Construction and testing of the parametric criterion of chemical damage of the employee

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Abstract. This article examines the process of the chemical used in the painting of boiler housings and heaters. The effect on acetone is considered. A statistical assessment of parametric criteria was carried out, taking into account the consequences of its impact on the human body.

1. Formulation of the problem
Technosphere-man-made artificial habitat. It manifests itself as a phenomenon that obeys laws that do not depend on the will of people. This causes many man-made hazards in the form of damaging effects on humans and their environment.

As a result, the emergence of industrial safety problems, the key of which was the analysis and quantitative assessment of the risk of hazardous objects of the technosphere, as well as the need to prevent potential diseases.

2. Introduction and description of the main outcomes of chemical damage
One of the results of a long-term impact on an employee of an enterprise dominated by a harmful production factor (factors) is chronic occupational disease (poisoning). At the same time, the result of such influence is a temporary or persistent loss of professional ability to work.

The painting of boiler bodies and heaters is one of the main types of technological operations in which the actions of harmful chemicals can lead to chronic occupational disease. As a result of the technological action of solvents (acetone is chosen), the following types of diseases take place on the employee's body even under the conditions of applying individual protection (austriators or masks) or collective protection (ventilation): acute and chemical intoxication, lung diseases and skin disease.

For further consideration, consider the following vertex outcomes:

1. 1-acute and chemical intoxications by inhalation of solvent vapors;
2. 2-lung disease;
3. 3-skin disease.

3. Selection and description of susceptibility parameters
To further analyze and quantify risk, we use the parametric model "impact \( v \) – easing \( f \) – susceptibility \( r \) » [1], where the parameter of the direct effect of the factor on the employee taking into account the protection

\[ s = v \cdot f \] (1)
In addition, we choose the two most likely channels of action per employee of two different by nature actions of "chemical" and "physical" harmful factors in the form of acetone and (or) its vapors:
- the presence of acetone vapors acting on the lungs and leading to acute and chronic intoxication of the employee, which is conditionally described as a vertex outcome 1, (VO1), and exposure parameter - vapour concentration is indicated by $n_{\text{steam}}$, mg/m$^3$, (steam);
- presence in the air of the working zone of a drip - liquid mixture (DLM) of acetone, which acts on the skin or eyes of the employee, exposure parameter - concentration $n_{\text{DLM}}$, mg/kg, (mixture or aerosol).

Moreover, as practice shows, the following outcomes can occur after VO1 in severity: lung disease, VO2; fatality, VO3.

As parameters of susceptibility [2], by which results of exposure of the employee to the specified harmful factors are determined, we take and designate the following parameters by severity. 1) Maximum permissible concentration (MPC) of acetone in the air of the working zone, $r_1 = 200$ mg/m$^3$ [3].

Moreover, the condition of vertex outcome occurrence VO1

$$n_{1}(t) \geq r_1$$

2) The maximum permissible concentration of drip - liquid mixture (DLM) of acetone, $r_2 = 300$ mg/m$^3$ - lung disease (VO2), and the condition for this outcome

$$n_{2}(t) \geq r_2$$

3) A critical susceptibility threshold , $r_3 = L_{50}$, which is defined as a 50% fatality, with acetone being assumed to be: $L_{50} = 1159$ mg/kg [3,4].

With the assumption of the monotonicity of fuzzy susceptibility to the action of harmful factors in the form of acetone vapors and droplet-liquid mixture, and based on the interval evaluation method [4], a "three-level" representation of the functions of belonging to the worker's susceptibility, and accordingly, the occurrence of possible outcomes, Figure 1, is adopted.

Note that on the other hand, this "three-level" representation is a model or "assembly" of susceptibility parameters, describing, taking into account monotonicity, the effect of increasing danger with increasing impact (load).

**Figure 1.** Three-level representation of the occurrence of vertex outcomes VO1, VO2, VO3 on the area of changing fuzzy parameters $s$ and $r$.

In figure 1 the following designations are accepted: $\mu(r)$ - function of accessory of parameter of susceptibility is; $r_1$, $r_2$, $r_3$ - is kernels;

$\Delta r_1$, $\Delta r_2$, $\Delta r_3$ - are fuzzy intervals of change in susceptibility parameters at levels 1, 2, 3.

Moreover, values are expressed through absolute errors in setting susceptibility parameters. In this case, the criterion of exceeding the fuzzy effect over the fuzzy susceptibility on the area of existence of these parameters is presented in the form: $s \succ r | s \prec r$. 

$r_1$, $r_2$, $r_3$, $r$ and $s$
that exceeding the exposure as the current concentration above the first level of susceptibility determining

Maximum permissible solvent [2].

Through the analysis of the provisions on sanitary standards identified

The following values or ranges of worker susceptibility values in accepted outcomes:

\[ r_1 = n_{11} = 200 \text{ mg/m}^3 \text{ – acute and chronic intoxications (VO1)} \]

\[ r_2 = n_{12} = 300 \text{ mg/m}^3 \text{ – lung disease (VO2)} \]

\[ r_3 = L_{50} = 1159 \text{ mg/kg fatality} \]

Density, \( \rho = \text{m/V} \) \( \rho = 0.79 \text{ g/sm}^3 = 800 \text{ kg/m}^3 \)

\[ r_1 = n_{11} = 200 \text{ mg/m}^3 = 0.2 \text{ g/m}^3 = 0.2 \cdot 10^{-3} \text{ kg/m}^3 \]

\[ r_2 = n_{12} = 300 \text{ mg/m}^3 = 0.3 \text{ g/m}^3 \]

\[ r_3 = L_{50} = 1159 \text{ mg/kg} \rightarrow 1400 \text{ mg/m}^3 \]

A generalized logical accident model (n.s.) is the logical sum of Boolean variables of possible outcomes

\[ Y_{\text{n.s.}} = x_1 \lor x_2 \lor x_3 \] (4)

Whereas the logical lethal outcome (LI) model is the logical product of these Boolean variables VO1, VO2, VO3

\[ Y_{\text{LI}} = x_1 \land x_2 \land x_3 \] (5)

Parameter \( s \) of direct action of factor on the employee considering protection \( f \) at different points of the work area

\[ s = v \cdot f \] (6)

\[ x_1 = 1, \text{ if } (s \geq r_1) \]

\[ x_2 = 1, \text{ if } (s \geq r_2) \]

\[ x_3 = 1, \text{ if } (s \geq r_3) \]

\[ s = f \cdot v \] (7)

For example, FMS data is derived from

1) measured value of parameter \( v \) of influencing factor on the employee is \( v_{11} = 200 \text{ mg/m}^3 \). Suppose that the accuracy class of the gas analyzer meter was 50. This means that the spread of influence is very large and the uncertainty of the onset of vertex outcomes is great.

In the first approximation, when assuming the linear approximation of fuzzy parameters (in the least informative version of their obtaining), the dependence is:

\[ \pi_{l_i} = 1 - zb \] (8)

\[ zb = (r - s) / (\Delta r + \Delta s) \] (9)

wherein \( r \) and \( s \) – are, respectively, "cores" of fuzzy susceptibility parameters \( r \) and exposure \( s \); \( \Delta r \) and \( \Delta s \) – "blur intervals" of fuzzy parameters of susceptibility \( r \) and exposure \( s \), see Figure 2.

![Figure 2. Linear approximation of effects and susceptibility belonging functions \( \mu(s) \) and \( \mu(r) \).](image)

Let us describe the symbols introduced in Figure 2: \( \bullet r, \bullet s \) and \( \Delta r, \Delta s \) respectively – nuclei and fuzzy intervals of parameters \( s, r \); \( \mu(s=\text{S/MPE}) \) and \( \mu(r=\text{R/MPE}) \) respectively, of belonging to fuzzy
normalized exposure parameters \( s \)/MPE and susceptibilities \( r \)/MPE, where the value of MPE generically represents the maximum permissible susceptibility of a person to the action of a factor of any nature, for example MPE, as a characteristic of human sensitivity to poison gases. By analogy with Figure 1, Figure 2 is used to illustrate the main variants of the relationship of the impact and susceptibility parameters, and together with the dependencies they are used for an accelerated express assessment of the system safety indicators [3,5].

\[ x_1 = 1 \] – this is a logical condition for the presence of acetone vapors affecting the worker with concentration \( n_{11} \) or \( n_{12} \) or \( n_{13} \) (*)

Then the logical model VO1 is represented as follows \( Y_1 = z_{11} \land z_{12} \)

\( z_{11} \) – Boolean variable of accounting for employee protection by using a respiratory device and accounting for vapour (gas) attenuation by a respiratory device:

Note here that condition \( f_{11} = 1 \) means that there is protection, but there is no weakening! Whereas condition \( f_{11} = 0 \) means that the protection is and the attenuation of the complete harmful factor is absent!

\[ z_{11} = 1, \text{ if } s_{11} = v \cdot f_{11} \geq n_{11} \] (10)

\( z_{12} \) – Boolean variable of employee protection accounting by use of protective robe:

\[ z_{21} = 1, \text{ if } s_{12} = v \cdot f_{12} \geq n_{12} \] (11)

\[ p_{z_{11}} = \text{Pro} (s \geq n_{11}) \]

\[ p_{z_{11}} = \text{Pro} (s_{11} = v \cdot f_{11} \geq n_{11}) \] (12)

\[ p_{z_{12}} = \text{Pro} (s_{12} = v \cdot f_{12} \geq n_{12}) \] (13)

Occupational disease (VO1) is considered as a logical multiplication of the conditions of insufficient protection of the respiratory and robe.

Then the probability of VO1

\[ P_1 = p_{z_{11}} \cdot p_{z_{12}} \] (14)

In turn, the logical model of VO2 is represented as follows

\[ Y_2 = z_{21} \land z_{22} \] (15)

where \( z_{21} = 1 \), if

\[ s_{21} = v \cdot f_{2} \geq n_{12} \] (16)

\( z_{21} \) – Boolean variable of accounting for worker protection against lung disease by using a respiratory agent: \( z_{21} = 1 \), if \( s_{21} = v \cdot f_{2} \geq n_{12} \)

\( z_{22} \) – Boolean variable of accounting for employee protection against skin disease by using protective robe:

\[ z_{22} = 1, \text{ if } s_{22} = v \cdot f_{2} \geq n_{22} \] (17)

Whereas probability of occurrence VO2

\[ P_2 = p_{z_{21}} \cdot p_{z_{22}} \] (18)

Thus, taking into account the occurrence of at least two outcomes from the action of two factors on two organs of the employee (lungs and skin), the "complete" probability of an incident as a probabilistic function of the incident from the logical sum of two outcomes has the form \( P = 1 - (1 - P_1) \cdot (1 - P_2) \).

The problem is considered solved if numerical values of impact and susceptibility indicators are obtained.

For example, FMS data is derived from
1) measured value of parameter $v$ of influencing factor on the employee is $v = 200$ mg/m$^3$. Suppose that the accuracy class of the gas analyzer meter was 50. This means that the spread of influence is very large and the uncertainty of the onset of vertex outcomes is great. 

$$z_{21} = 1, \quad \text{if } s_{12} = v \cdot f_{12} \geq n_{12}.$$  

(19)

The following dependency was used to calculate the possible outcome measure \[1.4\] $s = 1, \quad s + \Delta s = 200$

exposure blur interval $\Delta s = 199$;

Susceptibility Core $r = 2$;

blur interval $\Delta r = \delta \cdot r = 1$;

lower bound of disease susceptibility $r - r = 1$;

safety reserve $r - s = 1$;

total blur interval $\Delta r + \Delta s = 300$;

reduced safety margin $z_b = 0,005$

Then the VM value of the disease in the linear approximation model defined as:

$$L_i = 1 - z_b = 1 - (r - s) / (\Delta r + \Delta s) = 1-(2-1)/(1+199)=0.995$$

In the Gaussian approximation model, the value of VM disease:

$$n = \exp \left(-4.5 \times 0.005 \times 0.005\right) = \exp \left(-0.01125\right) = 0.988$$

As a result, taking into account the action on the employee of two negative factors, the VM of a professional disease will be close to 1 (~ 100%).

2) measured value of parameter $v$ of influencing factor on the employee is $v = 300$ mg/m$^3$. We will assume that the class of accuracy of the measuring device – a gas analyzer made 50. It means that dispersion of influence very big and uncertainty of approach of topmost outcomes of a bike.

$$z_{21} = 1, \quad \text{if } s_{12} = v \cdot f_{12} \geq n_{12}.$$ 

The following dependency was used to calculate the possible outcome measure \[1\] $s = 1, \quad s + \Delta s = 300$

exposure blur interval $\Delta s = 299$;

Susceptibility Core $r = 2$;

blur interval $\Delta r = \delta \cdot r = 1$;

lower bound of disease susceptibility $r - r = 1$;

safety reserve $r - s = 1$;

total blur interval $\Delta r + \Delta s = 300$;

reduced safety margin $z_b = 0,0033$

Then the VM value of the disease in the linear approximation model defined as:

$$L_i = 1 - z_b = 1 - (r - s) / (\Delta r + \Delta s) = 1-(2-1)/(1+299)=0.997$$

In the Gaussian approximation model, the value of VM disease:

$$n = \exp \left(-4.5 \times 0.0033 \times 0.0033\right) = \exp \left(-0.000049\right) = 0.99995$$

As a result, taking into account the action on the employee of two negative factors, the VM of a professional disease will be close to 1 (~ 100%).

3) measured value of parameter $v$ of influencing factor on the employee is $v = 1400$ mg/m$^3$. Suppose that the accuracy class of the gas analyzer meter was 50. This means that the spread of influence is very large and the uncertainty of the onset of vertex outcomes is great.

$$z_{21} = 1, \quad \text{if } s_{12} = v \cdot f_{12} \geq n_{12}.$$ 

The following dependency was used to calculate the possible outcome measure \[1.4\] $s = 1, \quad s + \Delta s = 1400$

exposure blur interval $\Delta s = 1399$;

Susceptibility Core $r = 2$;

blur interval $\Delta r = \delta \cdot r = 1$;

lower bound of disease susceptibility $r - r = 1$;

safety reserve $r - s = 1$;
total blur interval $\Delta r + \Delta s = 1400$;
reduced safety margin $zb = 0, 00071$

Then the VM value of the disease in the linear approximation model
defined as:

$$Li = 1 – zb = 1 – (r – s) / (\Delta r + \Delta s) = 1 – (2-1)/(1+1399) = 0,99929$$

In the Gaussian approximation model, the value of VM disease:

$$n = \exp (-4.5 \times 0.00071 \times 0.00071) = \exp (-0.000000227) = 0.9999997$$

As a result, taking into account the action on the employee of two negative factors of VM occupational disease, the value will be close to 1 (~ 100%).

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