

ORIGINAL ARTICLE

Evaluation of Tobacco Dust and Designing of Local Exhaust Ventilation (LEV) Systems in a Tobacco Processing Industry

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ABSTRACT

This study was carried out to evaluate tobacco dust concentration and also designing a suitable ventilation system for reduction of tobacco dust concentration in a tobacco processing factory in the north of Iran. Gravimetric method was used to determine the tobacco dust concentrations in the emission sources and also indoor workplace. A local exhaust ventilation system was designed according to the velocity pressure method recommended by ACGIH. Mean tobacco dust concentrations (ranged from 23.56 to 432.59 $\mu\text{g m}^{-3}$) were higher than TLV-TWA in the proximity of all indoor emission sources where some individuals were working. However, mean indoor and outdoor tobacco dust concentrations (7.71 and 0.04 $\mu\text{g m}^{-3}$ respectively) were lower than TLV-TWA. Totally 5 separated ventilation systems and 5 centrifugal fans were designed and selected to pull the air through 46 different hoods. Some downward slot hoods similar to VS-708 type were designed for the work-tables in tipping unit and some upward slot hoods that are similar to VS-903 type recommended by ACGIH's industrial ventilation committee were also selected for tipping manipulation unit. Some enclosing hoods were designed for feeders. Duct velocity of 1060 mm min^{-1} has been selected for all systems. Total air flow rates ranged from 240-369 $\text{m}^3 \text{min}^{-1}$. A very high efficient bag house containing several bag filters was used to collect dust. In conclusion, because of a high concentration of tobacco dust in the proximity of sources and risk of workers exposure to tobacco dust, a suitable local exhaust ventilation system was designed to reduce particulate air pollution concentrations in a tobacco processing factory.

Keywords: Tobacco dust, Tobacco processing, Industrial ventilation, Bag filter

INTRODUCTION

The importance of clean air in workplace is well recognized. Tobacco particulate air pollution is one of the most important problems in tobacco processing industries. Epidemiological studies showed that individual exposure to this type of air pollutant causes some adverse health effect especially respiratory

outcomes such as asthma, chronic obstructive bronchitis, and allergic respiratory or nasal diseases in workers whom exposed to tobacco dust [1-9]. Tobacco processing industries have been developed during recent decades. In some developing countries, tobacco factories are old and therefore they still use old machinery to produce tobacco products. Mohammadyan et al. studied the workers' exposure to tobacco dust in a factory and concluded that personal exposure to respirable dust concentration was higher than TLV-TWA (Threshold Limit Value Time Weighted Average)

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recommended by American Conference of Governmental Industrial Hygienists (ACGIH) [10]. Occupational exposure to tobacco dust higher than TLV is a risk factor for pulmonary disease in workers who are working in tobacco processing factories [1]. Teufik et al. studied the lung function of workers who exposed to tobacco dust and showed a significant prevalence of pulmonary disease among tobacco workers [2]. Exposure to tobacco dust would decrease lung capacities and airflows during the years [3]. Researchers found an association between disorders of the upper air ways and tobacco dust in the workplace, but they did not found any relationship between tobacco dust and the development of chronic disease of the lower respiratory system [4]. Evaluation of workers who had long contact with tobacco dust was carried out by Lander and Gravesen. They recognized that 69% of exposed workers had symptoms of asthma and chronic bronchitis [5]. In a study, 36% of workers were disabled for the reason of upper respiratory disease caused by tobacco dust exposure [6]. The prevalences of chronic respiratory or nasal symptoms, lung function abnormalities, positive specific IgE reactions to fungi and positive skin prick test in exposed workers were significantly higher than those in control workers [7]. Mustajbegovic and Zuskin screened for respiratory symptoms and lungfunction impairment in 121 workers occupationally exposed to tobacco dust in a tobacco-processing plant. They found a high prevalence of chronic respiratory symptoms among these workers, and this prevalence was significantly higher in exposed female workers than in female or male control workers. The ventilatory capacity data in studied tobacco workers showed statistically significant reductions in FEV(1), FEF(50), and FEF(25) in relation to predicted values [8].

Numerous workers are working in the tobacco-processing factories in the north of Iran. Most of them are working in old industries without or low efficient ventilation systems. Therefore, their exposures to tobacco dust concentrations are likely to be high. A walkthrough survey suggested by workers showed that most of the workers were suffering from respiratory disorders and eye irritation due to exposure to tobacco dust. The aim of this study was to evaluate the tobacco dust concentrations in the proximity of all sources in a tobacco- processing factory and designing a suitable Local Exhaust Ventilation (LEV) system for reduction of tobacco dust concentration in the workplace.

MATERIAL AND METHODS

Location

The present cross-sectional study was carried out in Sorak tobacco processing factory in the north of Iran in 2008. In total 500 workers were working in different workplaces such as tobacco leave processing sections, official services, laboratory and other related components. One hundred and fifty workers were working in the tobacco leave processing sections. There

are 19 production components in this factory. The most important work stations are tipping, vacuum, feeders, silos, manipulation, threshing, conditioning cylinders, midrib and lamina tunnels and final pressing. Tobacco dust is one of the most important indoor air pollutants in this factory that is emitted to the work space during the leave tobacco processing.

Sampling of tobacco dust

Gravimetric method was used to determine the tobacco dust concentrations in proximity of sources. A 110 mm in diameter glass fiber filter (Sibata, GB100R, Japan) was placed in a high volume environmental sampler. An air sampling pump with 150 lit/min flow rate (Sibata, HV500, Japan) was used to carry sampling air through the filter. Pump's flow rate was calibrated using a calibrated orifice in the lab before sampling. A 5 digit sensitive Sartorius balance was used for weighing sampling and blank filters. Tobacco dust samplings were carried out in following places: 19 samples were collected from different parts of the production halls in the height of 1.5 meter above ground surface. Nineteen samples from the dust emission sources, 3 samples from outdoor ambient air and 2 samples on the roof around the outside part of general ventilation stack.

Flow and static losses calculations methods

The calculations of the local exhaust ventilation system were done according to the velocity pressure method recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). In this method, all of losses (frictional and dynamic) have been mentioned as a coefficient of velocity pressure in system. Coefficients of entry losses for hoods (f_h) were determined according to the hoods' form and structure and their entrance angles. Hood entry loss (h_e) was calculated from the multiplication of the hood coefficient and velocity pressure. In the base of workplace circumstances, some joints, elbows, branches and other type of connection parts were used in local exhaust ventilation system which caused some pressure losses. The pressure losses were calculated by multiplying of coefficients presented on charts and velocity pressure and entered to the calculated sheet that recommended by ACGIH for local ventilation system designing [Equation 1]. Balancing of the pressure loss among the parallel branches is one the most noticeable points in local ventilation systems which achieved by changing of ducts diameter or the hoods air flow rates in the system.

$$[\text{Equation 1}] \quad h_e = 4.5 VP + 0.43$$

Selection of dust collector equipments

Before discharging the polluted air that collected by ventilation system, it should be filtered and cleaned by collectors. For this purpose a suitable cleaning device should be used in the ventilation system. Some factors such as dominant pollutant navigate, density and concentration of polluted air, collector's value, maintenance costs, and limitations should be considered for collector selection. The collector must have a

Table 1. Mean total tobacco dust concentrations in different locations of tobacco processing factory

Sampling location	Total tobacco dust concentration (mgm ⁻³)
Midrib manipulation – Emission source	39.85
Primary midrib feeder – Emission source	432.59
Primary tipping feeder – Emission source	23.56
Outlet of secondary midrib feeder– Emission source	145.70
Tipping unit– Emission source	67.01
Outdoor air	0.04
Indoor air	7.71
Outlet of ceiling fans	5.5

significant efficiency for collecting fine particles. However, efficiency of filter depends on its material, texture and thickness and also the diameter and the area and the particle density along with the flow rate. In some casual felt filters the collection efficiency is more than 99 % and therefore this type of filter is suitable for dust collection. Emitted particles in the tobacco processing factories are mostly small particles with low density which must be collected with a suitable filter. Basically synthetic felt and fabric filters have high efficiency for dry dust and metal fumes in low air temperature. Reverse pulse jet system that is one of the best and the most efficient cleaning system were selected for cleaning the filters. The pressure loss in bag house for this type of filter is usually ranged from 7.6 to 17.8 cmH₂O which causes a reduction in pressure loss due to air flow rate passed through filter and other internal and external losses in the filter chamber. According to the chamber's dimensions, pressure loss was 0.5VP. Following equations are used to calculate the dimensions of the Bag house and filter's total area [Equations 2-7]:

$$[\text{Equation 2}] \quad f = 2\pi rh$$

Where f is area of each tube (ft²), r is tube's radius (ft), h is tube's height (ft)

$$[\text{Equation 3}] \quad F = \frac{Q}{V}$$

Where F is filter's total area (ft²), Q is air flow rate (cfm), V is air velocity in the filter (ft/min)

$$[\text{Equation 4}] \quad n = \frac{F}{f}$$

Which n is number of tubes

$$[\text{Equation 5}] \quad \begin{cases} \frac{Q}{xy - an} \leq 300 \text{ fpm} \\ 2x = y \end{cases}$$

X is bag house's length (ft), y is bag house's width (ft), a is each tube's segment area (ft²), n is tube's numbers

$$[\text{Equation 6}] \quad H = h + L + Z$$

$$[\text{Equation 7}] \quad Z = \frac{Q/300}{x}$$

H is total height of bag house (ft), Z is height of bag house's upside room (ft), L is distance between hoppers bottom and the ground (ft).

Fan selection method

At the first step required air flow rate was corrected according to the indoor air temperature and the pressure using NIOSH's calculation sheet recommended by American National Institute of Occupational Safety and Health. Then static and total pressures and fan's power of the system were calculated. According to the mentioned calculations and results and with considering the pollutant's nature and workplace conditions, a suitable fan was selected. Finally, using the related calculation sheets and graphs, all dimensions and technical characteristics of the ventilator were calculated.

RESULTS

Measurement of tobacco dust

Total tobacco dust concentrations were higher than TLV recommended by ACGIH for occupational exposure in all indoor sources such as tipping unit, midrib manipulation, primary feeders and outlet of secondary midrib feeder units (ranging from 23.56 to 432.56 mgm⁻³). However, mean indoor and outdoor tobacco dust concentrations and also fans' outlet dust level on the roof were lower than TLV (0.04-7.71 mgm⁻³ respectively). Because of the high level of tobacco dust near the sources, workers' exposure to tobacco dust is likely to be high (Table 1).

Hood selection

To collect dust from the source and to prevent emission of tobacco dust into the workplace environment, some downward slot hoods similar to VS-708 type recommended by ACGIH's industrial ventilation committee were designed for the work-tables in tipping unit [9]. This type hood with a suitable design and exhaust flow would be able to capture polluted air from source without any interference with other processing machinery and workers job. It also could be installed between strap and tables for better collection efficiency for midrib manipulation unit (Fig 1).

Some upward slot hoods that are similar to VS-903 type recommended by ACGIH's industrial ventilation committee were also selected for tipping manipulation unit (Fig. 2).

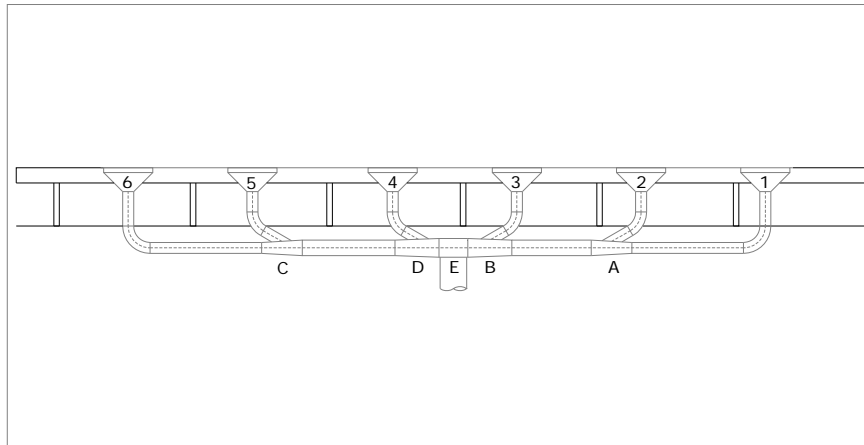


Fig 1. Downward slot hoods designed for the work-tables in the tipping unit

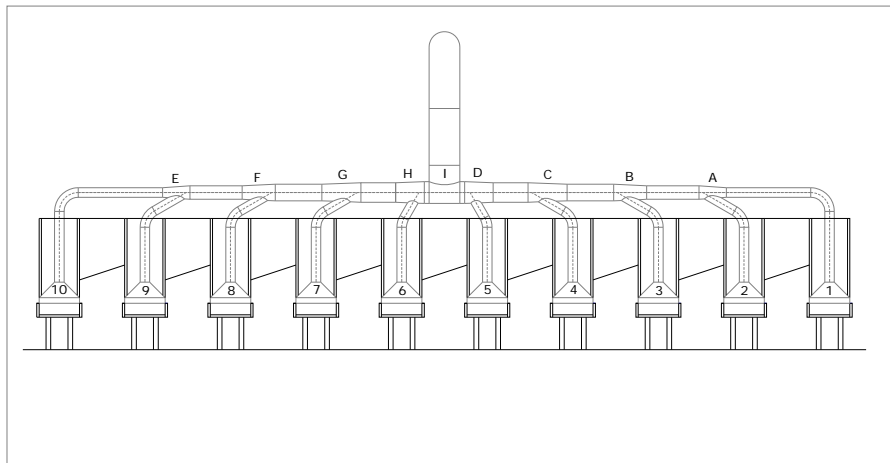


Fig 2. Upward slot hoods designed for tipping manipulation unit

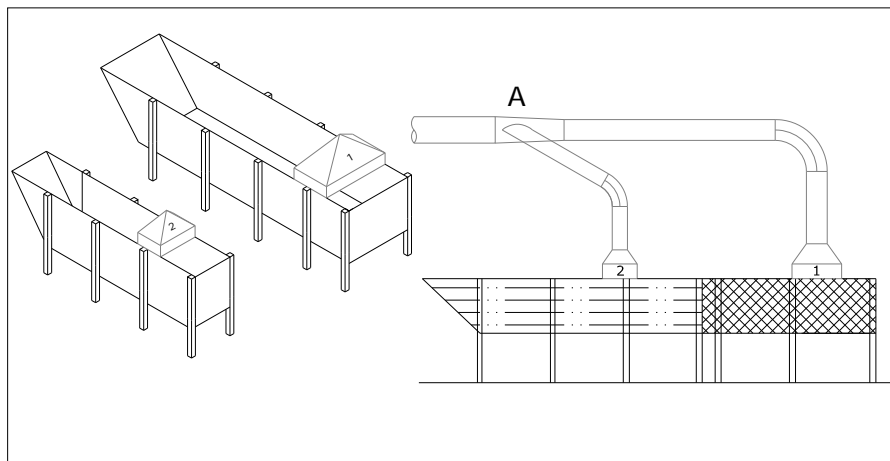


Fig 3. Enclosing hoods designed for feeders

Some enclosing hoods were designed for feeders considering the machinery type and work limitation for the operator (Fig. 3). In total 46 hoods were designed and selected to collect particulate matters from all three exist systems. The capture velocities of 45, 60, 75 meter per minute (mmin^{-1}) were chosen for downward slot

hoods, upward slot hoods, and enclosing hoods respectively.

Selection of ducting system and air flow calculations

Ducts' paths were selected considering some parameters such as production process, position and

Table 2. The characteristics of designed bag houses in the tobacco processing factory

Bag filter	Length of filter (m)	Width of filter (m)	Height of filter (m)	Flow rate (m ³ min ⁻¹)	Pressure loss (cm H ₂ O)	Total area (m ²)	No. of tubes	Efficiency (%)
1 and 2	3.27	1.64	1.65	313	15.34	128.3	44	>99.9
3	2.85	1.42	1.65	235	15.14	96.3	33	>99.9
4 and 5	3.58	1.69	1.80	370	16.76	151.7	52	>99.9

Table 3. The characteristic of selected fans in tobacco processing factory

Ventilation system No.	Total air flow rate (m ³ min ⁻¹)	Static pressure (cmH ₂ O)	Total pressure (cmH ₂ O)	Blade diameter (cm)	Rotate velocity (rpm)	Total power (hp)
1	312	27.28	29.29	102	1135	31.47
2	312	26.67	28.73	102	1124	30.87
3	240	23.77	26.34	93	1168	20.90
4	369	28.55	30.53	114	1014	38.18
5	369	27.94	29.92	114	1008	37.27

height of machineries, studying and balancing of the pressure losses in different ductworks, safety considering, suitable appearance and preventing any obstacles. Duct velocity of 1060 mmin⁻¹ has been selected for all systems. Ducts' dimensions and their required flow rates were calculated according to the duct velocities. Then, the suitable duct work systems were selected (Figs 1-3).

The features of the different parts of the system were determined using some calculations based on the velocity pressure method. In these calculations, the average temperature of 30 °C, the air pressure of 758 mmHg and the relative humidity of 72% were assumed for all system functions. The static pressure losses in system from hoods to collectors and adjusted flow rates according to the average air temperature and ambient pressure were estimated.

Bag house calculations

A non textural felt made synthetic fibers type 6 nylon with the weight of 300 gm⁻² that were available in national markets have been chosen for making the bags. This type of felt filter could pass the air flow of 1.5-3.6 mmin⁻¹, which is necessary for high air flow ventilation systems. The filter's air passage of 2.44 m³ m⁻²min⁻¹ was chosen for this bag filter system. The bags were cylinder shape with a diameter of 12.24 cm and the length of 3m, so in this case the area of each bag was 2.92 m². According to the mentioned data and the total area of filters and considering the dimensions of the bag tubes, required number of tube were calculated and the dimensions of the filters' chamber were estimated (Table 2).

Calculation and fan selecting results

According to the average indoor temperature and barometric pressure in the factory (the average temperature of 32.2 °C and the pressure of 758 mmHg), the temperature and pressure coefficients of 1.04 and 0.962 were estimated respectively. The static pressure loss and systems air flow that were resulted from the calculation sheets according to velocity pressure method, have been used to select the centrifugal type

fans with radius blades. Other features of fan and findings have shown in Table 3.

DISCUSSION

Study of tobacco particulate matter concentrations showed that there was a high level of tobacco dust concentration in all indoor emission sources in this industry, but a lower level of dust was found in the outlets of ceiling fans. It can be explained that most of the coarse particles are settled on the surface of machineries and also on the floor of workplace after emission. Thus, only fine particles are scattered in the air and are propelled through the ceiling fans. The outdoor total dust concentration showed the lowest particle concentration. This factory is located in a green and humid nature place in the north of Iran and therefore because of the clean outdoor air, the particulate air pollution is diluted to lower concentration. Results of the current study showed that mean particulate matter concentrations indoor halls were lower than the threshold limit value that recommended by ACGIH [11] and also Occupational Exposure Limit than proposed by Iranian Technical Committee of Occupational Hygienists [12]. Zhang et al. studied the tobacco dust concentrations indoor a similar tobacco processing industry and concluded that the total dust concentrations in different sites varied from 2.42 to 10.78 µgm⁻³. Results of their study were similar to those of current study [13]. A study was carried out to examine tobacco dust concentration in a tobacco factory in Thessaloniki in Greece. In contrast with the result of the current study they found a very high level of total suspended dust in workplace (45.3-54.4 µgm⁻³) [4]. The relationship between vocational contact with tobacco dust concentration and pulmonary disease was studied and it was found that the total dust concentration in the tobacco processing factory ranged from 4.2 to 24.1 µgm⁻³ that in some cases the dust concentrations were higher than those resulted in the current study [14]. In some cases that workers had to approach to the working machines for repairing and operating the systems, a high level of dust concentration has reported in worker's position. Therefore high level of workers' exposure could be happened.

Indoor emission sources such as tipping, midrib manipulation and feeder units were known as major tobacco dust sources. Therefore, it was necessary to design suitable local exhaust ventilation systems to remove produced dust before emission into the workplace. Selection of the type of ventilation system, dimensions of ductworks and the system installation methods are among the most important parts of designing a local ventilation system. Considering the importance of the interference with operators' job and the operation characteristics, the best possible instruments and methods were applied for ventilation systems.

CONCLUSION

Because of the high tobacco dust concentrations in the proximity of the emission sources and workers' complaints some suitable local exhaust ventilation systems were designed considering the factory process and job limitations. To reduce workers' exposure to tobacco dust in the workplace it is necessary: To pass all dried tobacco leaves through a vacuum room before any manipulation. To clean all machines and the workplace's surfaces using an air suction system. Application of the compressed air nozzle for removing dusts from surfaces.

It is also necessary for the workers to use personal protection device such as suitable respirators when high level of tobacco dust exist.

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