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PM10, PM2.5 and PM1 Concentrations in Cotton Ginners

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Abstract: Particulate Matter concentrations in three different fractions (PM10, PM2.5, and PM1) were measured in the ginning, storage and press sections of two ginners. PM concentrations were measured using a continuous measurement device and the climatic factors were measured using a thermo-hygro-anemometer. Measurements suggested that the PM10 concentrations were higher than threshold limit value of 1000 µg/m³. Although no threshold limit values were specified for PM2.5 and PM1 for raw cotton, the limits that apply to PM2.5 are 200 and 750 µg/m³ in textile industry, respectively for spinning and weaving. Based on these figures, it was concluded that the PM10, PM2.5, and PM1 concentrations were much greater than the threshold limit values. The high PM concenrations were due to the poor natural and forced ventilation conditions in the facilities. Thus the ventilation systems need to be improved while the workers should take personal preventions to avoid upper respiratory system nuisances because of PM10 exposure and lower respiratory system nuisances due to PM2.5 and PM1 exposure. The individual effect of temperature, relative humidity, and air velocity on measured concentrations was generally insignificant while the interaction of these factors general had a significant effect.

Key words: Particulate Matter, concentration, cotton ginner, PM10, PM2.5, PM1

INTRODUCTION

Working environment has a profound effect on health and efficiency of workers in both indoor and outdoor applications. The most commonly studied factors are noise, vibration, dusts, gases, and climatic factors in work areas. Among other factors, workers in ginners are exposed to various levels of different fractions of particulate matter (PM). Due to the mediocre tehcnology used in cotton conveying and feeding into the ginners, the particulate matter inhalation deserves to be studied since cotton production and processing is important in the region. Cotton production and processing gains utmost importance when cotton production in South East region of Turkey is included in such an evalutaion beacuse the great majority of the irrigated land is devoted to cotton production.

Particulate matter may cause poisoning and allergy in the respiratory system (Witney, 1988). Early records indicate that the inflammation of the eyes, lungs, and the skin are some other effects of personal PM exposure (Matthews and Knight 1971). Numerous researchers relate diseases such as asthma, pulmonary fibrosis, and lung cancer with dust inhalation (Maynard and Howard, 1999; Baker et al. 2005).

Not much information is available on the generation of concentration levels of different PM fractions in ginners in Turkey. Thus the objective of this study was to continuously measure PM10, PM2.5, and PM1 concentrations in two ginners. The climate conditions were also measured to determine whether the workers were in the comfort zone.

MATERIALS and METHODS

Materials

Two contiunous samplers (HAZ-DUST 5000) were used to determine the real-time PM concentration levels. A thermo-hygro-anemometer (Delta OHM DO 9847) was used to measure climatic data. One device can record data only for one PM fraction by choosing appropriate the sampling head. Measurements were done in two roller ginners.

Methods

The measurements were done in the Kahramanmaraş Province of Eastern Mediterranean region of Turkey. The continous measurement device can only measure one fraction at a time. Therefore two devices were used to measure PM10 and PM2.5 simultaneously whereas PM1 concentration was measured in another day. The thermo-hygro-anemometer was located in a location near the workers along with the continuous sampler.

Ambient climatic conditions may affect the nuisance experienced by a worker. Measurement of ambient temperature, relative humidity and air speed may be helpful in making better assessment on the effect of all measured parameters. The comfort zone for human was defined as a temperature range of 18-24 °C and relative humidity range of 30-70% (Suggs, 1991). The working conditions of operators were compared to these criteria to determine whether these parameters could make any contributions to operators' nuisance in addition to disturbances potentially caused by PM inhalation.

The threshold limit value for PM10 is 1000 μg/m³ for raw cotton whereas the threshold limit value for PM2.5 is 200 and 750 μg/m³ for spinning and weaving in textile industry (OSHA, 2010) as shown in Table 1. Therefore OSHA standards were used to determine whether threshold limits were exceeded in the ginner area, press unit, and storage of ginners (Table 1).

The effect of temperature, relative humidity, and air velocity was determined using Pearson correlation test while the interactions these factors on measured concentrations were determined using regression analyses. The level of generated PM concentrations in different sections of ginners were compared through multiple mean comparsion tests.

Table 1. Exposure limits for PM10 and PM2.5 (OSHA, 2010)

Feature	Limit values (μg/m³)	Particle size
Lower respiratory system nuisance limit	5000	PM2.5
Total nuisance limit	15000	PM10
Raw cotton	1000	PM10
Spinning	200	PM2.5
Weaving	750	PM2.5

RESULTS and DISCUSSION

All fractions of PM had concentrations higher than the threshold (1000 μg/m³) in the working areas of the ginners (Table 2) except PM1 in the storages. Fine (PM2.5) and very fine (PM1) particle concentrations were too high and were even greater than the limit value set for PM10. These results imply that concentration levels both for coarse and fine particle fractions generated in the work places of ginners are very hazardous for workers' health.

Real time measurements in ginners showed that both the means and the standart deviations of PM concentrations were profound. Coefficient of variation (CV) was the smallest in the case of PM10 with 0.33 in the storage unit while it was the greatest with 1.17 for PM2.5 in ginner area. CV for PM1 data was also high with 1.1 in the ginner area. According to the data given in Table 2, CV ranges between 0.33 and 0.54 for PM10, which is the narrowest range among the three PM fractions.

It was notable to observe highly variable fine and very fine particle concentrations in the ginner area. Continuous measurements clearly show the fluctuations in the PM concentrations during short time durations (Figures 1-3). All graphs agree that PM concentration levels vary rapidly at random intervals.

Table 2. Descriptive statistics for different fractions of measured PM concentrations (μg/m³)

PM fraction	Working area	Number of samples		PM concentration			
		Total	Average	Mean	Std. dev.	Min.	Max.
PM10	Ginner	868	434	14344,91	7568,72	3352,34	55435,28
	Press unit	434	217	10406,73	3440,18	5448,72	39628,03
	Storage	908	454	7995,75	4373,36	2041,22	39626,08
PM2.5	Ginner	742	371	13908,69	16253,28	4790,62	103298,09
	Press unit	446	223	7405,78	3272,90	337,09	23361,76
	Storage	456	228	6021,64	4307,35	1131,64	38653,67
PM1	Ginner	336	336	6637,84	7379,02	72,00	42155,68
	Press unit	183	183	5646,17	2414,26	214,39	29124,66
	Storage	223	223	575,90	224,08	66,14	1439,83

Furthermore, the variations were not consistent, resulting in either increasing or decreasing patterns with time, as shown for PM10 in Figure 1. Therefore, workers are exposed to different levels of PM concentrations during the shift in each working area of the ginners. Observations as to the PM2.5 and PM1 are alike (Figure 2-3).

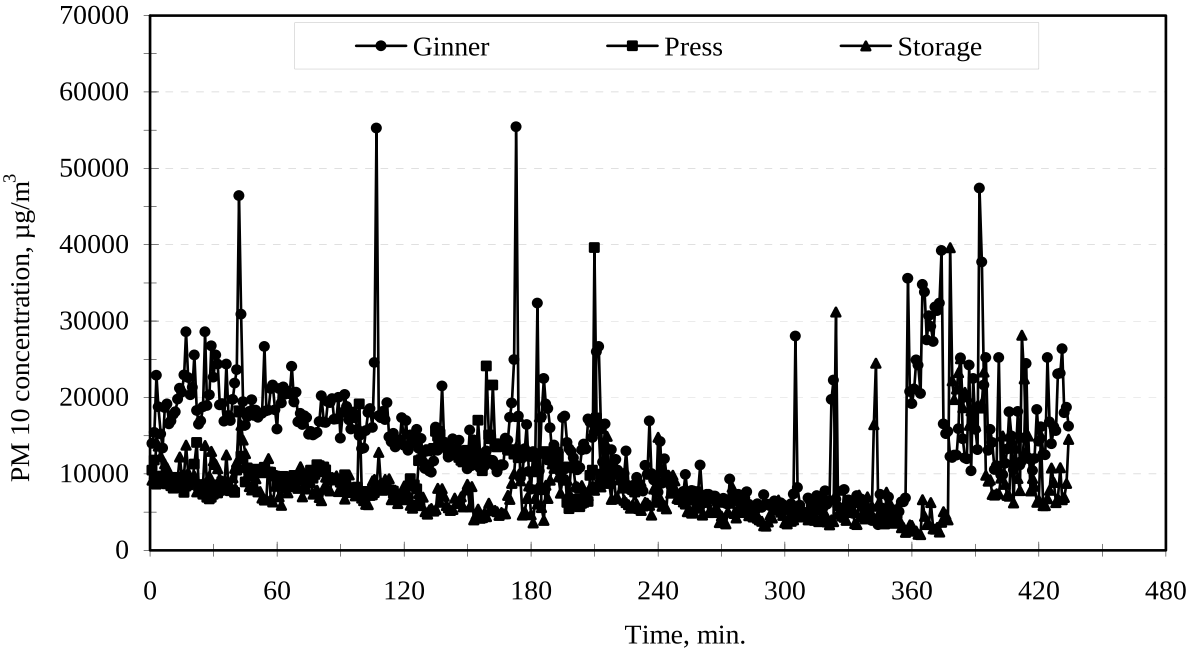

Figure 1. Continuous PM10 concentration measurements in three different working areas of ginners

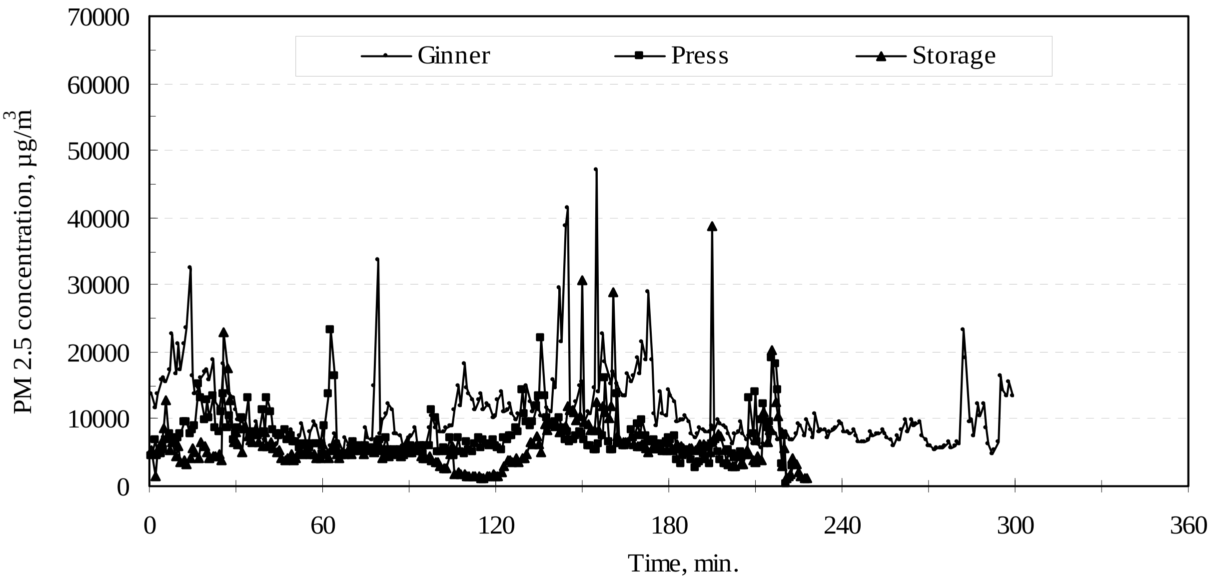

Figure 2. Continuous PM2.5 concentration measurements in three different working areas of ginners

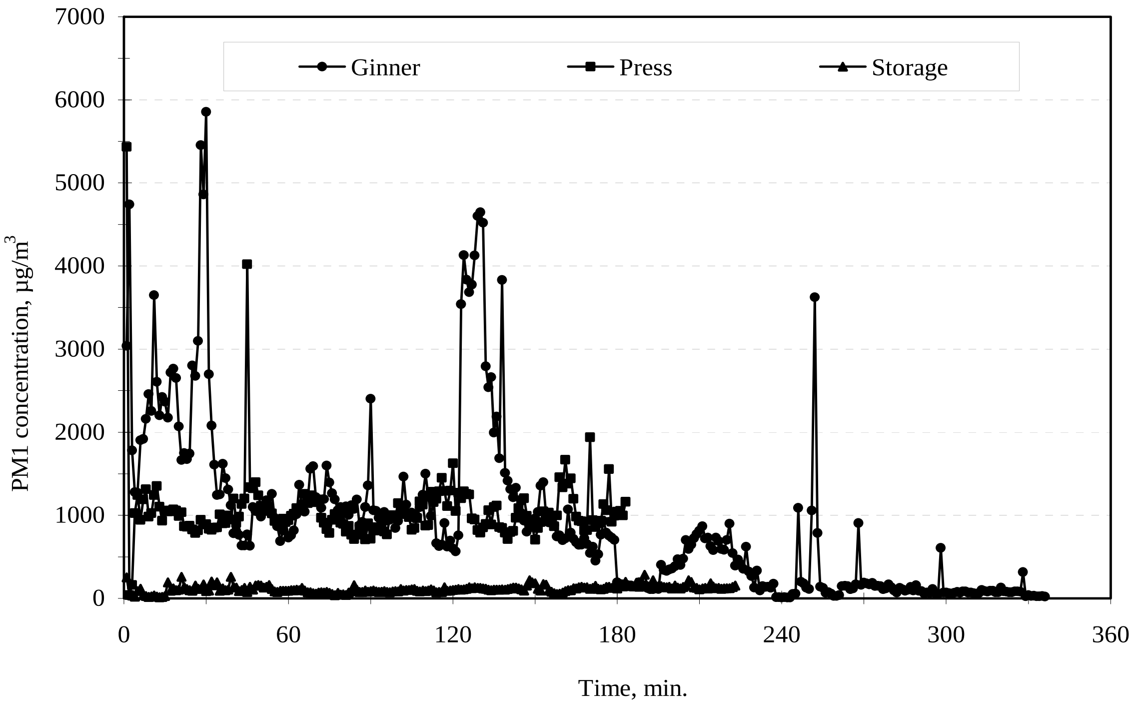

Figure 3. Continuous PM1 concentration measurements in three different working areas of ginners

It was observed that the PM concentrations varied in all working areas. The causes of these variations could be explained based on the technology used and the way these facilities are operated:

- The level of technology used in the ginners were very low compared to up-to-date technology. Raw cotton is conveyed and processed in closed conduits in a modern ginner. A modern ginner may have a cleaning unit to remove chaff and foreign materials, relative humidity control systems to optimize cleaning, and automatic cotton feeders. But the raw cotton is conveyed in open conduits and is dropped from a certain height into the ginner or near the ginner to be fed manually into the ginner, causing high level of PM generation.
- Old ginners require repair and maintanence more often. As a result, the number of active ginners varies during the day and thus amount of raw cotton processed and number of ginners causing PM pollution vary during the shift. There is no air conditioning in ginners on the contrary to textile plants. Two methods are used to exhaust particulate matters from the factory. First is natural ventilation through windows and forced ventilation using axial fans. In the second method, a worker sweeps the floor to collect coarse dusts. The number and capacity of ventilation fans do not seem to be sufficient since the workers exlaimed inflammations in the eye, skin, and the respiratory system.
- There are no automatic dust collectors or dust canals on the floors. Dust collection cannot be made periodically and the factors affecting PM concentrations cannot be controlled effectively.

Ginners are usually active during a limited period in the autumn and winter, following the harvest season in October. Big textile companies may run the ginners most of the year by importing raw cotton from different countries. On the contrary to the textile companies, no air conditioning is done in ginners, resulting in poor conditions in term of temperature and humidity control in the work areas. As a result, temperatures were not within the comfort zone during the ginning season (Table 3).

The ambient temperature, relative humidity, and air velocity are expected to have an effect on measured PM concentrations. First, Pearson correlation test was used to assess the effect of each factor on measured quantities (Table 4). PM10 concentrations were affected by relative humidity in the storage and all factors had an effect on PM concentrations in the ginner areas. PM10 concentration was affected by ambient conditions as well, albeit weakly.

PM2.5 concentrations was moderately affected by ambient temperature in the storage area and weakly affected by relative humidity and air velocity in the ginner and pres units. PM2.5 concentration was either not affected or weakly affected by ambient conditions in other working areas. Very fine particles (PM1) were moderately affected by relative humidity and temparature only in the storage area and weakly in the ginner. Very low air velocity should have caused the low correlation between air velocity and measured concentrations in the case of fine particles.

The effects of the interactions of the climatic factors on PM concentration are given in Table 5. Despite the medium and low level correlations found using single factor Pearson test, interactions of climatic factors usually affected measured PM concentrations. The strongest correlations occurred in the case of the effects of all three factors combined together.

PM10 concentration in each working area was significantly different. PM2.5 concentration was the same in the ginner and press units whereas PM1 concentrations were the same in the ginner and the storage areas. Measured concentrations of different PM fractions were high enough to have an adverse effect on the health of workers. Additionally, the average PM levels that the workers were exposed to were relatively higher, suggesting that workers in these areas should take personal preventions to avoid health hazards due to PM inhalation.

The averages of the PM concentration levels in different working areas were compared through multiple mean comparisons (Table 6). The PM10 means were different in the ginner, press, and storage units. PM2.5 concentrations in the ginner and press units were the same, with a lower mean concentration in the storage whereas the mean PM1 concentration was the same in the ginner and press units. The greatest mean values were found for fine (PM2.5) and very fine (PM1) in the ginner areas.

Table 3. Descriptive statistics for climatic factors in ginners

PM fraction	Working area	Factors	Number of samples	Mean	Std. dev.	Min.	Max.
		Temperature (°C)	863	18,17	1,89	14,9	21,20
	Ginner	Relative humidity (%)	863	39,12	4,48	25,0	48,20
		Air velocity (m/s)	863	0,06	0,10	0,00	0,74
PM10		Temperature (°C)	321	14,91	4,63	9,91	22,26
	Press unit	Relative humidity (%)	321	46,76	10,94	30,0	63,80
		Air velocity (m/s)	321	0,09	0,10	0,00	0,98
		Temperature (°C)	698	18,18	2,29	14,3	21,20
	Storage	Relative humidity (%)	698	42,27	2,57	37,0	48,20
		Air velocity (m/s)	698	0,02	0,06	0,00	0,46
		Temperature (°C)	621	17,38	1,65	13,5	22,26
	Ginner	Relative humidity (%)	621	58,48	12,85	30,0	74,20
		Air velocity (m/s)	621	0,03	0,06	0,00	0,41
PM2.5		Temperature (°C)	373	12,93	3,52	9,91	19,8
	Press unit	Relative humidity (%)	373	42,45	13,13	20,3	56,42
		Air velocity (m/s)	373	0,09	0,12	0,00	1,08
		Temperature (°C)	381	16,97	2,33	14,3	22,26
	Storage	Relative humidity (%)	381	40,60	7,61	30,0	63,80
		Air velocity (m/s)	381	0,05	0,08	0,00	0,46
		Temperature (°C)	468	16,62	1,03	13,5	18,04
	Ginner	Relative humidity (%)	468	64,77	3,73	57,0	74,20
		Air velocity (m/s)	468	0,03	0,06	0,00	0,35
PM1		Temperature (°C)	230	14,23	0,29	13,6	15,54
	Press unit	Relative humidity (%)	230	58,11	1,61	50,0	60,50
		Air velocity (m/s)	230	0,08	0,10	0,00	0,54
		Temperature (°C)	239	14,23	0,28	13,6	15,54
	Storage	Relative humidity (%)	239	58,18	1,62	50,0	61,60
		Air velocity (m/s)	239	0,08	0,10	0,00	0,54

Table 4. Pearson correlations between PM concentration and ambient conditions in ginners

PM fraction	Working area	Parameters	n	r	P
PM10	Ginner	PM-temperature	799	0,560	0,000
		PM-relative humidity	799	0,476	0,000
		PM-air velocity	799	0,285	0,000
	Press unit	PM-temperature	361	0,161	0,290
		PM-relative humidity	361	0,105	0,156
		PM-air velocity	361	0,076	0,304
	Storage	PM-temperature	684	0,084	0,212
		PM-relative humidity	684	0,223	0,001
		PM-air velocity	684	0,140	0,036
PM2.5	Ginner	PM-temperature	621	0,021	0,579
		PM-relative humidity	621	0,142	0,000
		PM-air velocity	621	0,124	0,002
	Press unit	PM-temperature	373	0,033	0,520
		PM-relative humidity	373	0,110	0,330
		PM-air velocity	373	0,127	0,014
	Storage	PM-temperature	381	0,302	0,000
		PM-relative humidity	381	0,053	0,301
		PM-air velocity	381	0,022	0,665
PM1	Ginner	PM-temperature	336	0,113	0,001
		PM-relative humidity	336	0,141	0,000
		PM-air velocity	336	0,042	0,234
	Press unit	PM-temperature	183	0,062	0,239
		PM-relative humidity	183	0,030	0,576
		PM-air velocity	183	0,028	0,598
	Storage	PM-temperature	223	0,212	0,000
		PM-relative humidity	223	0,320	0,000
		PM-air velocity	223	0,022	0,572

Table 5. Correlations between the PM concentration and the interactions of the climatic factors

PM fraction	Working area	Interactions	n	r	P
PM10	Ginner	PM-temperature*relative humidity	799	0,562	0,000
		PM-temperature*relative humidity*air velocity	799	0,566	0,000
	Press unit	PM-temperature*relative humidity	361	0,178	0,055
		PM-temperature*relative humidity*air velocity	361	0,207	0,049
	Storage	PM-temperature*relative humidity	684	0,226	0,003
		PM-temperature*relative humidity*air velocity	684	0,242	0,004
PM2.5	Ginner	PM-temperature*relative humidity	621	0,262	0,000
		PM-temperature*relative humidity*air velocity	621	0,272	0,000
	Press unit	PM-temperature*relative humidity	373	0,120	0,069
		PM-temperature*relative humidity*air velocity	373	0,150	0,038
	Storage	PM-temperature*relative humidity	381	0,304	0,000
		PM-temperature*relative humidity*air velocity	381	0,305	0,000
PM1	Ginner	PM-temperature*relative humidity	336	0,146	0,000
		PM-temperature*relative humidity*air velocity	336	0,156	0,000
	Press unit	PM-temperature*relative humidity	183	0,125	0,060
		PM-temperature*relative humidity*air velocity	183	0,127	0,123
	Storage	PM-temperature*relative humidity	223	0,367	0,000
		PM-temperature*relative humidity*air velocity	223	0,373	0,000

Table 6. Multiple mean comparisons of measured PM fractions in three different working areas of ginners

PM fraction	Working area	Mean±standard error
PM10	Ginner	4876,97±9,92b
	Press unit	4590,16±4,62a
	Storage	1285,93±5,67c
PM2.5	Ginner	5091,93±1,37a
	Press unit	3431,69±4,52a
	Storage	611,12±6,78b
PM1	Ginner	6637,84±7,370b
	Press unit	5646,17±2,41b
	Storage	575,90±2,24a

Most of the workers spend their active time in ginners and the workers should be protected particularly against lower respiratory system nuisances and diseases. However, the hazardous effect of PM10 should not be underestimated since workers exclaim disturbances related to eye and skin inflammations. Since most of the cotton ginners are active about one season, the effects of exposures from different PM fractions may be limited but deserves to be studied further along with medical stories of the workers.

Better technologies need to be adapted in order to reduce the PM concentration levels in ginners. The governmental incentives should be directed to better technologies when cotton ginners are to be established. In addition, PM concentration levels need to be checked on a more regular basis by the work security agencies with proper measures to mandate appropriate aspiration systems in these facilities.

Elçi et al. (2002) found 958 larnyx cancer stories in 6731 patients diagnosed with cancer at Okmeydani Hospital, Istanbul and administered a questionnaire to investigate the PM exposure of the patients. They made assessments on silica, asbestos, wood, cotton, grains, age-, smoking-, and alcohol-related issues. Patients exposed to silica and cotton dusts turned out to have more cancer rates but no correlation was found between larnyx cancer and asbestos, wood or grain dusts. As a result, laryngeal cancer, especially supraglottic tumors resulted from silica and cotton dusts. Cotton industry became one of the most important sectors since 1980s in Turkey, providing employement for tens of thousands of workers, suggesting health hazard to workers. It may be concluded that health controls should be practiced more often in textile industry, including ginners.

CONCLUSIONS

The followings could be concluded as a result of this study:

- Measured PM10, PM2.5, and PM1 concentration levels were higher than the threshold limit values of 1000 µg/m^3 for raw cotton.
- The workers should use personal preventions to minimize the potential adverse health effects of personal PM exposure.
- The ginners should utilize forced ventilation systems to effectively remove inhalable and respirable dusts from the working environment and the official agencies should be incentive in installing higher ventilation technologies during the estabishment of ginners.

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