ASSESSMENT OF BAGGING OPERATORS EXPOSURE TO WITH PVC AIRBORNE PARTICULATES

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ABSTRACT

Dust consists of tiny solid particles carried by air currents. These particles are formed by many different processes. One of these processes is polymerization of inert plastic such as Polyvinyl Chloride production plant. According to the Occupational Health and Safety Assessment Series requirements, section 4.4.6, occupational health and safety risks must be defined and controlled where needed. This field study was conducted to evaluate the occupational exposure of packaging operators to airborne polyvinyl chloride dust in order to health risk assessment and recommend feasible controlling methods. The mass concentration of polyvinyl chloride particulate was measured in two fractions according to the particle size that expressed as total and respirable particulates. The Air Sampling Methods, Methods for the Determination of Hazardous Substances 14/3, of Health and Safety Executive were used as a standard sampling protocol. The average mass concentrations for respirable and total particulates were measured 3.54±0.3 mg/m^3 and 11.89±0.8 mg/m^3 respectively. Also health risks of studied condition were estimated as significant level, category one, therefore the risk must be reduced below the standard level. According to the work requirements to reduce the emission rate and mitigate the health risk exposure, a local exhaust ventilation system design was recommended for bag-filters of hopper tank.

Key words: Polyvinyl chloride, personal sampling, total particles, respirable particles, chemical health risk

INTRODUCTION

The hazard potential of airborne particles is dependent on the mass concentration as well as the particle size. Particle size determines the deposition site within the respiratory tract and the subsequent health effects. Particle-size is considered from two viewpoints: The size-fraction most closely associated with the specific health effect, and the mass concentration within that size fraction.

Polyvinyl chloride (PVC) is one of the most widely used plastic materials (Lewis, 1999). At the end of the PVC synthesis process, the material may exist as an airborne dust includes total or repirable particulates. Szende *et al*., (1970) first suggested that exposure to PVC dust might cause pulmonary abnormalities similar to pneumoconiosis. They diagnosed advanced pneumoconiosis in a 31 year old man who had been exposed to high concentrations of PVC dust for 12 months and developed severe respiratory failure. A number of studies (Lilis *et al*., 1975; 1976; Soutar *et al*., 1980; Mastrangelo *et al*., 1981; Ng *et al*., 1991; Lee *et al*., 1991) showed that impairment of lung function and higher prevalence of small opacities on chest X-ray were associated with PVC dust exposure. These changes were more pronounced in individuals with longer exposures. However, the risk factors and the mechanisms of this impairment are still unclear. The prognosis of pulmonary changes caused by PVC dust differs in different reports. For instance, a patient with reduced lung function and fine nodular opacities in both lower lobes, as evidenced by high resolution computed tomography (HRCT), after 8 year PVC exposure, had an improved pulmonary function 3 months after cessation of exposure; both lung function and HRCT improved further 1 year later (White and Ehrlich, 1997). In contrast, the patient reported by

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Arnaud *et al*., (1978) presented withexertional dyspnea, pulmonary function changes, and chest radiographic abnormalities even after cessation of PVC exposure for 6 years.

In a study conducted by the National Institute for Occupational Safety and Health (NIOSH) in the United State, rats, guinea pigs and monkeys were exposed by inhalation (6 h/day, 5 days/week) for up to 22 months to a 13 mg/m^3 concentration of PVC dust. No fibrosis or significant cellular infiltrates were noted in the lungs of animals, with the exception of aggregates of alveolar macrophages containing PVC particles, and no significant effects on pulmonary function could be demonstrated in monkeys exposed to PVC. In a comparable study, in which rats were exposed by inhalation to 12mg PVC dust/m^3 for 7 h/days, 5days/week for 5 months, no evidence of significant pulmonary disease was observed, with particle deposition in the lungs.

Based upon the epidemiological evidence, exposure to high levels of PVC dusts in the workplace can lead to low-grade pneumoconiosis, similar to that experienced with inhalation of other unreactive dust. Chest X-rays of workers often have shown abnormalities, yet these changes have not always been associated with decreased lung function. A critical review of the epidemiological data on the respiratory effects of PVC dusts in humans concluded that such exposures did not produced neoplastic effects (Wagoner *et al*., 1983). The weight of evidence from data generated by inhalation and intratracheal exposure to PVC particles in experimental animals indicates that PVC itself possesses little or no biologic activity, with its physical presence producing benign pneumoconiosis at elevated dust concentration.

The American Conference of Governmental Industrial Hygienists (ACGIH) considers occupational exposure to PVC dust under category of Particulates Not Otherwise Classified (PNOC). These particles also are named "nuisance dusts". ACGIH believes that even biologically inert, insoluble, or poorly soluble particles may have adverse effects and recommended that airborne concentration should be kept below 3 mg/m^3 for respirable particles, and 10 mg/m^3 for inhalable particles. In the present study, to measure the mass concentration of airborne PVC particulates, HSE Air sampling methods was conducted for both respirable and total particulates, and health risk of occupational exposure of packing operators to PVC particulates were evaluated by a well-designed qualified method with respect to ACGIH Time Weighted Average-Threshold Limit Values (TWA-TLVs). Following the measurement of mass concentration and health risk assessment, some feasible engineering controls were suggested. This study generally focuses on the occupational exposure of packing operators and their health risk assessment.

MATERIALS AND METHODS

The present study was conducted in the packing unit of PVC production plant. The mentioned unit consist of three packer lines were named as train A, B and C. The unit work schedule was based on 8 h shift work with 4 mornings/ 4 evenings/ 4 nights/ 4 off days rotation cycle.

In each shift two people were assigned for each packing line, that one of them working and another one resting by an hour interval. Morning and evening shifts were chosen to measure mass concentration of particulates because these shifts had the most workers and the highest production rate. In addition all packing lines were completely identical. All initial sampling preparations and filter measurements were done in the faculty laboratory.

Personal breathing-zone air sampling

In order to assess the occupational exposure to PVC dust, personal sampling was performed by considering the HSE Air Sampling Methods, Methods for the Determination of Hazardous Substances (MDHS) 14/3, the particle size fraction were sampled by using recommended head sampler (cyclone for respirable and IOM for total particulates), and the mass concentration with that size fraction was measured using MDHS 14/3 instructions. The packer operators exposure was measured by determining their personal exposure to respirable and total particulate individually in morning and evening shifts of three sequence days.

Respirable particulate mass concentration

According to the MDHS 14/3, respirabe particulate samples were collected by cyclone sampler on dehumidified, pre-weighted, 37 mm (diameter), 0.8 µm (pore size) PVC membrane filters. Interpretation of occupational exposure was done based on time weighted average mass concentration. Therefore for covering full shift sampling the 2.2 L/min flow rate with 2h sampling period intervals were selected and four samples in each shift were collected. Before initial weighting, all filters were put in a desiccator for 24h for dehumidifying, and then filters weighting were performed using a calibrated balance in controlled room by psychometric conditions (20°C±1°C and 50%±5% RH). The weighted filter was put in a separate numbered dish and plumbed. After air sampling was carried out filters were measured gravimetrically, as noted in MDHS 14/3, to obtain the mass concentration.

Total particulate mass concentration

In accordance with MDHS 14/3, total PVC dust samples were collected by IOM sampler on open-face, dehumidified, pre-weighted, 37 mm (diameter), 5 µm (pore size) PVC membrane filters. Also for covering full shift sampling we were chosen the 2 L/min flow rate with 2h sampling period intervals. As previous section, before initial weighing, all filters were kept in a desiccator for 24h for dehumidifying and above sequence were repeated.

Background mass concentration of total particulates

In accordance with MDHS 14/3, the background mass concentration of PVC particulates were measured by mounted the suitable sampler on a fixed point far from obstructions, fresh air inlet or storm winds. The sampling procedure was the same as previous section. In this study a pre-test sampling were conducted including 6 samples with the σ=1.324, d=1.0 mg/m^3, the significance of $P<0.05$ and t-student value 2.571. Therefore 16 samples were taken to determine background mass concentration of total particulate along morning and evening shifts in both upper and lower side of packer lines for interpretation the emission rate of pollutant, as shown in Fig. 1.

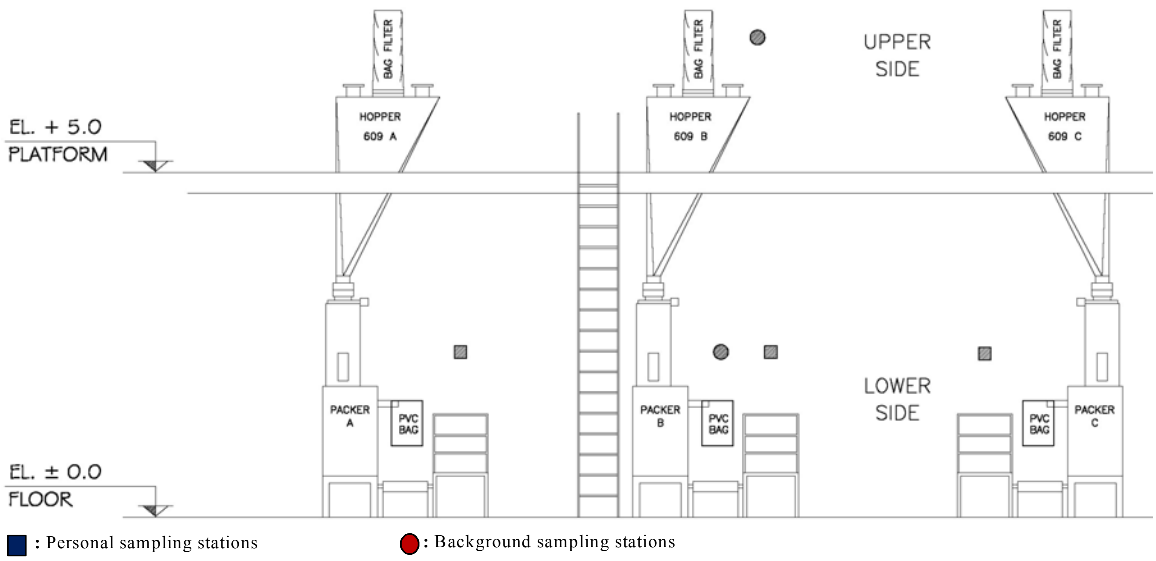

Fig. 1: Elevation view of packing unit, including upper and lower sides

Chemical health risk assessment

In this study a well-designed method for qualitative assessing of health risk of operator exposure with PVC particulates were applied. The chemical health risk assessment is qualitative with a rating system, in that the severity of hazard and the chance of overexposure are rated on a five scale rating. The risk has been defined as follow:

Risk=Hazard×Exposure

Where, the hazard component will take into consideration the nature of hazard and the potential adverse health effect from the possible routes of entry. The exposure component looks at the chance of overexposure occurring by taking into account the frequency of exposure, the duration of exposure, and the intensity or magnitude of exposure.

To obtain the Risk Rating (RR), the first step is to define work unit that is a group of workers doing similar tasks (e.g. having similar potential for exposure) that in the present study was named "Packer Unit".

The next step is to identify the hazard rating (HR) that was assigned base on adverse health effects of PVC airborne dust; then the exposure rating (ER) was obtained by combining two values, the frequency (FR) or duration ratings (use the higher rating) and the magnitude rating. Exposure rating matrix is shown in Table 1. The hazard rating and exposure rating were used to compute the risk rating, as matrix is shown in Table 2.

Table 1: Exposure rating matrix

Rating		Magnitude Rating				
		1	2	3	4	5
Frequency Rating /Duration Rating	1	ER =1	ER =2	ER =2	ER =2	ER =3
	2	ER =2	ER =2	ER =3	ER =3	ER =4
	3	ER =2	ER =3	ER =3	ER =4	ER =4
	4	ER =2	ER =3	ER =4	ER =4	ER =5
	5	ER =3	ER =4	ER =4	ER =5	ER =5

Table 2: Risk rating matrix

Rating		Exposure Rating				
		1	2	3	4	5
Hazard Rating	1	RR =1	RR =2	RR =2	RR =2	RR =3
	2	RR =2	RR =2	RR =3	RR =3	RR =4
	3	RR =2	RR =3	RR =3	RR =4	RR =4
	4	RR =2	RR =3	RR =4	RR =4	RR =5
	5	RR =3	RR =4	RR =4	RR =5	RR =5

The above risk matrix may be used to identify and prioritize control strategies. Priority in implementing control measures will depend on the degree of risk, number of people at risk, and the practicability of the control measure.

For the purpose of prioritizing action to control risk, two categories can be assigned at significant risk, including Risk Rating: 3, 4 and 5.

Category 1: risk rating 3 and 4

Risks to be controlled to below the Threshold Limit Values or As Low As Reasonably Practicable (ALARP) where no limits are specified. Practicable means practicable after taking into considerations:

1. The severity of the risk,
2. The state of knowledge about the risk and the availability and suitability of ways of removing or mitigating the risk; and
3. The cost of removing or mitigating the risk.

Action to control risks under category 1 is considered to be of lower priority than controlling those risks under category 2.

Category 2: risk rating 5
This is considered intolerable risk, where the chemical hazardous to health should be eliminated. If this is not possible then substitution of the hazardous chemical with a less hazardous chemical; total enclosure of the process and handling system; or isolation of the work to control emission of chemical hazardous to health need to be adopted so that employees exposure are kept well below the threshold limit values.
For gathering further information about health risk assessment procedure, please refer to Chemical Health Risk Assessment guidebook.

RESULTS

By correcting the volumetric flow rate to atmospheric pressure and ambient temperature the mass concentration of PVC dust was calculated.
Respirable Particulate Mass Concentration.
The average of respirable mass concentration for three days was obtained 3.54±0.3 mg/m^3.
The TWA concentration in each individual shift is expressed in Table 3.
The distribution of respirable mass concentration of PVC particulate along the morning and evening shifts of each day is shown Fig. 2.

Total particulates mass concentration
The overall mass concentration of total particulate for three days was obtained 11.89±0.8 mg/m^3. The TWA concentration in each individual shift is noted in Table 4.
The distribution of total mass concentration of PVC particulate during morning and evening shifts of each day is shown in Fig. 3.

Table 3: Respirable particulates mass concentration data

Station A/B/C	Date yy/mm/dd	Shift M/E	TWA mg/m^3
A	07/08/28	M	3.63
A	07/08/28	E	3.58
B	07/08/29	M	3.34
B	07/08/29	E	3.56
C	07/08/30	M	3.50
C	07/08/30	E	3.65

A: Packer line A; B: Packer line B; C: Packer line C
M: Morning; E: Evening

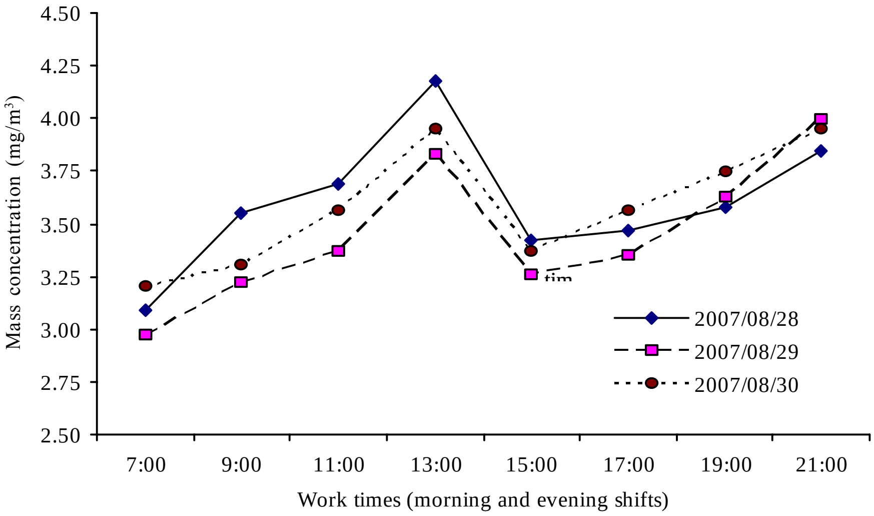

Fig. 2: Distribution of respirable particulate mass concentration

Background mass concentration of total particulates
The overall background mass concentration of total particulate for upper and lower sides of the packer unit is noted in Table 5. The distribution of total mass concentration of PVC particulate in upper and lower sides of packer unit during the morning and evening shifts is shown in Fig. 4.

Table 4: Total particulates mass concentration data

Station A/B/C	Date yy/mm/dd	Shift M/E	TWA mg/m^3
B	07/08/28	M	11.87
B	07/08/28	E	11.93
C	07/08/29	M	11.60
C	07/08/29	E	12.20
A	07/08/30	M	11.82
A	07/08/30	E	11.94

A: Packer line A; B: Packer line B; C: Packer line C
M: Morning; E: Evening

Table 5: Background mass concentration data of total particulate

Station A/B/C	Date yy/mm/dd	Shift M/E	TWA mg/m^3
U	07/08/27	M	14.46
U	07/08/27	E	14.83
L	07/08/27	M	16.33
L	07/08/27	E	16.68

U: Upper side; L: Lower side; M: Morning; E: Evening

Chemical health risk assessment

We were considered the health hazard of respirable particulate as a main health risk for operator exposure to airborne PVC dust. Because the mass concentration is lower than 3×TLV (9 mg/m^3) we were evaluated the overall health risk by considering the TWA concentration 3.54 mg/m^3. All operators have been exposed at least 50% of shift, therefore duration rating of exposure was 4 to 7h/shift. Frequency rating of exposure was frequent because all operators exposed to PVC dust while working. Magnitude rating of exposure was above TLV but lower than 3×TLV. Hazard rating of exposure, based on inherent effects of PVC dust, is evaluated as a harmful chemical with severe effects after repeated or prolonged overexposure.

Finally the risk rating of bagging operator exposure with PVC dust was obtained equal RR=4, therefore it was considered as a significant risk-category 1.

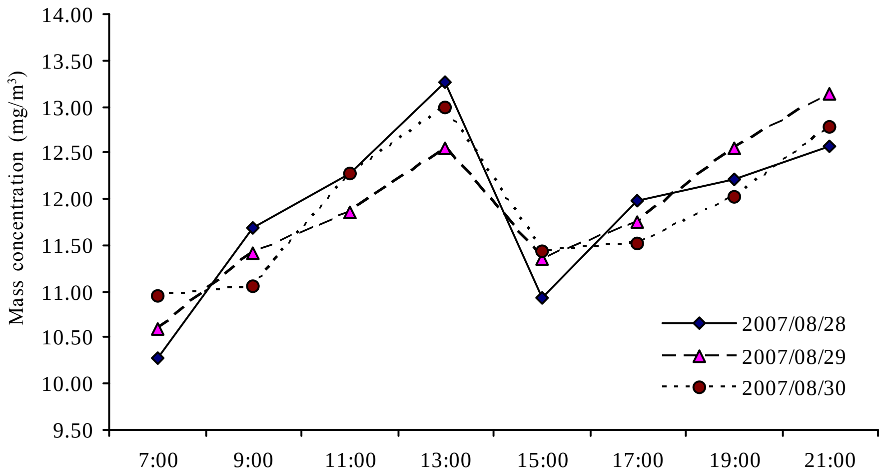

Fig. 3: Distribution of total particulate mass concentration

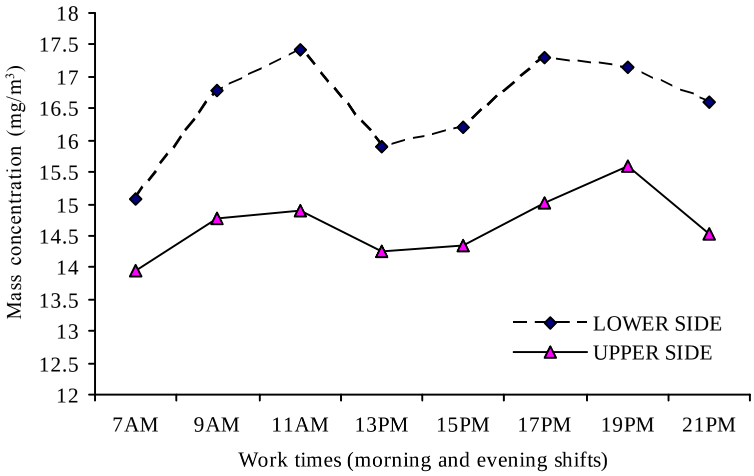

Fig. 4: Distribution of background mass concentration of total particulate

DISCUSSION

With respect to the ACGIH criteria about exposure to nuisance dust, 3 mg/m^3 for respirable particles and 10 mg/m^3 for total particles, all packer operators exposed to unacceptable mass concentration of PVC dust either respirable (3.54 mg/m^3) or total (11.89 mg/m^3) particulates.

As shown in Table 3, the emission rate actually depended on packing lines operation and the mass concentration of PVC respirable dust in packer lines A, B and C is almost even because they have completely identical mechanism and the minor different was caused by personal characteristics of operators or operator posture (e.g. how close to packer nozzle) and other interference parameters.

As shown in Fig. 3, the morning shift started at 6 Am but actually the bagging operation started at 6:30 Am, which means between two consequence shifts there was almost one hour gap time that no packer lines operate. Therefore the mass concentrations at the beginning of the shift was low (around 3 to 3.25 mg/m^3), by time elapsing the mass concentration was grown because of increasing emission rate and accumulation of airborne particles.

As it was expected, the exposure rate was increased at the end of shift period because the operators had to do housekeeping task from 13:30 to 14:0, therefore the operator must sweep the area around the packer lines and clean the floor covered by PVC powders. Therefore the exposure rate of the operator increased (around 4 mg/m^3). Packing lines were stopped till 14:30 then the next shift personnel started to work (14:0 to 14:30 is shift changing period), therefore the mass concentration was decreased to 3.25 mg/m^3, then by time elapsing and accumulation of airborne particles the exposure rate increased again as explained for the morning shift.

This condition is true for Table 8 that shown the TWA concentrations of total PVC dust and Fig. 4 that shown the distribution of total PVC particulates along both morning and evening shifts.

As shown in Table 9, the background mass concentration in the upper side of the unit (area where the bag filter of hoppers distinguished as an emission source) was around 14 mg/m^3 that caused by hopper air filtration to atmosphere and in the lower side of the unit (area where the packer nozzles considered as an emission source) was around 16 mg/m^3 that caused by falling upper side powder through gaps of grating stand in the breathing zone of operator and also leaked powder during bag filling.

As explained in results section, the health risk rating was obtained equal 4 with priority category 1; therefore according to the site condition and job specification some practicable and cost-benefit studied control strategies were suggested to reduce the emission rate and mitigate the health risk exposure with airborne PVC dust as follows:

- Bag-filters of hopper were recognized as main sources of pollutant emission that must be controlled; therefore the local exhaust ventilation system was designed to capture released dust from bags and prevents dispersing them in breathing zone of operators.
- Changing the bag-filter of hopper regular intervals to maintain the efficiency (e.g. every 6 months)

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