Industrial Health 2006, **44**, 556–563 **Original Article**

Lung Disorders of Workers Exposed to Rush Smear Dust in China

Guo-Bing XIAO[1]*, Kenji MORINAGA[2†], Ren-Yuan WANG[3], Lai-Rong XU[4], Zao-Hua MA[5], Xing ZHANG[6], Takumi KISHIMOTO[7] and Norihiko KOHYAMA[8]

[1] Ningbo Municipal Agency for Public Health Inspection and Supervision, Ningbo 315010, P.R. China
[2] National Institute of Industrial Health, Kawasaki 214-8585, Japan
[3] Health Bureau of Ningbo, Ningbo, 315010, P.R. China
[4] YinZhou district Center for Disease Control and Prevention, City of Ningbo, 315040, P.R. China
[5] Institute of Occupational Medicine, Ningbo Municipal Center for Disease Control and Prevention, Ningbo, 315010, P.R. China
[6] The Academy of Medical Sciences, Zhejiang Province. Hangzhou, 310013, P.R. China
[7] Okayama Rousai Hospital, Okayama, Japan
[8] Toyo University, Tokyo, Japan

Received June 29, 2005 and accepted March 13, 2006

Abstract: The aim of this study was to evaluate the lung disorders of the workers exposed to rush smear dust. A cross sectional study was carried out on 1,709 current workers (788 male, 921 female) in 80 factories. All subjects were asked by questionnaire, and health examination including chest X-ray was conducted for 661 workers in 35 factories. Lung function test was also examined for 119 non-smoking males among 661 subjects. Dust samplings were collected and total and respirable dust concentrations at 127 spots in 35 factories were measured. The geometric mean dust concentration in the workshops was up to 20.00 mg/m^3, and the geometric mean respirable dust concentration reached 8.22 mg/m^3. The mean quartz concentration of accumulated dust was 29.2%. The prevalence of radiographic small opacities profusion category > or = 1/0, according to the ILO 1980 Classification System, was 2.6% among 661 employees. One worker was found to have pneumoconiotic findings of 2/2 profusion accompanied with large opacity. The prevalence of pneumoconiosis (1/0 or more) correlated with cumulative dust exposure (r=0.192, p<0.0001). The similar relationship was found between the prevalence rate of cough or sputa and worksite dust concentration. In non-smokers, a positive association was found between the prevalence of cough and occupational exposure duration (r=0.080, p=0.004). Approximately 19.3% and 34.5% of employees suffered from respiratory impairment for FVC and FEV1.0, respectively. This is the first report of "rush" pneumoconiosis in China. Rush mat workers were found to be at high risk for pneumoconiosis, a preventable disease. Our results showed a dose-response relationship between rush-mat dust level and the prevalence of pneumoconiosis. Similar relationship between the prevalence of cough and sputum and the work duration was found for non-smoking workers but not for smoking workers.

Keywords: Rush mat, Pneumoconiosis, Lung function, Dust, Silica

*To whom correspondence should be addressed.
†Present affiliation: National Institute of Occupational Safety and Health, Japan.

Introduction

"Tatami" matting produced from rush is used in almost all households in Japan. In recent years, rush growth and tatami production has been extended to several other countries in Southeast Asia. Now, nearly half of matting is imported from China, and about 75% of its import is from Ningbo, Zhejiang province. Rush mat process has more than 20 years' history in China, which was introduced from Japan. Rush cultivating and processing began in 1980s in Ningbo. In 1999, the cultivating area reached 5,980 hectares, and exports of matting to Japan was 45,000 meters long. There are about 350 factories and 5,000 employees estimated in this area.

In order to prevent the mat color from fading of the tatami mat color and to increase its strength, fresh reaped rush is smeared with mud[1–3]. During the process of drying, selection and weaving, workers are heavily exposed to the dust of dried mud. The dyeing dust contains 20–30% of free silica and therefore is a potential cause of pneumoconiosis. But the effect on workers exposed to the dust in China has not been explored. The aim of this study is to assess the current status of rush mat dust exposure in Chinese matting industries, and to assess the health effect of the exposed workers.

Material and Methods

Survey design

The study was conducted from June 1999 to December 2001 in a town of Zhejiang province. Factories to be studied were randomly drawn from local registered enterprises, and all employees of those factories were invited to participate in this study. In total, 80 factories participated in the study, and 1,709 respondents were examined, which corresponded 94% of total employees. Nearly half of those factories have less than 20 employees. A questionnaire on the detailed occupational history, respiratory symptoms, and smoking habit were asked to the subjects. A group of 661 current workers was randomly selected from 35 factories, and received the screening of PA chest X rays and other physical examination coupled with detailed occupational work histories about the intensity and characteristics of exposure to dust. A total of 119 non-smokers among 661 workers were also examined on lung function test.

Dust sampling

Dust samplings were collected by passive dust monitors according to the Chinese criteria method of dust measurement in the workplace (1). Total dusts were collected by ordinary dust sampler (total dust) (WUHANG Analytic Instrument Factory FC-2 dust sampler, China). And the respirable dusts were collected by respirable dust sampler (WUHANG Analytic Instrument Factory, CCH-301 respirable dust sampler, China) with the cellulose acetate filter using polyvinyl chloride. This technique conforms that the flow rate which in principle with the the BMRC criteria. Simultaneously digital dust monitor (Sibata, Model LD-1L) was also used. In factory A, respirable dust was also measured by digital counter which count 7 μm and smaller dust. Simultaneously, dust was collected by ordinary sampler, and the count was adjusted by K value. Furthermore, we collected Sedimentation dust by brush from Factory A, B and C. Then, the sedimentation dust was separated by water sedimentation method to 7 μm and smaller (respirable) and larger than 7 μm. The contents of free silica in the sidementation dust and in respirable dusts were quantitatively analyzed by X-ray diffraction and pyrophosphoric acid methods, respectively. The chemical compositions of dust were analyzed by X-ray diffraction (XRD) spectrometry. Cumulative of silica exposure of each employee was estimated by the concentration of each job categories and work duration.

Pneumoconiosis diagnosis

Two Chinese medical doctors and two Japanese physicians read these chest X-ray films independently, and classified them according to the Chinese Standard Classification of Pneumoconiosis, (GB5906-2000), and also to the ILO 1980 Classification of Radiographs[4, 5]. Chinese medical doctors have Chinese certificates of reading chest X-ray films of pneumoconiosis and two Japanese physicians are the members of the Pneumoconiosis Panel of the prefectural Labor Office in Japan. A case with more than 1/0 profusion of the ILO classification was defined as pneumoconiosis. If the classification of the radiographs was disagreed, most readers' score was adopted.

Pulmonary function test

Standardized measurements of lung function test using the Spirometry (Fukuda Sangyo ST-95, Japan) were conducted for 119 non-smoking males among 661 rush mat workers and a control of 193 male non-smokers who were working in the same city, but not in dusty working environment, which were employed in Machinery Manufacturing Plant. FVC defined as forced vital capacity (total amount air exhaled), and FEV1 as amount of air exhaled during the first second of forced expiration. Predicted values were calculated by the spirometer that based on race, gender, age, height, and weight. The abnormity was defined as actual value/predictive value <80% for FVC and FEV1, and <70% for FEV1 / FVC as actual value.

Statistical analysis

All results are analyzed using a SPSS 10.0 package of statistics using ANOVA, χ^2 test, and multiple regressions.

Results

The rush mat processing began around 1978 in China. Now, Ningbo city is the major exporter of rush mat. The techniques of straw process are as follows; (1) fresh rush reaped is smeared with mud, and then dried. (2) The dried rush covered with a flimsy mud is stored in warehouse. (3) While carrying the dried rush bundles out of storage, selecting, cutting top and foot, and sorting rush root by length (selection). (4) A little wet is sprayed, and then rush is weaved by machines.

Dust concentration in workplace

Among various process of rush mat manufacturing, the highest respirable dust concentration was found in the rush dry, and its geometrical mean was 21.25 mg/m^3 (Table 1).

The chemical compositions of rush smear soil

The rush mat smear soil was composed of various kinds of minerals, and result from crashing, rubbing, griddling and other process. 25.6% of quartz on average (15.8–35.6%) in weight was found in the worksite sedimentation dust by pyrophosphoric acid analysis. The results of x-ray diffraction were shown in Table 2. The main mineral phases of the dust were kaolinite, quartz, pyrophyllite, alunite, sericite, rutitle, illite and so on.

The characteristics of workers

The mean age was 36.6 yr old for 788 male workers and 34.4 yr old for 921 female workers (Table 3). Both male and female workers had mean less than 3 years' working duration, and the longest was about 17 yr. More than two thirds had less than 5 years' work duration, and only less than 3% had more than 10 yr working history (Table 4). The distribution of the working duration for the 661 cohort was shown in Table 5.

Smoking status

Nearly half (49.9%, 393/788) had current smoking habit, and 5.6% (44/788) had ever smoking history. As there were few ever-smokers, we defined the smoker as those including ever-smokers and current smokers. However, nobody among 921 female workers had smoking habit.

Table 1. Dust concentration in workplace of rush mat process (geometric mean ± SD, mg/m^3)

Work title	Total dust		Respirable dust	
	n	*G* ± *G*s	N	*G* ± *G*s
Rush dry	17	61.02 ± 4.07	37	21.25 ± 3.45
Rush selection	26	31.05 ± 2.78	24	10.19 ± 2.28
Rush sorting	7	41.34 ± 2.62	18	11.53 ± 1.64
Cutting off rush top and end	8	51.89 ± 3.22	19	8.28 ± 2.32
Wiping off bad rush	10	11.33 ± 2.41	27	5.97 ± 2.28
Rush mat weaving	47	11.58 ± 1.74	54	5.55 ± 2.36
Rush mat mending	9	9.81 ± 1.50	10	3.56 ± 1.68
Rush mat clearing	0		11	5.53 ± 1.32
Total	127	20.00 ± 3.14	200	8.38 ± 2.75

Table 2. The contents of free silica in dust

Worksite	<7 μm ratio (%)	Content of free silica (%)	
		Total dust	Respirable dust
Factory A (respirable dust)	37	42	12
Factory A (sedimentation dust)	33	46	11
Factory B (sedimentation dust)	23	53	16
Factory C (sedimentation dust)	17	47	16

Table 3. The characteristics of 1,709 workers (mean ± SD)

Gender	n	Age (yr)	Age at the first employment (yr)	Work duration(yr)
Male	788	36.61 ± 10.25 (17.35–68.21)	31.72 ± 10.16 (13.34–62.12)	2.83 ± 2.46 (0.10–16.90)
Female	921	34.22 ± 8.23 (17.18–67.22)	29.31 ± 8.06 (13.67–64.04)	2.59 ± 2.16 (0.10–16.50)
Total	1709	35.32 ± 9.29 (17.18–68.21)	30.42 ± 9.16 (13.34–64.04)	2.70 ± 2.31 (0.10–16.90)

Table 4. Distribution of work duration

Work duration	Male		Female		Total	
	n	%	n	%	n	%
<1	137	17.4	182	19.8	319	18.7
1–	524	66.5	633	68.7	1,157	67.7
5–	104	13.2	88	9.6	192	11.2
10–	23	2.9	18	2.0	41	2.4
Total	788	0.00	921	0.00	1,709	100

Table 5. The age distribution of the 661 workers by sex

Age	Males		Females		Total	
	n	%	n	%	n	%
<20	6	1.72	11	3.53	17	2.57
20–	99	28.37	77	24.68	176	26.63
30–	119	34.10	133	42.63	252	38.12
40–	70	20.06	76	24.36	146	22.09
50–	50	14.33	14	4.49	64	9.68
60–70	5	1.43	1	0.32	6	0.91
Total	349	100.00	312	100.00	661	100.00

Respiratory symptoms

The prevalence of cough in male smokers was 26.5% (116/437), and that of sputum was 22.4% (98/437), which were significantly higher than those of male non-smokers (16.2%, 13.1%, respectively). The prevalence of cough and sputum in female workers was 7.9% (73/921), and 6.4% (59/921), respectively. The prevalence rates of cough and sputum in non-smoker were low in workers with duration <1 yr, but high in workers with duration ≥7 yr (Table 6). χ^2 for linear trend and Pearson's R between work duration and prevalence of cough in non-smokers (both sexes combined) were significant (χ^2= 8.10, p=0.004; Peason's R=0.08, p= 0.004), but those of sputum in non-smokers and those of two symptoms in smokers were not.

Table 7 shows that the prevalence rates of two symptoms in non-smokers and smokers were low in management workers, but high in rush dry and selection workers of which workplaces shown high concentration of total and respirable dust (Table 1). χ^2 for linear trend and Pearson's R between jobs and prevalence of cough in non-smokers, sputum in non-smokers, cough in smokers and sputum in smokers were significant (see to Table 7).

Pulmonary function test

Base on the results of FVC, $FEV_{1.0}$, and $FEV_{1.0}\%$, abnormity prevalence and scale were shown in Table 8. Approximately 19.3% and 34.5% of employees suffered from respiratory impairment for FVC and $FEV_{1.0}$, respectively.

Chest radiographs

A total 661 workers were received chest X-ray screening. Main work titles were selection, repairing, and storing in male, and weaver in female. After reading these films, we have found 17 cases with category 1/0 or more. The prevalence of pneumoconiostic finding reached 2.57% (17/661). The mean age of these 17 cases was 37.67 ± 8.28 (22.2–50.0) yr, and mean work duration was 6.39 ± 4.02 (3.2–17.0) yr. Most of all cases revealed small rounded opacities as shape and size of type p in the upper and/or middle lung field. Only one case was found 2/2, and several smaller nodules coalesced, and agglomerated in right upper lung field. The case is a selecting worker, with 30 yr old and 6.0 yr work duration (Figs. 1 and 2). All cases denied other dust work history. The prevalence of pneumoconiotic findings was related to work duration and work title (Table 9).

Discussion

Rush dyeing dust pneumoconiosis (defined as sendo-dust pneumoconiosis in Japanese literatures) is a pneumoconiosis caused by dust containing free silica in a very high degree of dispersion is seen in rush mat (tatami) workers. In the Japanese-language literature, it has been estimated that the incidence of pneumoconiosis in igusa mat workers is > 30%. It has been found that the workers tend to acquire a relatively early stage of pneumoconiosis after approximately 20 yr of dust exposure[1, 2]. Yamawaki *et al.* (1998) reported the prevalence of pneumoconiosis with category 1/0 or more was 19.6% for males and 34.6% for females, and found 4 cases (3 males, 1 female) with large opacities, those had

Table 6. The relationship between prevalence of respiratory symptoms and working duration

Working duration	Non-smokers					Smokers				
		Cough		Sputum			Cough		Sputum	
	n	Positive of No.	%	Positive of No.	%	n	Positive of No.	%	Positive of No.	%
0–	244	12	4.92	10	4.10	75	16	21.33	10	13.33
1–	619	70	11.33	59	9.55	193	52	26.94	48	24.87
3–	249	25	10.08	19	7.66	98	31	31.63	25	25.51
5–	102	11	10.78	9	8.82	38	9	23.68	7	18.42
7–	60	12	20.00	8	13.33	33	8	24.24	8	24.24
Total	1,274	130	10.22	105	8.25	437	116	26.54	98	22.43
χ^2 for linear trend		8.096		3.593			0.190		0.796	
p value		0.004		0.058						
Pearson's *R*		0.080		0.053						
p value		0.004		0.058						

Table 7. The relationship between prevalence of respiratory symptoms and job title

Jobtitle	Non-smokers					Smokers				
		Cough		Sputum			Cough		Sputum	
	n	Positive of No.	%	Positive of No.	%	n	Positive of No.	%	Positive of No.	%
Manager	99	6	6.1	4	4.0	28	4	14.29	3	10.71
Repairing	94	11	11.7	11	11.7	83	9	10.84	6	7.23
Rush mat mending	650	43	6.6	33	5.1	35	7	20.00	7	20.00
Rush mat weaving	122	17	13.9	15	12.3	83	26	31.33	22	26.51
Rush dry and selection	309	53	17.3	42	13.7	208	70	33.65	60	28.85
Total	1,274	130	10.2	105	8.3	437	116	26.54	98	22.43
χ^2 for linear trend		19.28		14.71			17.96		17.11	
p value		0.001		0.001			0.001		0.001	
Pearson's *R*		0.123		0.108			0.203		0.198	
p value		0.001		0.001			0.001		0.001	

Table 8. Abnormal frequency of ventilatory function in non-smokers

Group	n	FVC abnormity		$FEV_{1.0}$ abnormity		$FEV_{1.0}$% abnormity	
		Case	Prevalence (%)	Case	Prevalence (%)	Case	Prevalence (%)
Exposed	119	23	19.3*	41	34.5***	2	1.7
Control	193	21	10.9	32	16.6	4	2.1
Total	312	44	14.1	73	23.4	6	1.9

*, *** $p<0.05$, $p<0.001$ *vs*. Control.

engaged for more than 28 yr in Japan[6]. Yoshimoto *et al*. (1991) found a case with larger opacities who engaged for 20 yr in rush mat process[7]. However, the health risk of rush mat process has not been known in China. In our study, we found the prevalence of category 1/0 or more was 2.6% of the 661 employees. This is the first case of pneumoconiosis among rush mat workers in China. The prevalence of pneumoconiosis in China is lower than that in Japan, but the working duration for Chinese workers is quite short than that of Japanese workers. Our cases in Ningbo, China were

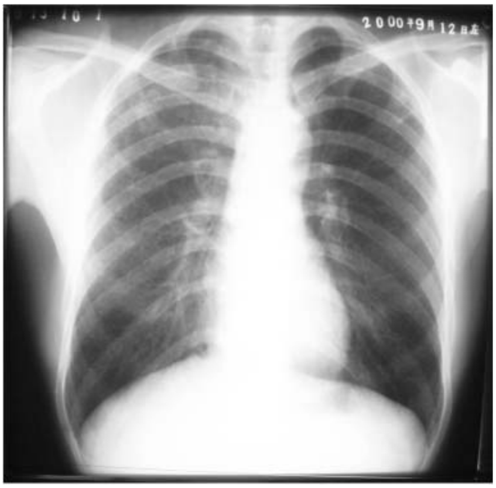

Fig. 1. Male, 31 yr old, employed in rush selection 6.0 yr. A conglomerate *pneumoconiosis*.

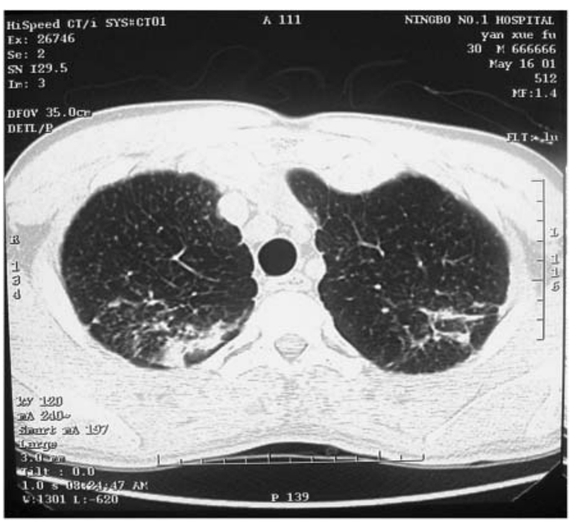

Fig. 2. The same case, HRCT revealed 10 mm × 15 mm large opacities in right upper lung field.

Table 9. Prevalence of small rounded opacities 1/0 or more by cumulative silica exposure

Cumulative silica exposure (mg/m^3–yr)*	n	Positive no. of X-ray categories 1/0 or more	Prevalence rate (%)
0–	156	0	
5–	147	1	0.68
10–	138	2	1.45
20–	80	3	3.75
30–	40	1	2.50
40–	29	3	10.34
50–	18	2	11.11
60–	13	2	15.38
70–	40	3	7.50
Total	661		2.57

χ^2 for linear trend: 24.308, p value <0.0001
Pearson's R: 0.192, p value<0.0001
*cumulative silica exposure= work duration × workplace respirable concentration

all young ranging from 22.2 to 50.0 yr old, and the work duration was very short ranging from 3.2 to 17.0 yr. The conglomerate pneumoconiosis case had only mean 6 years' work duration and 31 yr old. Dust containing crystalline silica inhaled over prolonged periods promotes the formation of the classical nodules for a long time. The results show that the serious risk of pneumoconiosis in the rush mat process in the China setting.

The radiographic findings have been reported as consisting of small, rounded type-p and irregular type-s opacities, the latter type being generally dominant involving mainly the middle and lower lung zones[2]. Fujimoto reported that sendo-dust pneumoconiosis is a distinct form of pneumoconiosis seen in tatami workers[8]. Although sendo contains free silica, typical silicotic nodules are not seen histologically, and progressive massive fibrosis, lymph node calcification, and lymphadenopathy are not seen on the radiograph or high-resolution CT. The radiographic and high-resolution CT findings consist of small nodular opacities < 3 mm in diameter and bronchial and bronchiolar abnormalities. The dust contains 25.6% silica, it seems reasonable to speculate that the different appearance is related to the lower concentrations of silica, high density dispersion, and length of time performing tasks as compared to the patients with typical findings of silicosis. In our study, However, from the X-ray founds, the density of small rounded opacities is a little light when compared to typical silicosis. The radiographic findings was similar to that in Japan. But, it is clear, one case was found 2/2, and several smaller nodules coalesced, and agglomerated in right upper lung field in the present study. Kishimoto and Yamawaki reported cases of tatami rush pneumoconiosis with large opacities[9, 10]. Consequently, it is reasonable to deduce that the rush mat dyeing dust can also damage the exposed worker by pneumoconiosis with large opacities.

Ueda *et al.* reported that in the process of drying and storing, approximately 70 to 80% of particles of floating dusts measure < 5 pm in diameter. The workers are exposed to dense concentrations of sendo dust (50 to 100 mg/m^3) for 1 to 3 h/d in drying and storing, and continually exposed to low- density (1 to 5 mg/m^3) sendo dust during the weaving process and relatively dense concentrated dust (15 to 25 mg/m^3) in the tatami storing process[1]. In our study, some employees are exposed chronically to a rather low density rush dying dust during the weaving process (3.76 mg/m^3), and some exposed to high dense concentrations during rush selection (respiratory dust concentration 10.79 mg/m^3) and drying (16.22 mg/m^3) for about 8–10 h. Employees in rush process have high risk of getting pneumoconiosis because of high dust exposure compared to Japanese results.

The upper respiratory tract is a remarkably efficient filter, removing upwards of 90% of particles > 7 pm in diameter[11]. Smaller particles may remain in suspension and be exhaled or may be deposited on the respiratory epithelium[12]. The dust accumulates predominately in the respiratory bronchioles and alveolar ducts. The results of the present study show a prevalence of work-related complaints among workers employed in the rush mat processing industry. The prevalence of cough and sputum was 10.22%, 8.25%, respectively. Other symptom was rarely complained. From the difference of prevalence rate between non-smoker and smoker, we concluded that dust may partly account for the increased prevalence of respiratory symptoms among exposed workers.

It is well known that smoking is an independent contributor to declines in lung function[13]. Pulmonary function revealed mild functional impairment consistent with small airway obstruction and mild air trapping. In a 12 yr followup study, Swedish granite crushers exposed to mean cumulative respirable silica dust fraction of 7 mg had a greater loss of FEV1 by 150 ml (4.6%) and of FEV1/FVC% by 3.2 (5.4%) when compared to age and smoking matched unexposed controls[14]. In order to avoid the effect of smoking, we examined lung function for only non-smoking workers. Approximately 34.5% of employees suffered from respiratory impairment for FEV1.0. A weak dose-effect relationship between exposure to rush-mat dust and ventilatory function (FVC, FEV1) loss were found in nonsmokers. The relationship between radiographic hyperinflation and deterioration of pulmonary function was observed in silica-exposed workers[15]. However, in the present study, the relationship can not be found.

The risk of pneumoconiosis among the workers exposed to dust containing silica depends on several factors such as crystalline silica content of the rush mat dust, effective equipment and tools used in the factory, length of time performing tasks, type and level of ventilation, work practices, housekeeping, and dust suppression methods. The rush smear mud is a mixture soil, which contains several minerals.

We noticed that the majority of overt exposures occurred in small and unregulated industrial settings. Intervention and supervision should be taken on in these plants.

(1) Cooperation. The process was imported from Japan. But, the related protective equipments and tools, and knowledge had not been imported simultaneously. The majority of overt exposures occurred in small and unregulated factories, and resulted in the fearful pneumoconiosis. Consequently, international cooperation in research achievement, technical support and equipment should be increased.
(2) All enterprises must be regulated, and small and unregulated plants should be eliminated. Reducing exposure to crystalline silica can be achieved through the use of wet processes and eliminating or severely restricting duration of dry process work. Local exhaust ventilation may be adapted to this industry. Mechanical operation may be substituted for manual selection process. The authors of this study found that the process could be substituted to mechanical operation in all factories.
(3) Given the high airborne concentrations of respirable silica and particulates generated during smear, selection and weaving, it should be recommended to employers that all exposed workers wear respiratory protection equipment until exposure controls were implemented. Develop and implement a written respiratory protection program for all dust operations.
(4) Medical examinations should be available to all workers who may be exposed to crystalline silica. Such examinations should occur before job placement and at least every one year thereafter. The examination should include PA chest X rays, internal routine check, and others.
(5) Good practice of housekeeping to prevent dust from re-suspending into the air. Dry sweep and usage of compressed air must be forbidden because these re-suspend the dust and increases exposure to workers.
(6) Training of workers on the hazards of silica. Training should include information on health effects, work practices, personal protective equipment, and methods to reduce exposure to rush mat dust or silica.

Conclusion

The mineralogical phases of the dust were kaolinite, quartz, pyrophyllite, and mica, and the sedimentation dust contained nearly 26% (15–36%) of quartz in weight. Rush mat workers were found to have a high risk for pneumoconiosis. Accelerated pneumoconiosis may be associated with heavy exposure to exiguous dust, long work time, lack of protective equipments, untrained workforces, smoking and others reasons. Dose-response relationship between the prevalence of cough and sputum and the work duration was found for non-smoking workers. The percentage of abnormity for FVC and FEV1 among the exposed workers was significantly greater than the controls (non-dust exposed). the MAC with 1 mg/m^3 for respirable dust is not safe enough.

Acknowledgements

This research was partly funded by Japan-China Medical Association and Ningbo City Science Fund, P.R. China. The authors wish to express cordial thanks to Prof. You-Xin Liang, Prof. Tai-Yi JIN, and Prof. Xi-Peng JIN, Fudan University School of Public Health for their kind suggestions and constructive comments on the manuscript.

References

1) Ueda A, Futatsuka M, Ueda T, Arimatsu Y, Ueno T, Nagano M, Nomura S (1984) A follow-up study on the lung disorders of rush (igusa) farmers exposed to "sendo" dust. Sangyo Igaku **26**, 32–44.
2) Fujii T (1970) Pneumoconiosis caused by "sendo" dust ainong rush-mat workers. Nippon Igaku Hoshasen Gakkai Zasshi **30**, 266–86 (in Japanese with English abstract).
3) Hosoda Y, Ueda A, Fujii T (1991) Clay dye pneumoconiosis among rush mat workers. Semin Respir Med **12**, 55–7.
4) Chinese GB Standards (1996) GB16225-1996, Health standard for respirable silica dust in the air of workplace. Beijing (in Chinese).
5) International Labor Organization (1980) Guidelines for the use of ILO international classification of radiographs of pneumoconioses. ILO, Geneva.
6) Yamawaki Y, Kuwahara K, Morinaga K, Kishimoto T, Sato Y, Kudo M, Ohyama M, Yokoyama K, Sera Y, Kohyama N (1998) "Rush (Igusa)" pneumoconiosis in Fukuama, Japan. In: Advance in the Prevention of Respiratory Diseases. 1199–202, Elsevier Science B.V., Amsterdam.
7) Yoshimoto S, Konishi H, Kawahara S, Tada A, Ejiri T, Sugano H, Matsuyama T, Nakajima M, Manabe T, Kibata M (1991) A case of rush dust (igusa-sendo) pneumoconiosis with a large conglomerate mass shadow. Jpn J Thoracic Dis **29**, 1489–94.
8) Fujimoto K, Muller NL, Kato S, Terasaki H, Sadohara J, Rikimaru T, Hayabuchi N (2004) Pneumoconiosis in rush mat workers exposed to clay dye "sendo" dust clinical, radiologic, and histopathologic features in seven patients. Chest **125**, 737–43.
9) Kishimoto T, Morinaga K, Yamawaki Y, Kawahara S, Matsushima T, Kohyama N (1999). Clinical evaluation of live cases of *tatami* rush pneumoconiosis with large opacities on chest x-ray. Jpn J Clin Radiol **44**, 127–32 (in Japanese)
10) Yamawaki Y, Kishimoto T, Morinaga K, Kohyama N (2000). Epidemiological, occupational hygine, and mineralogical study on rush mat pneumoconiosis in Bingo area, Japan. Occup Health J **23**, 31–7 (in Japanese).
11) Raabe OG (1984) Deposition and clearance of inhaled particles. In: Occupational lung disease, Gee JBL, Morgan WKC, Brooks SM (Eds.), 1–37, Raven Press, New York.
12) Davis GS, Calhouii WJ (1993) Occupational and environmental causes of interstitial lung disease. In: Interstitial lung disease, 2nd Ed., Schwarz MI, King TE Jr (Eds.), 179–228, Mosby Year Book, St. Louis, MO.
13) Xu X, Dockery DW, Ware JH, Speizer FE, Ferris BG (1992) Effects of cigarette smoking on rate of loss of pulmonary function in adults: a longitudinal assessment. Am Rev Respir Dis **146**, 1345–8.
14) Malmberg P, Hedenstrom H, Sundblad B-M (1993) Changes in lung function of granite crushers exposed to moderate highly silica concentrations: a 12 year follow up. Br J Ind Med **50**, 726–31.
15) Wang X, Yano E (1999) Pulmonary dysfunction in silica-exposed workers: a relationship to radiographic signs of silicosis and emphysema. Am J Ind Med **36**, 299–306.