Advances in Engineering Research, volume 123
2nd International Conference on Materials Science, Machinery and Energy Engineering (MSMEE 2017)

Modeling Study on the Hazardous Effects of Battlefield Chemical Attack

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Keywords: chemical weapons, hazardous effects, modeling

Abstract: Precisely making a judgment after a chemical weapon attack in the battlefield on its hazardous effects is the fundamental work in order to perform a safe and whole chemical defense in the army. In this article, the author has conducted a throughout analysis on its antipersonnel effect, delaying effect and harassing effect and accomplished a calculating model on the chemical attack hazardous effect in battlefields. This model can perform a positive function in concluding an attack result and further offers a technological support in leading instructors making related defense resolutions.

1. Introduction

When there happens a battlefield chemical attack, there exists many intoxication ways of poisons by which will form a wide poisoning space and sustained poisoning effect to kill, wear out and delay the opposite's effective forces[1]. Being different from the normal weapon attack, chemical weapon attack applies various kinds of toxic agents leading to various hazardous situations with different related influencing factors. The establishment of hazardous effect model of battlefield chemical attack clearly forms a corresponding relation between different kinds of chemical weapon attack and their related hazardous effect to finally determine the whole damage situation of the battlefield. By this final conclusion, people can evaluate the influencing degree on the whole battle arrangement and find practical grounds for fight decisions.

2. Modeling Foundations

Chemical attack ability can be shown as the effective poisoning area during a certain time exerted by a certain number of chemical weapons [2]. It is related with the chemical weapons' performance, number, weather conditions and the other party's defense degree [3].

Normal weapons conduct a physical damage shown by killing radius. For example, missiles and artillery are often measured by their killing radius. While the chemical weapons possess a more complicated attack ability, which cannot simply be shown by the killing radius. It mainly aims at spreading the toxic agents into human respiratory tract and skin to perform a large-scale damage and killing, rather than the direct shrapnel attack. Comparing with normal weapons physical attack, chemical weapons possess several characterizes of invisible, extending and fast diffusion.

According to the various toxic agents qualities and different damage ways on human body, the paper divides the hazardous effects of chemical attack into antipersonnel effect, delaying effect and harassing effect. The hazardous effect of battlefield chemical attack can be shown in the formula below:

$$M = M_{dk} \cdot M_{gl} \cdot M_{al}$$

Therein:

M: hazardous effects of battlefield chemical attack
M_{dk}: antipersonnel effect
M_{gl}: delaying effect
M_{al}: harassing effect

3. Antipersonnel Effect Modeling

The load of quick-acting agent in chemical weapons can lead to certain extent personnel intoxication in a short time and perform an antipersonnel effect. This kind of attack aims at wiping out all effective forces in a short time. Its attack effect is decided by the properties, qualities and explosive ways of the filling toxic agents normally illustrated by strength zone [4]. In accordance to the attack form of the toxic agents, this kind of attack effect can be divided into aerosol toxic agents and liquid droplet toxic agents. The former one means that aerosol will be breathed into human body leading to some damage after the temporal toxic agents explosion, while the latter means that the droplets of persistence toxicant diffuses on the human skin forming a damage.

a) Aerosol toxic agents attack effects

Let's say C (x, y, 0; t) is the location function of chemical ammunition concentration on the ground, then the active number of toxic agents in t time can be counted as follow:

$$T_{50} = \frac{1}{L_{ct50}} \int_0^t C(x, y, 0, t) dt \tag{1}$$

Basing on the Gradient Theory and applying the Lachterman Equation, the chemical ammunition concentration equation can be concluded as below:

$$C(x, y, z) = \frac{QK_u e^{-\frac{(x-u_1 t)^2 + y^2}{4k_0/u_1 + r^2}}}{\pi\Gamma(1+1/n)(4k_0 x/u_1 + h^n)^{1/n}}$$

Applying this equation into (1) equation, we can conclude this:

$$T_{50} = \frac{QK_u \exp(-\frac{y^2}{4k_0/u_1 + r^2})}{\pi\Gamma(1+1/n)(4k_0 x/u_1 + r^2)(k_1 n^2 x/u_1 + h^n)^{1/n} I_{ct50}} \cdot \int_0^t e^{-\frac{(x-ut)^2}{4K_0/u_1 + r^2}} dt \tag{2}$$

Therein:
T_{50}: a half of relative value (x, y, 0) completes a killing equals this certain number of agent dose in t time;
Q: dose quality in toxic agents, g;
K_u: the proportion of droplets and aerosol in the air;
r, h: the original size of toxic agent cloud cluster, m;
u_1: the average wind speed in t time and 1m height, m/s;
n:air vertical stability feature;
k_0:horizontal turbulent diffusion coefficient;
Γ（1=1/n）:Gamma Function

$$\Gamma(x) = \int_0^\infty t^{x-1} \cdot e^{-t} \cdot dt$$

If given the chemical weapon's basic parameter (Q, K_u, r, h) and weather conditions (u_1, n, k_1, k_0), then the value of T_i , limited toxic agent dose in given duration, of any point (x, y, 0) can be calculated. Then the related P_i value can be found out according to T-P Graph.

$$M_{dk} = \sum S_i P_i \tag{3}$$

b) Droplet toxic agents attack effect

Due to the fact that persistence toxicant cannot be vaporized quickly, it usually shapes into droplets to attack the available forces. Its direct damage effect not only relates to the toxic agents poisonousness, but also determines by its density location and functional poisonous area. Here is an instance of air point source release to calculate its poison infection distribution.

Suppose that after the toxic agent ammunition explosion, the agents fall down leeward at an average wind speed. Because of the different speeds and different locations, it finally forms an scattered distribution. Fig 1 illustrates its releasing process.

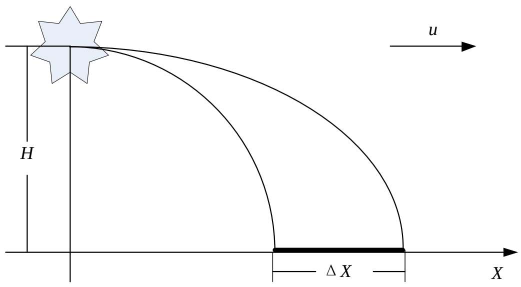

Fig 1 releasing process of point source droplets of toxic agents

X axis in Fig 2 stands as the downwind, then there is this one:

$$X = ut = u\frac{H}{V}$$

Therein:

X: distance to the exploding point in the downwind direction of droplets, m;

u: average wind speed;

t: duration of droplets in the air to the ground;

V: speed of droplets with diameter d, m/s;

According to the Fluid Mechanics, here we can apply the similar formula:

$$V = 5\sqrt{\rho d}$$

Therein:

P: toxic agent's density, g/m3

D: diameter of toxic droplets, mm

Therefore the coverage area of droplets falling on the ground is mainly decided by its falling speed.

$$\Delta X = X_2 - X_1 = Hu(\frac{1}{V_2} - \frac{1}{V_1})$$

We can conclude from above formula that the distribution of droplets only related to V which is the function of droplet diameter. Basing on the distribution function of droplets mass to zero dimension diameter x, and we can find this one below:

$$f(X) = 2\frac{X_0^2}{X^3}\sqrt{\frac{K}{\pi}}e^{-4K(\ln(X_0/X))^2}$$

In Y direction, the droplets distribution shows a normal state, thus here is this one:

$$f(Y)=\frac{1}{2\pi}e^{-\frac{Y^2}{2\sigma^2}}$$

Droplets are separately existed in both X and Y direction:

$$F(X,Y)=\frac{dQ_{X,Y}}{Q_0K_u dXdY}=f(X)f(Y)$$

Then here is the poisoning density distribution formula:

$$\Delta_{X,Y}=QF(X,Y)=\frac{\sqrt{2K}QK_uX_0^2}{\pi X^3\sigma}\exp(-(\frac{1}{4K}+4K(\ln(\frac{X_0}{X}))^2+\frac{Y^2}{2\sigma^2}))$$

Therein:

Q: droplets mass on the ground, g;

$$Q=Q_0K_u$$

Q_0: loading mass in toxic agents, g;

X_0: X-coordinate of diameters;

$$X_0=H\bar{u}\frac{1}{V_0}=\frac{H\bar{u}}{5\sqrt{\rho d_0}}$$

From the above casualty to poisoning density relation, dose amount in battlefield chemical attack area can be concluded as:

$$T_{50}=\frac{1}{L_{ct50}}\Delta_{X,Y}$$

Then the killing and damage effect of droplets can be calculated out from formula (3).

4. Delaying Effect Modeling

After a chemical attack on a certain region, the opposite army will be trapped in their weapon, equipment and topographic, be shaped with a chemical obstruction to divide the whole battlefield into small regions and have to force themselves slow down their moving, combat command and logistics efficiency. This is called as delaying effect [5].

There mainly exists two elements in chemical attack delaying effect. One is the territory protection which means a battlefield area of Sg affected with toxic agents will not allow any army without protection going through. The other is the duration limitation that refers to the long lasting poisoning in the affected area to keep the opposite soldiers combat capability down to a low degree in Tg duration. It can be expressed as below:

$$M_{gl}=S_g\cdot T_g$$

Suppose the allowing fight dose in toxic agents is I_a, density distribution on the ground is C (x, y, 0, t), then the S_g of dose curves like I_a can be calculated as:

$$S_g=\int_0^{I_a}\int_0^t C(x,y,0,t)dt$$

T_g stands for the preserving duration of dose on the ground also called as toxic agent endurance. The consumption of agents on the ground is mainly due to hydrolysis and evaporation.

$$Q=Q_0(1-K+Ke^{-\frac{E_f t}{KQ_0}})(1-\frac{Q_h}{Q_0})$$

Therein:

E_f: evaporation rate of toxic agents on smooth surface, g/s;
K:free liquid fraction relating to the soil structure;
Q_0: the original dose amount (can be calculated according to the previous description);
Q_h: the hydrolyzed toxic agent amount in t mine, g;
Then here is this:

$$T_g = -\frac{\ln(\frac{I_a}{Q_0 - Q_h} + K - 1) \cdot KQ_0}{E_f}$$

$$M_{gl} = -\int_0^{I_a} \int_0^t C(x,y,0,t)dt \cdot \frac{\ln(\frac{I_a}{Q_0 - Q_h} + K - 1) \cdot KQ_0}{E_f} \quad (4)$$

5. Harassing Effect Modeling

Harassing attack is mostly used in disturbing the other party's military arrangements and formation and forcing them into self-protect mode to weaken their combat capability. There are two influential elements of disturbing time T and defense degree impact factor θ_i, the final results into the influential degree on the combat capability.

$$M_{al} = T * \theta_i \quad (5)$$

Therein:
θ_i : current defense degree for soldiers
T: total duration of people staying in the poisoning region
Due to the fact that each toxic agent requires for different levels of defense degree, there lies a need to firstly determine the influential factors basing on different defense levels. In light of American army's defense degree, the army defense level can be divided into five levels [6], the related impact factors ranges from θ_0 to θ_4, as shown in Table 1.

Table 1 chemical defense degree of American Army

Defense Degree	Defense Equipment status				Impact Factor
	respirator	chemical prote-cttive clothing	Gas-protective Shoe Sheath	Gas-protecti-ve Gloves	
MOPP0	T	—	—	—	θ_0
MOPP1	T	W	T	T	θ_1
MOPP2	T	W	W	T	θ_2
MOPP3	W	W	W	T	θ_3
MOPP4	W	W	W	W	θ_4
T:CARRY W:WEAR					

6. Conclusion

In this paper, the author has established three kinds of hazardous effect models in battlefield chemical attack and the corresponding relations between hazardous results and chemical toxic agents attack. On a separate note, these three hazardous results probably can penetrate with each other in one chemical attack. For example, antipersonnel chemical attack can not only cause personnel damage but also delay their military move. Meanwhile, when they organize their protection mode, they also will be worn out their energy. Different chemical toxic agents also has different kinds pf damages. For example, GD is mostly used in damaging available forces to produce direct killing and damage effect while in low density using, it exerts a disturbing effect. VX and HD are mainly used in road and ground poisoning with a long-lasting enduration and effective delaying performance. Also, in high density usage, it can also produce direct damage effect.

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