Industrial Health 2010, **48**, 119–122 **Field Report**

Acute Expanded Perlite Exposure with Persistent Reactive Airway Dysfunction Syndrome

Chung-Li DU[1], Jung-Der WANG[1, 2], Po-Chin CHU[1, 2] and Yue-liang Leon GUO[1, 2]*

[1]Department of Environmental and Occupational Medicine, National Taiwan University Hospital, 17 Syujhou Road, Taipei 100, Taiwan

[2]Institute of Occupational Medicine and Industrial Hygiene, National Taiwan University College of Public Health, Taiwan

Received December 25, 2008 and accepted June 23, 2009

Abstract: Expanded perlite has been assumed as simple nuisance, however during an accidental spill out in Taiwan, among 24 exposed workers followed for more than 6 months, three developed persisted respiratory symptoms and positive provocation tests were compatible with reactive airway dysfunction syndrome. During simulation experiment expanded perlite is shown to be very dusty and greatly exceed current exposure permission level. Review of literature and evidence, though exposure of expanded perlite below permission level may be generally safe, precautionary protection of short term heavy exposure is warranted.

Key words: Expanded perlite, Spill, Provocation test, Simulation, Reactive airway dysfunction

Introduction

Perlite, light gray to glossy black color porous glass containing interstitial water, originates from volcanic eruption. For industrial purpose, perlite is heated up to 1,000 degree Celsius to become expanded perilte that is used as agriculture substrate, lightweight concrete aggregate, packaging material, and construction and industrial insulator for wall and floor and so on, according its various size. The expanded perilte has a high surface area, is fluffy white and insoluble in water. According to material safety data sheet, expanded perlite is a mineral composed of sodium, potassium, aluminum, silicate, and alpha-cristobatite & tridymite, and alpha-quartz, etc. depending on its ore body that dictating the substance's chemical composition. It is regarded as generally safe, and the time weighted average of threshold limit value (TLV-TWA) was 10 mg/m^3 without short-term exposure limit[1)].

Subjects and Methods

In a factory located in one of the Science Park of Taiwan, because of abnormal pressure was noted in a safety valve of liquid nitrogen tank (49.2 m^3), replacement of its evacuation valve was scheduled. The introduction of helium gas during the maintenance process brings the pressure within the vacuum layer to accumulate and break out through the safety valve. The insulator material, consisting of mainly expanded perlite powder, had an accident explosion and spilling out. This caused large amount of powders to continue falling covering hundred meters of area. A woman staff in the outside ground, unable to escape reported to have inhaled the powder and developed symptoms of sore throat, persisted cough, and chest tightness. An industrial hygiene officer and another security guard went over immediately to check the accident and stayed at the polluted space without mask for several minutes. Later on more company staffs wearing paper or carbon masks were dispatched to clean the polluted ground using water jets and brooms for several hours. Many of them also complained of eye and throat irritation, cough and dyspnea afterwards.

For the exposed workers an initial health examination at nearby hospitals was arranged though not all visited doctors, and later on referred to our hospital, one of the tertiary referral centers in Taiwan. The 24 cases had onsets of respiratory irritation at the first or second day of their exposure to perlite, and their symptom varied and

*To whom correspondence should be addressed.
E-mail: leonguo@ntu.edu.tw

were off and on (for several months) before visiting NTUH, where questionnaire survey were performed. Chest radiograph and pulmonary function tests (PFT), including non-specific broncho-provocation test, using serial dosage of methacholine, were performed for them as well. Positive result was defined as a 20% decrease in FEV_1 (PC_{20}) upon threshold value equal or less than 16 mg/ml of methacholine inhalation.

Results

The results in Table 1 showed the previous history, exposure and protection condition, symptoms, pulmonary function of 24 perlite exposed workers. Among the 24 workers, the prevalent symptoms observed among these workers up to 3 months after incident were cough (in 12 patients), eye irritation (in 11 patients), shortness of breath (in 12 patients), and throat irritation (in 7 patients). Many victims had more than 6 months of respiratory symptoms and three of them (case 1,2,4) had cough and chest tightness complaint at the first exposure and thereafter with slight obstruction of PFT (%FEV_1 <80). For the other lightly exposed workers, none remained symptomatic after 6 months of follow-up and their pulmonary function test results were all within normal limits (Table 2). None of them had known prior history of lung diseases such as

Table 1. The previous history, exposure and protection condition, symptoms, pulmonary function of 24 expanded perlite exposed workers

Case no.	Irritation sites & symptoms				Exposure conditions	Protection (respirators)	Initial PFT at NTUH			Past history & notes
	Cough	Eye	Throat	Dyspnea or chest tightness			FEV_1	FVC	FEV_1/FVC	
1	✓			✓	passing by, powder pouring down over whole body	nil	104	113.2	81.4	female
2	✓	✓		✓	guard, exposed 20 min in emergency watching	nil	86.4	86.1	80.6	smoking 1/2 PPD for 10 yr
3				✓	safety officer, at the scene for minutes, & cruise whole area later on	mask	107	109.9	83.9	
4	✓			✓	cleaning of tank area for several hours	mask	88.3	106.7	71.3	
5	△	△		△		mask/N95	96.9	92.7	90.8	
6	✓		✓			mask/N95	100.5	96.3	85.7	
7		△		△		mask/N95	91	92.3	84.3	
8		✓				mask	nil	nil	nil	
9	✓			✓	cleaning of other grounds for several hours	mask/N95	99.7	114.7	75.3	heart disease EKG normal
10	✓	✓	✓	✓		N95	100.5	106.5	82.3	provocation test negative at 32 mg/ml
11	△	✓				N95	116.2	112	90.6	
12	△	△				N95	nil	nil	nil	
13	✓					N95	nil	nil	nil	
14	△			△		mask/N95	108	112.2	83.4	smoking 1/2 PPD for 8 yr
15			✓			N95	86.8	91.7	82	
16	✓			✓		mask/N95	98.9	98.7	85.4	
17		✓	✓			mask/N95	117	117	87.3	
18		△				mask/N95	93.8	95.7	84	
19			△	✓		N95	109.8	123.9	78	
20		✓	✓	✓		N95	102.4	105.1	83.7	
21					cleaning of polluted cars	nil	nil	nil	nil	
22		✓	✓			nil	nil	nil	nil	
23	✓				later exposed for minutes	nil	117.1	113.4	84.8	
24					Sanitary work for 1 h (after major cleaning)	N95	nil	nil	nil	female, prior history of asthma inhaler Rx

When visit NTUH clinic △ means symptoms subsides, ✓ means persistent symptoms.

Table 2. The victims of expanded perlite incident exposure groups and the percentage of workers' with persistent respiratory symptoms and impaired pulmonary function results

Classification	Exposure condition	Respiratory symptoms up to 3 months	Respiratory symptoms more than 6 months	With obstructive ventilation defect*	Meet PC_{20} criteria**
Heavy exposure group (n=8)	first contactor, immediate exposed, or cleaning of tank leaking area	5 (62.5%)	3 (37.5%)	3 (42.9%)	3 (37.5%)
Light exposure group (n=16)	cleaning of other grounds and lately	6 (37.5%)	0 (0%)	0 (0%)	0 (0%)

*: Obstructive ventilation defect is defined as FEV_1/FVC <80%, there are 7 workers in the high exposed group perform pulmonary function test.
**: PC_{20} means provocation test is positive at methacholine ≤16 mg/ml that causes 20% drop in FEV_1 from baseline.

emphysema, chronic bronchitis, tuberculosis or lung cancer except one light exposed case with prior asthma history. Chest radiography was obtained in 22 workers which were considered normal except minimal fibrotic change in 4, increased lung marking in 3, and pleural thickening in 2 workers. Among the three persistent symptomatic workers, case no.1 is the directly exposed woman staff (38 yr old), the case no.2 is the guard (55 yr old), although symptom persist, his pulmonary function tests showed improvement after one month of follow up (FVC from 86.4% to 93.8%, FEV_1 from 86.1% to 90.2% and FEV_1/FVC from 79.0 to 80.6% predicted). The case no.4, a 39 yr old worker cleaning the tank leakage area, who had normal pulmonary function in periodical physical examination last year, developed persistent cough and dyspnea after this incident. His serial pulmonary function test showed persistent mild obstructive pattern. These three cases have persistent symptoms even after treatment with beta-agonist inhaler plus anti-allergic (all three cases), or theophylline and prednisolone (case 1 only). The follow up broncho-dilatation test showed borderline or no response (case 1&4), and serial provocation tests are still positive (<16 mg/dl) for cases 1&2 after follow-up for 9 months and case 4 for 2 yr, in this worker persistent obstructive pulmonary function throughout the follow up course and diffusion capacity impairment (75.0%) was noted at the latest follow up.

Discussion

In the incident described herein, three exposed workers without history of pulmonary disease developed persistent cough and dyspnea after a single heavy exposure to expanded perlite. According to the original definition of reactive airway dysfunction syndrome (RADS)[2] the victim's symptoms will develop very quickly, within minutes or hours after a single, high-intensity exposure and the asthma-like symptom (chest tightness, cough or dyspnea) persisted for a longer period and usually non-specific challenge test is usually positive, and with postitive histiopathological result. Lately recommended cardinal diagnostic features of RADS[3] are: (a) identification of date, time, frequency and extent of exposure. (b) symptom occurred within 24 h (c) no latency period between exposure and symptoms (d) symptom less likely to improve away from work (e) objective (pulmonary function) test demonstrate obstruction (f) presence and persistence of non-specific bronchial hyper-responsiveness (such as methacholine challenge test). These three RADS workers have demonstrated all the above features. Based on American Thoracic Society guidelines[4], by the severity of air hyper-reactiveness (AHR) to methacholine, there were 4 degrees: moderate to marked (PC_{20}, ≤1.0 mg/ml); mild (PC_{20}, 1 to 4 mg/ml); borderline (PC_{20}, 4 to 16 mg/ml); and normal (PC_{20}, >16 mg/ml). If the last concentration inhaled was ≤16 mg/ml, it was found that the percentage fall in FEV_1 was similar across the AHR severity scheme (about 25%). At concentrations of >16 mg/ml, the average fall in FEV_1 was approximately 15%. In this accident, all three cases of RADS have a PC_{20}≤16 mg/ml, which confirms positive bronchial responsiveness to methacholine. The three symptomatic workers who become airway hyper-reactiveness (AHR) have no previous exposure to sensitizers[5] in their workplace before this incident. Nevertheless, as shown in the literature RADS usually occurs to corrosive or irritating gas, vapor, fume or dust[6] exposure, and thus it is also categorized as irritant induced occupational asthma[7], while perlite had never been recognized in the above list, either as an irritant[6] or a sensitizer[8]. The remaining perlite powder on the ground was analyzed and it showed some Cr, As, Cd, Hg (<5 ppm) and Pb (80 ± 5 ppm). They are unlikely to be the original constituents of expanded perlite as revealed from material safety data sheet, and are assumed to be contaminants from exfoliated paint of the worksite or maybe from very small amount

of inside tank wall exfoliated paint. The original raw material of expanded perlite powder was also analyzed and which does not show free SiO_2. Using sand dust test machine and in a condition of pre-set pressure of 0.01–0.2 MPa (mega pascal, 1 MPa =9.869 atm) to simulate filling pressure of nitrogen gas in the insulation layer before the accident occurred, expanded perlite powder was stirred in the hood for 15 s and the chamber light was on so to visually simulate the cloudy leakage while dust concentration was simultaneously monitored. The safety officer and two colleagues agrees that by visual comparison the average air concentration was estimated to be around 191–4,150 mg/m^3, around 20–400 folds of TLV-TWA for expanded perlite. From a study of insulation installer's dust exposure, it had been noted that expanded perlite could be much dusty than any other fibrous powders[9]. Thus, we speculated by the dusty nature that the spill out cause a lot of floated expanded perlite to be inhaled by heavy exposed workers.

Thirty years ago, the health effect of perlite exposure was once reported in an orchid grower with pulmonary irritation and mild hemorrhage, and perlite crystals were found in the upper brochi[10]. In a subsequent experiment, guinea pigs exposed to higher concentration of perlite dust, 6.6 ± 5.2 mg/ml and 30 min per day in a special chamber for 24 wk were found to have intracellular dust particle throughout the lungs with lymphoid aggregation and perivascular inflammatory response[11]. However, follow up for workers in perlite mining and processing factories for up to 23 yr of exposure, there was no evidence of pneumoconiosis by chest radiography or pulmonary dysfunction[12] and their exposure of perlite is around the permissible level[13]. A recent study of Indian perlite workers exposed to very low level of expanded perilte (in the ng/m^3 range)[14] for more than 10 yr also revealed no clinical pulmonary silicosis or fibrosis cases, but only mild effect on their pulmonary function was noted. Thus, to our knowledge, this is the first report of RADS associated with expanded perlite exposure.

According to our investigation, we have followed 24 symptomatic cases up to 6 months or more, and identified three cases fulfilling RADS. They mainly expose to expanded perlite, maybe also with trace metals which were not related to respiratory distress or RADS. The victims' symptoms developed shortly after exposure of perlite and could persist even with beta-agonist treatment up to a maximum of 24 months. In the simulation experiment, we estimated the exposure level may be more than 20–400 folds of STEL. We also show that the heavy exposed group victims have a higher incidence and persistent symptoms of respiratory distress. Thus, we speculate the three RADS cases are due to short term, heavy exposure of dusty expanded perlite. The limitation of this study is lack of airway histological proof in these victims. However, appropriate respiratory protection such as air purifying respirator is suggested to be placed near-by. Though chronic exposure to sub-TLV concentration of expanded perlite may not be hazardous, the initiative to regulate the short term exposure limit of expanded perlite to prevent workers from high level of exposure may be further explored.

References

1) American Conference of Government Industrial Hygienists (ACGIH) (2005) Threshold limit values for chemical substances and physical agents in the work environment. ACGIH, Cincinnati.
2) Brooks SM, Weiss MA, Bernstein RL (1985) Reactive airway dysfunction syndrome (RADS). Chest **88**, 376–84.
3) Gautrin D, Bernstein IL, Brooks S (1999) Reactive airway syndrome. In: Asthma in the workplace, 2nd Ed., Bernstein IL et al. (Eds.), Marcel Dekker, New York.
4) Davis BE, Cockcroft DW (2002) Extrapolation of methacholine PC_{20}. Chest **122**, 1499–500.
5) Boulet K, Malo JL, Ghezzo H, Gautrin D (2007) Airway hyper responsiveness and risk of chest symptoms in an occupational model. Thorax **62**, 260–4.
6) Mapp CE, Boschetto P, Maestrelli P, Fabbri LM (2005) Occupational asthma. Am J Respir Crit Care Med **172**, 280–305.
7) Alberts WM, do Pico GA (1996) Reactive airway dysfunction syndrome. Chest **109**, 1618–26.
8) Kampen VV, Merget R, Baur X (2000) Occupational airway sensitizers: an overview of the perspective literature. Am J Ind Med **38**, 164–218.
9) Breum NO, Schneider T, Jorgensen O, Rasamussen TV, Eriksen SS (2003) Cellulose building insulation versus mineral wool, fiberglass or perlite: installer's exposure by inhalation of fibers, dust, endotoxin and fire-retardant additives. Ann Occup Hyg **47**, 653–69.
10) Cooper WC (1976) Pulmonary function in perlite workers. J Occup Med **18**, 723–9.
11) McMichael RF, DiPalma JR, Blumenstein R, Amenta PS, Freedman AP, Barbieri EJ (1983) A small animal model study of perlite and fire bark dust on guinea pig lungs. J Pharm Methods **9**, 209–17.
12) Cooper WC, Sargent EN (1986) Study of chest radiographs and pulmonary ventilatory function in perlite workers. J Occup Med **28**, 199–206.
13) Cooper WC (1975) Radiograph survey of perlite workers. J Occup Med **17**, 304–7.
14) Polatli M, Erdinç M, Erdinç E, Okyay E (2001) Perlite exposure and 4-year change in lung function. Environ Res **86**, 238–41.