ 0.15 & 0.38 & 0.58 & 0.45 & 0 & 0.42 & 0.6 \\ 0.2 & 0.3 & 0.5 & 0.6 & 0.42 & 0 & 0.52 \\ 0 & 0 & 0.6 & 0 & 0 & 0 & 0 \end{bmatrix}$$

matrix 3

$$x_3 = e_{i_3 7} = \max\left\{0.15,\ 0.34,\ 0,\ 0.36,\ 0.6,\ 0.52,\ 0\right\} = 0.6$$

Let $e_{5j}=0$, ($j=7$, $j=1,2,\ldots,6$) and $e_{75}=0$, then we have matrix 4 as follows:

0	0.1	0	0.2	0.15	0.2	0.15
0.1	0	0.4	0.35	0.38	0.3	0.34
0.3	0	0	0	0	0	0
0.2	0.35	0.55	0	0.45	0.6	0.36
0	0	0	0	0	0	0.6
0.2	0.3	0.5	0.6	0.42	0	0.52
0	0	0.6	0	0	0	0

matrix 4

$$x_4 = e_{i_4 5} = \max\left\{0.15,\ 0.38,\ 0,\ 0.45,\ 0,\ 0.42,\ 0\right\} = 0.45$$

Let $e_{4j}=0$, ($j=5$, $j=1,2,3,4,6,7$) and $e_{54}=0$, then we have matrix 5 as follows:

0	0.1	0	0.2	0.15	0.2	0.15
0.1	0	0.4	0.35	0.38	0.3	0.34
0.3	0	0	0	0	0	0
0	0	0	0	0.45	0	0
0	0	0	0	0	0	0.6
0.2	0.3	0.5	0.6	0.42	0	0.52
0	0	0.6	0	0	0	0

matrix 5

$$x_5 = e_{i_5 4} = \max\left\{0.2,\ 0.35,\ 0,\ 0,\ 0,\ 0.6,\ 0\right\} = 0.6$$

Let $e_{6j}=0$, ($j=4$, $j=1,2,3,5,6,7$) and $e_{46}=0$, then we have matrix 6 as follows:

0	0.1	0	0.2	0.15	0.2	0.15
0.1	0	0.4	0.35	0.38	0.3	0.34
0.3	0	0	0	0	0	0
0	0	0	0	0.45	0	0
0	0	0	0	0	0	0.6
0	0	0	0.6	0	0	0
0	0	0.6	0	0	0	0

matrix 6

$$x_6 = e_{i_6 6} = \max\{0.2,\ 0.3,\ 0,\ 0,\ 0,\ 0,\ 0\}$$
$$= 0.3$$

Let $e_{2j}=0$, $(j=6,\ j=1,2,3,4,5,7)$ and $e_{62}=0$, then we have matrix 7 as follows:

$$\begin{bmatrix} 0 & 0.1 & 0 & 0.2 & 0.15 & 0.2 & 0.15 \\ 0 & 0 & 0 & 0 & 0 & 0.3 & 0 \\ 0.3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.45 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.6 \\ 0 & 0 & 0 & 0.6 & 0 & 0 & 0 \\ 0 & 0 & 0.6 & 0 & 0 & 0 & 0 \end{bmatrix}$$

matrix 7

$$x_7 = e_{i_7 2} = \max\{0.1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0\}$$
$$= 0.1$$

So $C_1 = (0.3\ 0.6\ 0.6\ 0.45\ 0.6\ 0.3\ 0.1)$.

We can find out $C_2,\ C_3, \ldots, C_7.$ respectively using same method as follows:

$$C_2 = (0.38\ 0.6\ 0.6\ 0.55\ 0.6\ 0.2\ 0.1)$$

$$C_3 = (0.6\ 0.6\ 0.45\ 0.6\ 0.3\ 0.1\ 0.3\ )$$

$$C_4 = (0.6\ 0.52\ 0.6\ 0.58\ 0.4\ 0.1\ 0.2)$$

$$C_5 = (0.6\ 0.6\ 0.55\ 0.6\ 0.3\ 0.1\ 0.15)$$

$$C_6 = (0.6\ 0.55\ 0.6\ 0.6\ 0.38\ 0.1\ 0.2)$$

$$C_7 = (0.6\ 0.58\ 0.55\ 0.6\ 0.3\ 0.1\ 0.15)$$

Finally, according to the (V), (Vi) and (Vii), part 4, [1], we have

$$q_1 = \sum(0.3,\ 0.6,\ 0.6,\ 0.45,\ 0.6,\ 0.3) = 2.85$$

$$q_2 = \sum(0.38,\ 0.6,\ 0.6,\ 0.55,\ 0.6,\ 0.2) = 2.93$$

$$q_3 = \sum(0.6,\ 0.6,\ 0.45,\ 0.6,\ 0.3,\ 0.3) = 2.85$$

$$q_4 = \sum(0.6,\ 0.52,\ 0.6,\ 0.58,\ 0.4,\ 0.2) = 2.9$$

$$q_5 = \sum(0.6,\ 0.6,\ 0.55,\ 0.6,\ 0.3,\ 0.15) = 2.8$$

$$q_6 = \sum(0.6,\ 0.55,\ 0.6,\ 0.6,\ 0.38,\ 0.2) = 2.93$$

$$q_7 = \sum(0.6,\ 0.58,\ 0.55,\ 0.6,\ 0.3,\ 0.15) = 2.78$$

$$\max(2.85, 2.93, 2.85, 2.9, 2.8, 2.93, 2.78) = 2.93$$

$$h_1 = \frac{2.93}{6} \approx 0.488$$

Similarly, we can calculate h_2 from Table 3.

	color	excretory quantity	disso- lution	slow toxi- city	acute toxi- city	slow toxi- cosis	acute toxi- cosis
color	1	0.1	0.3	0.2	0.15	0.2	0.15
excretory quantity	0.1	1	0.7	0.65	0.68	0.6	0.58
disso- lution	0.3	0.7	1	0.85	0.88	0.8	0.9
slow toxicity	0.2	0.65	0.85	1	0.75	0.8	0.7
acute toxicity	0.15	0.58	0.88	0.75	1	0.85	0.9
slow toxicosis	0.2	0.6	0.8	0.8	0.85	1	0.78
acute toxicosis	0.15	0.85	0.9	0.7	0.9	0.78	1

Table 3

$$h_2 = \frac{4.4}{6} \approx 0.733$$

When 0.488 and 0.733 are substituted into the (4) of [1]

$$1 - \left|(h_1 - h_2)\right| \qquad (4)$$

we have

$$1 - \left|0.488 - 0.733\right| = 0.755$$

Thus the possibility of MAC of VS being 30mg/m^3 is 0.755 with the fuzzy maximum path method.

5. Conclusion

In this paper we have used three methods of fuzzy analogical reasoning to infer the MAC of VS. Method 1 is concise, method 2 and method 3 may yield better inferentical results. If the addition power comprehensive method and fuzzy the biggest path calculation are combined to use, the results will be very effective.

References

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