New sporicidal foam for biological decontamination of facilities

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NEW SPORICIDAL FOAM
FOR BIOLOGICAL DECONTAMINATION OF FACILITIES

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Introduction

In 2001, several letters containing Bacillus anthracis spores were sent through the U.S. Postal Service to recipients in government and private-sector buildings. Consequently, 23 human inhalational or cutaneous anthrax infections occurred[i]. Five of the 11 inhalational anthrax infections were fatal. This alerted the European and American public opinion on the reality of the threat of bioterrorism. This also threatens large civilian infrastructures (subway, airport, offices, exhaust ducts…) and in case of spreaded biological agents, the priority for the authorities, just after limiting the effects on the civilian population, is the rapid decontamination of exposed infrastructure to prevent overspread of agents and to permit the reuse of the buildings without any risk. There is therefore a need to develop adapted decontamination processes. Decontamination of large facilities is actually a challenge : fumigation by filling an enclosed or semi-enclosed part of the building with gas (Chlorine dioxide ClO_2) is developed by US EPA (United States Environnemental Protection Agency) and complementary technics for target contaminants in specific hot spots such as liquid decontaminants sprays on vertical and horizontal surfaces ([ii]).
Among infrastructures, some are inaccessible, such as, for example, vents or exhaust ducts of wastewater. In addition, the decontamination process to develop has to be effective on a wide range of biological agents.
Literature described many foaming formulations for neutralization of chemical, biological and industrial toxic agents and some of them are complex. Among them, DF 100 and 200 formulations and EasyDECON® 200 developed by Sandia National Laboratories and SDF from Allen Van Guard are well known[iii]. These foams are versatile because there are effective to neutralize chemical warfare agents such as sarin, mustard gas, the O-ethyl S- [2-(diisopropylamino) ethyl] méthylphosphonothioate (or VX) and soman, toxic industrial chemicals and biological agents such as B. anthracis and Y. pestis. Nevertheless the humidity of the foam and its stability are unknown. To treat building materials or civil infrastructures in the frame of CBR (Chemical, Biological, Radiological) post-event, the Decontamination and Supercritical Processes (LPSD) and the Innovative technologies for Detection and

Diagnostics (LI2D) laboratories from the French Atomic Energy and Alternatives Energies Commission (CEA) have developed new processes since 2006 using gels and foams[iv,v]. These new techniques for CBR decontamination of solids are secure, easily deployable by end users and strongly reduce the cost, the secondary wastes production and the workers exposure. These are alternatives to wiping techniques or fumigation. We focused last year on the development of a new biological decontamination process using aqueous foam[vi]. This foam is able to decontaminate huge (>100 m^3) and complex shape materials in a static way, such as rooms, offices, ventilation systems and galleries. The foam could be used by classical spraying devices but also in a static way which is more original: the facility to decontaminate is filled with foam that wets all the surfaces to treat during 30 minutes and drains freely for some hours.

Foam Formulation

Aqueous foams can be viewed as a dispersion of gas bubbles in a liquid stabilized by surface-active molecules called surfactants at the gas–liquid interfaces. Gas is usually air.
The foam wets the substrate of the facility to decontaminate with a thin wetting liquid film on the wall containing the decontaminant agent. The contact time of the foam with the solid substrate to decontaminate is controlled by the life-time of the foam.

Like in solid porous materials, the water flows through the continuous network of interconnected channels between air bubbles that constitutes the main part of the "foam porosity". Foam ages because of several interrelated physical processes, namely the liquid drainage in films and channels, the so-called disproportionation process, and the coalescence of bubbles. As a major destabilizing effect of drainage, the liquid films thin progressively, thus promoting their rupture and the resulting collapse of the foam sample. As the collapse of the foam can be detrimental to the contact time between contaminants and foam, a possible strategy to enhance the foam stability is precisely to reduce the liquid drainage. This is traditionally achieved by means of viscosifiers[vii] which act as stabilizers. This approach using viscosifiers is suitable for generating high volume of stable foams which are used in the static way by filling the facility. It enhances the contact time between the contaminants present onto the solid wall and the foam, from 10 mm to 1 hour depending on the viscosifier concentration. Our major objectives were to study the compatibility and stability of the foaming solution with the well- known disinfectants like hydrogen peroxide or bleach .

First, preliminary foaming experiments on small foam volume (150 ml) were performed to determine the optimal concentration for surfactant, viscosifier and bleach (or hydrogen peroxide). Then, liters of foams comprising air bubbles dispersed in a foaming solution containing one biodegradable polymer as foaming surfactants, a specific viscosifier polymer and one disinfectant were successfully prepared with a lab-scale generator. This humidity is controlled by the ratio air flow rate/ liquid flow rate.

Decontamination efficiency and kinetics on *Thuringiensis Bacillus* spores

Difficult cases to decontaminate such as spore inactivation were studied. First studies were performed on ***Bacillus Thuringiensis*** spores which were chosen to simulate ***Anthrax spores*.** Spores (more than 10^7/ml) were deposited in water droplets on both horizontal and vertical substrates. Droplets dried at room temperature. Foams are generated with a specific foam generator to control foam humidity. These foams are mechanically layed on the contaminated spots or there are used in the static way by filling small contaminated PVDF boxes.

Two foams formulation A and B were tested: bleach (NaOCl) and hydrogen peroxide (H_2O_2). The generated foam is efficient during the life-time, inactivates rapidly the biological contaminants and does not damage the surface of the materials.

Excellent efficiencies on *Bacillus Thuringiensis* spores >7 Log reduction, i.e., > 10^7) deposited on plastics were obtained, which are similar to other results with other technics (fumigation, wipes)[viii]. On other substrates (metal, concrete, ceramics…), studies are going on with preliminary results (>6 Log reduction) depending on the substrate.

Moreover, we also checked the efficiency after 30 minutes of the two foams A and B on *Bacillus Anthracis* spores (figure 1) and the decontamination were measured by Log reduction of the number of contaminants.

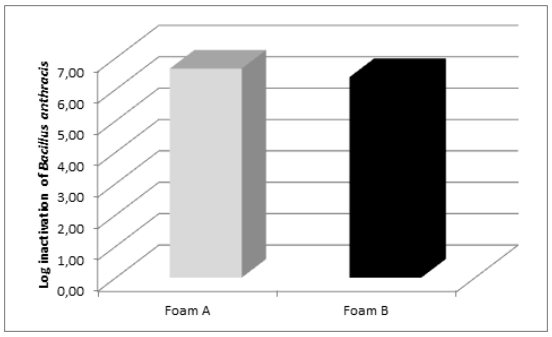

Figure 1: Foams A and B efficiencies on *Bacillus Anthracis*

These two foams are able to decontaminate more than 6 Log reduction of *anthrax* spores spotted on plastic surfaces.

<u>Two ways to use the foam: filling or spraying</u>

A 20m^3 tank which simulates a large facility was filled with the “bleach foam” A. The foam generator was specifically designed with nozzles that alloy to obtain high foam flow rate (100 m^3/h) at low pressure. Liquid and air flow rates were controlled to adjust foam humidity. The tank was filled in a few minutes and its stability was more than one hour.

Figure 2: Tank filling with a sporicidal stable foam (20m^3)

The humidity of the foam was homogeneous up to 4 meters high and foam stability was more than one hour. Moreover, this foam was sprayed on different walls to verify the adhesion on different substrates. This foam adheres to vertical wall.

Conclusion

The incorporation of a specific viscosifier in both bleach and hydrogen peroxide foams allows generating new stable foams that required foam properties for biological decontamination of large and complex shapes facilities. The structure of the foam and its humidity are stable during the decontamination time (30 minutes) and it permits the foam to wet all the surfaces to decontaminate rapidly large facilities such as offices, corridors, rooms… The efficiency of this biological decontamination foam process has been demonstrated on spores of *Bacillus thuringiensis* even on vertical substrates. The foam is able to be used in a simple static way just by filling the facility to decontaminate and could be an alternative to fumigation. The process is secure, easily deployable by end users and strongly reduces the cost, the secondary wastes production and the workers exposure.

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