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Research Article

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Environmental risks impact analysis of aerosol leakage by pathogenic microorganisms decay

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ABSTRACT

When pathogenic microorganisms' aerosol leakage accident occurred in High-level biosafety laboratories, pathogenic microorganisms' aerosols into the atmosphere will occur biological decay, and then reduce infectious aerosol concentration in the environment. Based on aerosol leakage environmental risk prediction model, this paper adds half-life decay index in the diffusion model to analyze environmental risks impact of infectious aerosol leakage by pathogenic microorganisms decay. The results show that when microorganism half-life greater than 30min, the less effect to maximum concentration and protection distance of external aerosol by microorganisms half-life. Smaller wind speed, greater impact. When microorganisms half-life less than 10min, concentration and protection distance of environmental aerosol will significantly be reduced. For example, when aerosol leakage in 5m height near the ground, and half-life reduced to 1min, the high-risk area will reduce from 500m to 200m, while the low-risk area from 1500m down to 400m. For aerosol leakage in 25m height, and half-life reduced to 1min, the low-risk area from 1200m down to 0m.

Key words: Pathogenic microorganisms, Biological aerosols, Risk prediction model, Environmental risks, Half-life

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INTRODUCTION

When pathogenic microorganisms aerosol leakage accident occurred in High-level biosafety laboratories, infectious aerosol concentration in ambient air may reach dangerous levels to make people pathogenic [1-3]. Affected by external environmental conditions, infectious pathogenic microorganisms' aerosols into the atmosphere will be occurred biological decay, and then reduce infectious aerosol concentration. Therefore it is necessary to carry out research on the environmental risks of pollutants leak in high-level biosafety laboratories, analyze environmental.

Risk impact of aerosol leaked by pathogenic microorganisms' half-life. Then establishing environmental risks prediction model suitable for infectious aerosol leakage occurs in high-level biosafety laboratories, to provide technical support for laboratory risk management.

PATHOGENIC MICROORGANISMS AEROSOL DECAY

Infectious pathogens aerosols into the atmosphere will occur biological decay, the main factors which causing the decay include air humidity, UV and ozone-depleting substances concentration in the air. Studies have shown that, SARS virus survival have a direct relationship with the humidity, temperature, and media communication. For example, when 37℃, SARS virus can survive 4 days, it will be killed when heating 90min in 56℃ or heating 30min in 75℃. Influenza virus can survival longer than 90min at 30 to 40% relative humidity, while only 30min at 60~70% relative humidity. Poliovirus has weakly heat resistance, can be rapidly (1~3min) killed in 60~80℃, and the same in ultraviolet radiation. Mycobacterium tuberculosis is UV-sensitive. It can be killed in several hours direct sunlight. Epidemic hemorrhagic fever virus can be killed when under pH5.0, heating 1 hour in 60℃ or heating 1 min in 100℃, and the same in 30min in ultraviolet radiation [4-7].

AEROSOL LEAKAGE ENVIRONMENTAL RISK PREDICTION MODEL

Environmental risk protection zone set up

When pathogenic microorganisms aerosol leakage accident occurred in biosafety laboratories, if infectious aerosol concentration in ambient air reach the dangerous levels of human-pathogenic, then we should designate environmental risk protection zone within a certain range around the accident. According to exposure duration in ambient air of infected objects and injury risk size, environmental risk level can be divided into high-risk, medium-risk and low-risk. For the pathogenic microorganisms which have 1 CFU infectious dose, their environment risk level classification and reference risk thresholds are shown in Table 1.

Table 1 Safety threshold reference standard of infectious aerosols environmental [8]

Environmental security level	Emergency measures	corresponding Infection concentrations (Equivalent CFU/m^3)
High-risk	areas need to occupant evacuation	8.4706
Medium-risk	need to take effective protective measures	2.8235
Low-risk	need to track and monitor	1.4118
No-risk	region almost no infection risk	＜ 1.4118

Aerosol risk dispersion model

Analog transmission and diffusion after infectious aerosol leakage, and basic diffusion model use plume model that recommended in China risk assessment guidelines [9]:

$$C(x,y,z)=\frac{2Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z}\exp\left[-\frac{(x-x')^2}{2\sigma_x^2}\right]\exp\left[-\frac{(y-y')^2}{2\sigma_y^2}\right]\exp\left[-\frac{(z-z')^2}{2\sigma_z^2}\right]$$

In this equation: $C(x,y,z)$-- pollutant concentration（mg/m^{-3}）in wind direction coordinates (x,y,z) at time t；

x',y',z' --Coordinate of plume center at time t;

Q--Aerosol emissions during accident, mg/s;

σ_x, σ_y, σ_z--diffusion parameters (m) of X, Y,Z direction at time t.

Pathogenic microorganisms decay correction algorithm

Infectious aerosols into the atmosphere will occurs biological decay, reduce the concentration of infectious aerosols in the environment, therefore need to add decay index of pathogenic microorganisms half-life in diffusion model, to correct source intensity of infectious aerosols:

$$Q(x) = Q_0 \times f_c$$

Where $f_c = exp[-0.693x/(ut_d)]$;

x--Downwind distance of accepted point, m;

u--Wind speed of air outlet, m/s;

t_d--Pathogenic microorganisms half-life, s.

CASE STUDY

Infectious aerosols risk leak source intensity

According to the research results, setting parameters of Infectious aerosols risk leak source intensity can be seen in Table 2. To analyze the greatest impact on the environment at risk accidents, assumed infectious aerosol leakage duration after accidents risk is 10min, and use largest leak source intensity to calculate.

Table 2 Risk emission source intensity settings [9]

Risk source intensity	Generation (CFU/S)	Leak rate（%）	Leak（CFU/S）	Leak time（min）
Minimum value	10	1	10^{-1}	10
Average value	10^3	10	10^2	10
Risk values	10^5	10	10^4	10
Extreme value	10^5	100	10^5	10

Pathogenic microorganisms decay parameters

Due to different activity effects on pathogenic microorganisms from different environmental parameters, there is no authority test result on pathogenic microorganisms' half-life. In order to consider the environmental risks impact from different setting of pathogenic microorganisms' half-life, we set seven different decay half-life plans in Table 3.

Table 3 Pathogenic microorganisms decay half-life setting program

Test program plan	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7
Half-life（min）	no decay	60	30	10	5	2	1

Other risk prediction parameters set up

Outfall height: Combined with actual outfall height of current domestic biosafety laboratory, outfall height set in two heights, including emissions near the ground (5m) and conventional discharge height (25m). At the same time, we take exit radius as 0.5m, flue gas velocity as 5m/s, smoke temperature as 20℃.

Weather condition: Select common weather conditions of Class D stability parameters. Wind speed: Consider total 10 wind speed segment, from 1.0m/s to 20m/s. There are total 54 kinds combinations in meteorological conditions [10].

Predicted downwind concentration distribution: Predict grid take Y =0, X direction coordinate from -300 to 6000m; grid spacing set 100m, a total of 64 grid points; elevation from ground of prediction point is 0m.

RESULTS AND DISCUSSION

Risk impact analysis of Emissions near the ground (5m)

Decay impact of aerosol environmental concentration: Figure 1 shows effect of downwind aerosol maximum concentration from different microbiological half-life, when exhaust height is 5m, and occur the maximum leakage dose of infectious aerosol. As we can see from Fig 1, when half-life longer than 30min, there are smaller impact of aerosol concentration in the external environment and impact areas, from Half-life changes.

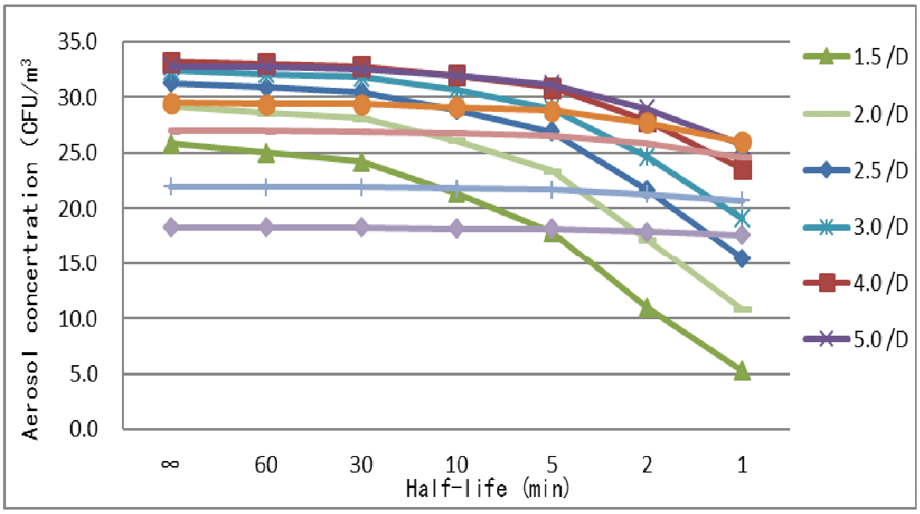

Figure 1 Effect of downwind aerosol maximum concentration in different decay (5m emissions)

When the ambient wind speed in small wind conditions (1.5m/s), without regard to microbiological decay, the maximum concentration of aerosol is 25.8CFU/m^3; while consider half-life as 1min, the maximum concentration of aerosol is only 5.32CFU/m^3. There is a big drop of 79.4%. Under common weather conditions, the maximum concentration of aerosols from 31.3 CFU/m^3 reduced to 15.5 CFU/m^3, the decline is 50.4%. In contrast, under windy conditions (20m/s), the maximum concentration of aerosols reduced from 18.3 CFU/m^3 to 17.6 CFU/m^3, fell only 3.8%.

Effect of risk affected area in different half-lives: Table 4 lists the risk range impact of affected area in different microbiological half-life, under common weather conditions (2.5m/s wind speed, Class D stability). In case of microorganism half-life greater than 30min, there is little impact to affected concentration and zone in external environment in downwind, only a slight decrease. When microorganisms half-life less than 10min, half-life changes produce greater impact to infected zone and aerosol concentrations in external environment.

In case of microorganisms' half-life less than 10min, affected concentration and zone in external environment in downwind are both decrease. The largest reduce of High-risk area is from 500m to 200m, while medium-risk area from 1000m down to 300m, low-risk area from 1500m down to 400m, shown in Figure 2.

Table 4 Range effect of risk affected area in different microbiological half-life (2.5m/s, Class D stability; Unit: m)

Risk Level\half-life	∞	60	30	10	5	2	1
High-risk region	500	500	500	400	400	300	200
Medium-risk region	1000	900	900	800	600	400	300
Low-risk region	1500	1400	1300	1300	900	600	400

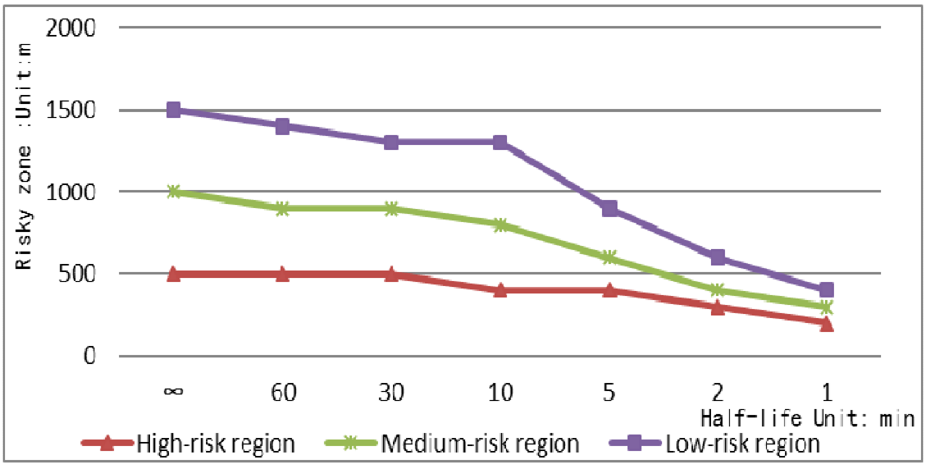

Figure 2 different half-lives range impact on the risk area (Unit: m)

Impact analysis of conventional emissions height (25m)

Decay impact of aerosol environmental concentration: Figure 3 shows effect of downwind aerosol maximum concentration in different microbiological half-life, when exhaust height is 25m, and occur the maximum leakage dose of infectious aerosol. In Fig 3, when half-life longer than 30min, impact of aerosol maximum concentration from Half-life changes is small.

When the ambient wind speed in small wind conditions (1.5m/s), without regard to microbiological decay, the maximum concentration of aerosol is 4.66CFU/m^3; while consider half-life as 1min, the maximum concentration of aerosol is only 0.344CFU/m^3. There is a big drop of 92.6%. Under common weather conditions (Class D stability, 2.5m/s wind speed), the maximum concentration of aerosols from 3.58CFU/m^3 reduced to 0.799CFU/m^3, the decline is 77.7%. In contrast, under windy conditions (20m/s), the maximum concentration of aerosols reduced from 0.652CFU/m^3 to 0.546CFU/m^3, fell 16.3%.

Effect of risk affected area in different decay: Table 5 lists the risk range impact of affected area in different microbiological half-life, under common weather conditions (2.5m/s wind speed, Class D stability). In case of microorganism half-life greater than 30min, there is little impact to affected concentration and zone in external environment in downwind, only a slight decrease. When microorganisms half-life change to 10min, half-life changes produce significantly impact to infected zone and aerosol concentrations in external environment. The medium-risk area reduces from 700m to 500m, and low-risk area from 1200m down to 900m. When the half-life reaches 1min, risk zone is down to 0m.

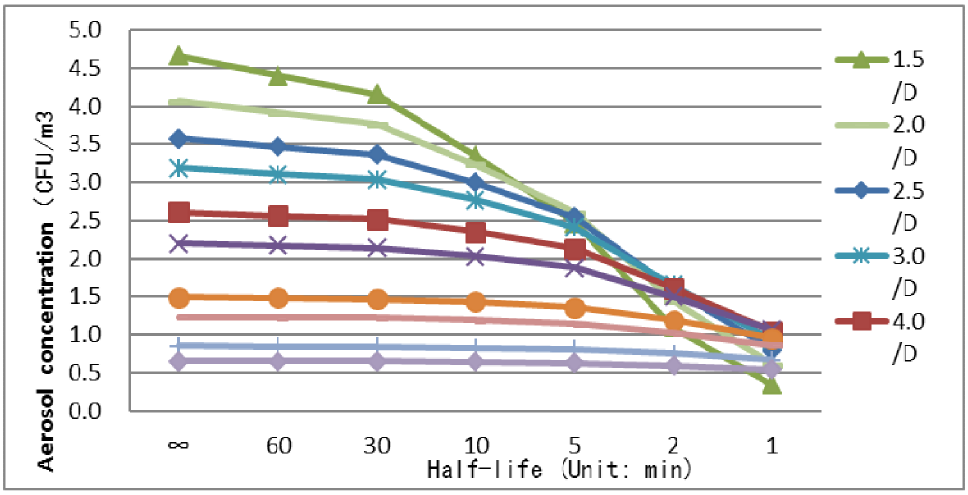

Figure 3 Effect of aerosol maximum concentration in different decay (25m emissions)

Table 5 Range effect of risk affected area in different microorganisms decay
(2.5m/s, Class D stability; Unit: m)

Risk Level \ half-life	∞	60min	30 min	10 min	5 min	2 min	1 min
High-risk region	0	0	0	0	0	0	0
Medium-risk region	700	600	600	500	0	0	0
Low-risk region	1200	1100	1100	900	700	400	0

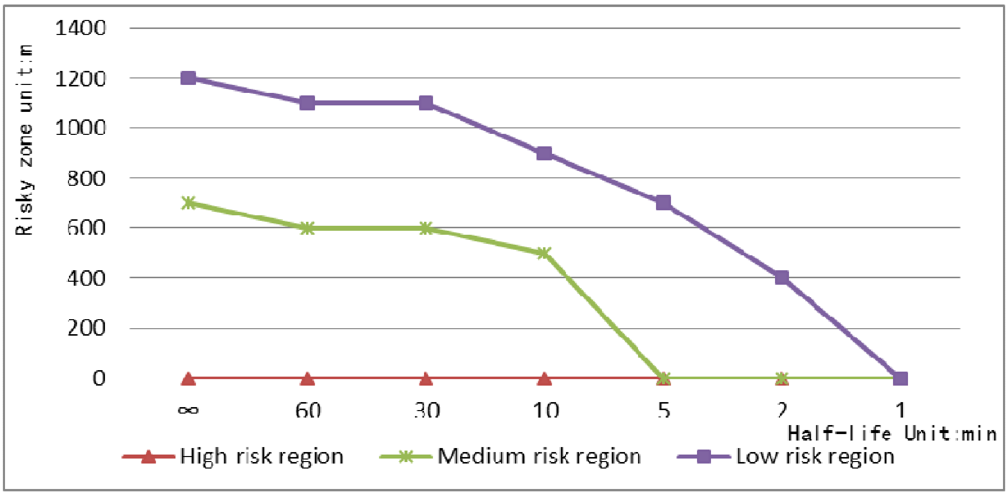

Figure 4-5 different half-life impact on risk area (Unit: m)

CONCLUSION

Due to the less studies on highly pathogenic microbes and viruses survive in air and half-life in current domestic and international, this paper will analyze the risks impact of pathogenic microorganisms half-life. Mainly based on a comparison of different parameters set of half-life, to analog and analyze impact of source intensity and risk from half-life parameters. The results showed that:

For aerosol leakage near the ground (5m), and half-life greater than 30min, there is little impact to aerosol maximum concentration in environment from half-life changes. Smaller wind speed, greater impact. While microorganisms half-life less than 10min, half-life changes produce greater impact to infected zone and aerosol concentrations in external environment. In case of microorganisms half-life in 1min, the largest reduce of High-risk area is from 500m to 200m, while medium-risk area from 1000m down to 300m, low-risk area from 1500m down to 400m.

For aerosol leakage in 25m height above the ground, and half-life greater than 30min, there is also little impact to aerosol maximum concentration in environment from half-life changes. When microorganisms half-life change to less than 10min, half-life changes produce significantly impact to infected zone and aerosol concentrations in external environment. The medium-risk area reduces from 700m to 500m, and low-risk area from 1200m down to 900m. When the half-life reaches 1min, risk zone is down to 0m.

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REFERENCES

[1] Li Jin-song. *China poultry*, **2007**, 29(17), 30-36.
[2] Wang Zhuang, Li Jin-song. J*ournal of Military Medical Sciences*, **2005**, 29(3), 263-267.
[3] Chen Jun. *China Animal Quarantine*, **2009**, 26(8), 24-25.
[4] Zhao Guo-xiong, Wang G.Z., Fang H., etc. *Chinese Pharmaceutical Affairs*, **2008**, 22(11), 971-974.
[5] Huang Ji-chen, Wang J.W., Lu B., etc. *Risk assessment*, **2009**, 26(10), 27-29.
[6] Wang Xin-wei, Li J.S., Jin M., etc. *Environment and Health*, **2004**, 21(2): 67-71.
[7] L. Jeyanthi Rebecca, V. Dhanalakshmi, S. Sharmila. *Journal of Chemical and Pharmaceutical Research*, **2012,** 4(11), 4875-4878.
[8] Ding Feng, Li S.B., BO X. *Military Medicine*, **2013**(01), 10-14.
[9] Ministry of Environmental Protection. Construction Project Environmental Risk Assessment Technical Guidelines, HJ/T 169－2004 China Environmental Science Press, Beijing, **2004**.
[10] Li Shi-bei, Dai W.N., Du Y.H. *Environmental Science*, **2007**, 20(5), 26-30.