

Mechanical intervention for reducing dust concentration in traditional rice mills

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Abstract: A huge number of workers are employed in traditional rice mills where they are potentially exposed to dust. In this study a dust collection system was developed to capture the airborne dust in the rice mill. The feeding and sieving section of the mill was identified as major dust creating zone. The dust was captured by creating suitable air stream at feeding and sieving sections of the mill and collected in cyclone dust collector. The air stream was created by blower which was selected on the basis to get minimum air speed of 0.5 m/s in the working zones of workers. It was observed that the developed system is successfully collects the significant amount of dust and able to reduce the dust concentration up to 58%. Further, the respirable dust concentration reduced to below 5 mg/m³ throughout the mill which is within the recommended limit of dust exposure.

Key words: Dust concentration, Respirable dust, Rice mill, Air borne dust, Air stream

Introduction

Rice is the staple food for most of the people in India. It is the largest consumed calorie source among the food grains. Rice production in India crossed the mark of 100 million Metric tons in 2011–12 accounting for 22.81% of global production in that year¹. The post-harvest processing of paddy (de-husking) is the oldest and the largest agro processing industry of the country. It is a basic process that can be found in local towns and villages across the country. Assam has been ranked 1st in rice production (51 lakh metric ton) with productivity of 1,969 kg per hectare². Approximately, Assam consists of 5,560 rice mills which include 1,363 modern and remaining traditional mills³. In traditional rice mill, at a time minimum 4–5 workers are required to monitor and control all the operations. Therefore, a large number of workers are employed in the rice milling industry in Assam, India.

It has been reported^{4, 5} that dust is a major problem

in traditional rice mills of Assam. Dust is scientifically defined as “Small, dry, solid particles projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or man-made processes such as crushing, grinding, milling, drilling, demolition, shovelling, conveying, screening, bagging, and sweeping”⁶. Dust particles are usually in the size range from about 1 to 100 μm in diameter, divided into three types⁷ (i) respirable fraction ($D_{50}=4 \mu\text{m}$ size) (ii) thoracic fraction ($D_{50}=10 \mu\text{m}$ size) and (iii) inhalable fraction ($D_{50}=100 \mu\text{m}$ size). As per report⁴, total dust concentration is 80, 59 and 49 mg/m³, at feeding-cum-sieving, polishing and packaging sections of the rice mill, respectively. The respirable dust concentration at feeding-cum sieving section is 9–11 mg/m³ which are much higher than the recommended value (5 mg/m³)⁸.

Dust as health issue for workers

It is proven fact that exposure to organic dust have high prevalence of respiratory diseases, such as asthma, chronic bronchitis, extrinsic allergic alveoli ties, toxic syndrome, and interstitial lung. These occupational diseases depend up on the dust concentration and duration of exposure apart from variation in personal immunity. The Swedish

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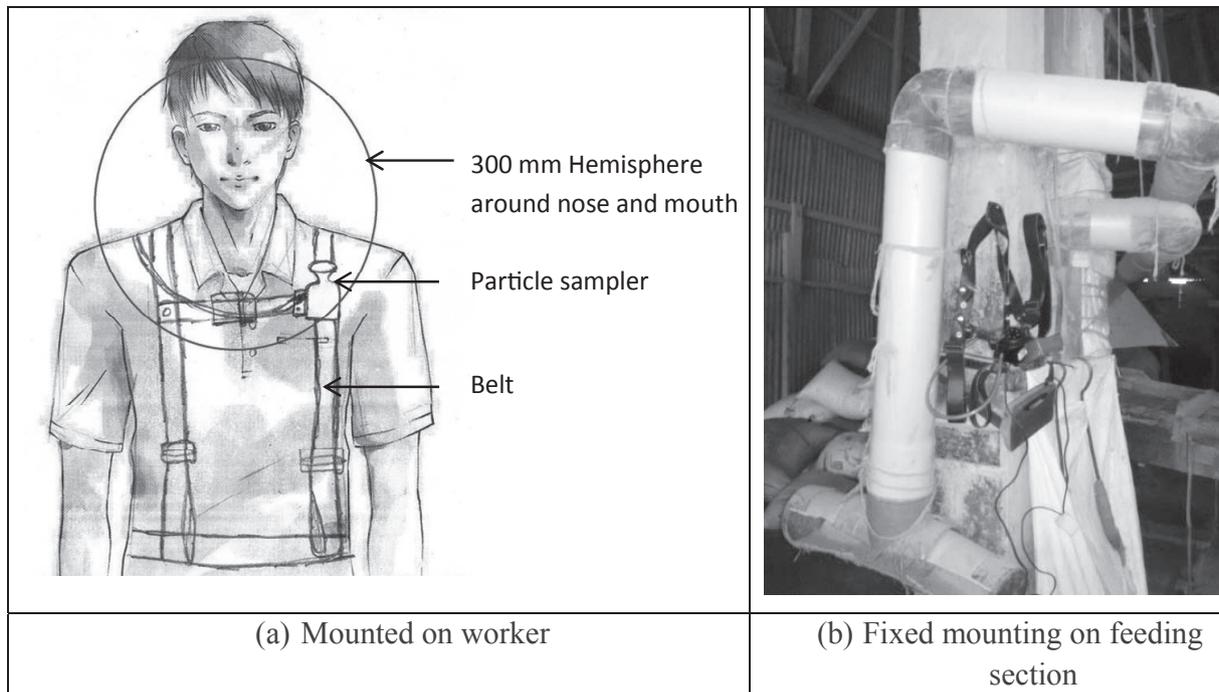


Fig. 1. View of mounted RPS on worker and fixed in a section.

National Board of Occupational Safety and Health has prescribed the dust exposure limit of 10 mg/m^3 and 5 mg/m^3 for normal and organic dust, respectively. Many studies have demonstrated and concluded that occupational diseases constitute serious health and economic problems to the nations. Occupational hygienists must look at the working environment. Several reports^{9–11} have suggested that unprotected dust exposures in agricultural work stations may lead to pulmonary fibrosis.

Grain dust has also long history diseases and its adverse effects on various organs such as eyes, nose, skin, lung and the airways¹². Asthma has been well documented as being a result of dust exposure. However, few studies have been reported on the effect of dust exposure in rice mill. The major dust hazards for workers in rice mills are the dust emissions from different sections i.e. dumping of rice at a place for subsequent collection in gunny bags, feed of paddy from gunny bags to the dumping pit, cleaning of paddy grains, removal of husk from the paddy and polishing of rice. In addition, a dusty mill increases the risk of workers' injury and fire hazard, which results in less production, higher insurance rates, and lawsuits. The increasing global attention on control of air pollution has made the containment of nuisance dust from rice milling operations within enclosures more imperative.

From these point of view, it is resolved that huge man power are employed in traditional rice mills of Assam

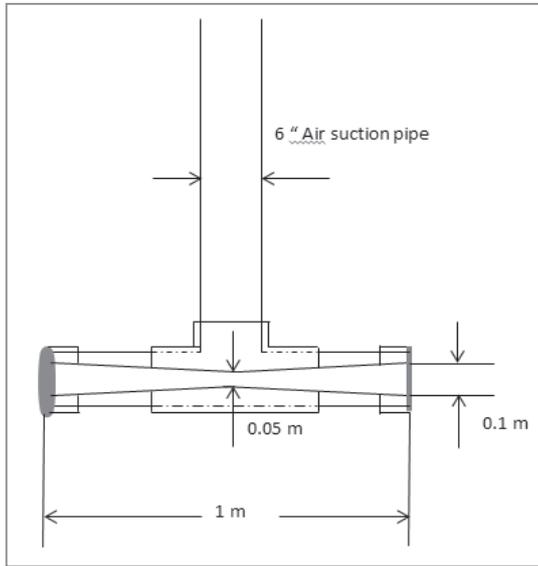
and they are potentially exposed to dust which might lead to adverse effect on their health. Therefore, a study was planned to develop a dust collection system to capture the airborne dust by creating air stream at feeding and sieving sections of the rice mill.

Materials and Methods

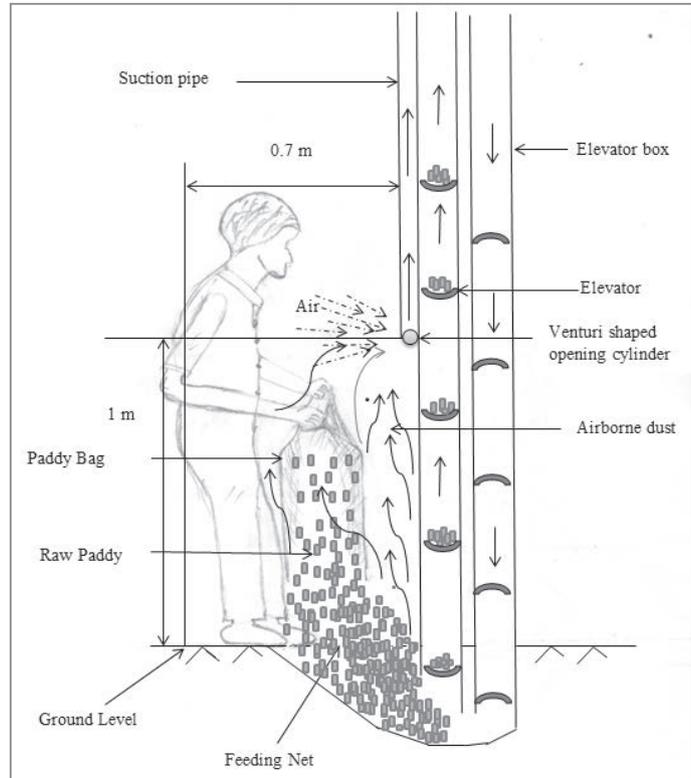
Measurement of dust

Dust exposure to rice mill workers was measured with the help of Respicon Particle Sampler {Model: 8522, TSI, USA; Instrument type-two stage, virtual impactor, with three stage gravimetric filter sampler; 50% cut aerodynamic dia.- Inlet: 100 micron, Stage 1: 4 micron, Stage 2: 10 micron, Stage 3: all remaining particles; Filter type- 37 mm diameter fiberglass without organic binders or PVC filters with 5.0 micrometer pore size; Sample flow rate-3.11 liters per minute} before and after mechanical intervention. The Respicon Particle Sampler (RPS) has three filters where different sizes of dust are being collected. The dust was measured by two methods:

- (i) Sampler was mounted in the breathing zone of worker (Fig. 1a) and allowed him to perform his work from 4 to 7 hours. The data collected through this method is presents as dust at feeding-cum-sieving section because the same person was moving from feeding to sieving during work.



a. Front view of venturi shaped opening cylinder



b. Incorporation of cylinder at feeding section

Fig. 2. Venturi shaped cylinder and its incorporation at feeding section of rice mill.

(ii) Sampler was fixed at one place (Fig. 1b) and started collecting dust for 4 to 7 hours during the mill operation. The dust concentration was collected at various zones viz feeding, sieving, polishing and packaging via this method.

To determine the mass concentration of each of the size fractions, the three Respicon Particle Sampler filters were post-weighed on the same digital micro-balance as was used to pre-weigh the filters. The calculation of dust concentration of each size fraction namely respirable, thoracic, inhalable and total dust was carried out through Data Spread sheet (TSI, USA) using Eqs. 1 to 4.

$$\text{Respirable Fraction (mg/m}^3\text{)} = \frac{m1 \times 1000}{Q1 \times ts} \dots(1)$$

$$\text{Thoracic Fraction (mg/m}^3\text{)} = \frac{(m1 + m2) \times 1000}{(Q1 + Q2) \times ts} \dots(2)$$

$$\text{Inhalable Fraction (mg/m}^3\text{)} = \frac{(m1 + m2 + m3) \times 1000}{(Q1 + Q2 + Q3) \times ts} \dots(3)$$

$$\text{Total dust concentration} = \text{respirable} + \text{thoracic} + \text{inhalable fraction} \dots(4)$$

where, $m1$ = Mass deposited on filter #1; mg
 $m2$ = Mass deposited on filter #2; mg
 $m3$ = Mass deposited on filter #3; mg
 $Q1$ = Flow rate through filter #1; l/min
 $Q2$ = Flow rate through filter #2; l/min
 $Q3$ = Flow rate through filter #3; l/min
 ts = Sample duration; minutes

Selection of site

The mechanical intervention was carried out in an existing traditional rice mill at Narayanpur, North Lakhimpur districts of Assam. This mill is located about 45 km away from NERIST. The mill was established in the year of 1988. The milling capacity of the mill is approximately 35–40 quintal per day. Approximately, 10 persons work in this mill per day in different shifts. This mill was selected on the basis of some mutual agreements between mill owner and authors.

Modification at feeding section

Modification at feeding section is very important as dust start propagating from feeding section as soon as paddy bags open. To capture the upward propagating dust before

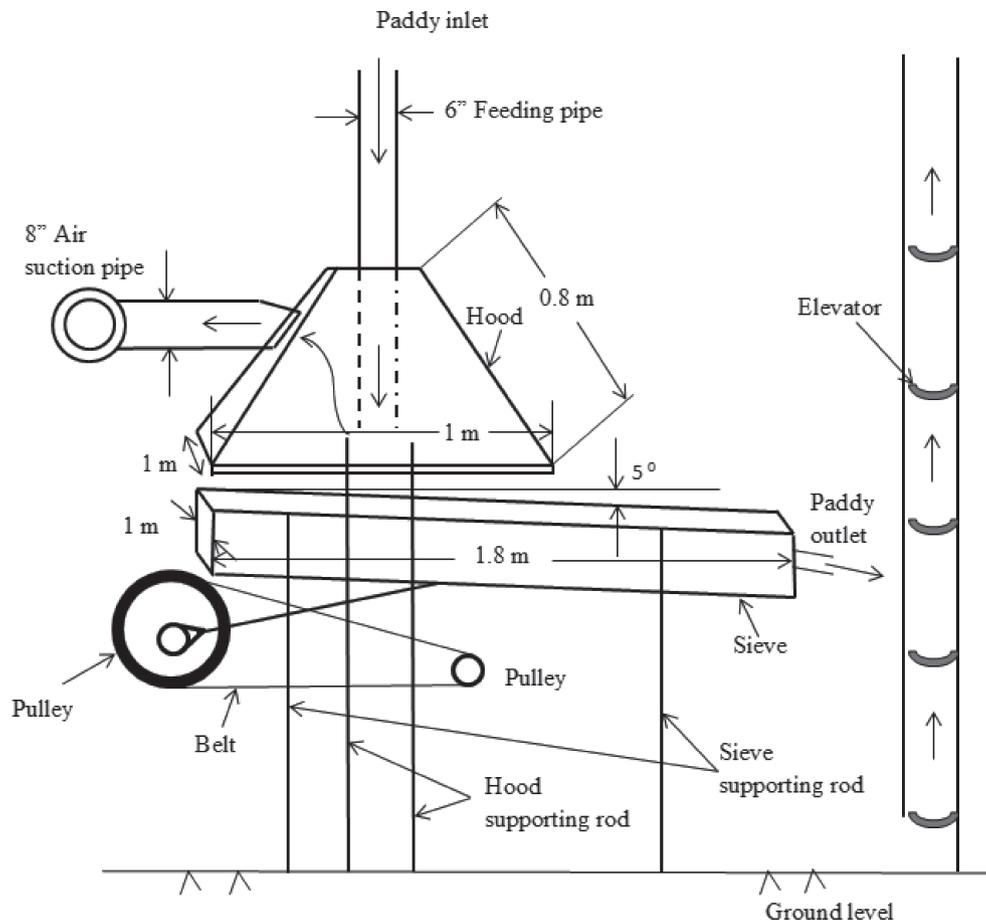


Fig. 3. Fabrication of hood over sieve to capture air borne dust due to sieving.

it reaches to the nose level of workers, a horizontal air suction is provided at a height of 1.0 m from the ground. The horizontal length of suction zone is kept 1.0 m as per the working zone of workers at feeding section. Venturi shaped cylinder having minimum opening of 5 cm at the middle and maximum of 10 cm at the end of cylinder is used to make uniform suction through out the working zone. The suction line is connected to a high capacity blower. The venturi shaped cylinder with suction line and its incorporation at feeding section is shown in Fig. 2.

Modification at sieving section

A rectangular shaped hood of size $100 \times 100 \times 80$ cm (length \times width \times slant height) was fabricated according to the existing sieve size of 180×100 cm (length \times width). The fabricated hood on the sieve with dimensions is shown in Fig. 3. The basic purpose of the hood is to collect and capture the airborne dust which was created over the sieve due to sieving action. An air suction pipe is provided at 0.25 m above the bottom portion of hood as per the suitability of fitting and other existing arrangements. From top

of the hood paddy falls on the sieve through elevator at constant rate. A necessary partition is provided between air suction and paddy falling point to avoid paddy flow in air suction line. A gap of 0.13 m is provided between top of the sieve and bottom of the hood because of frequent cleaning of sieve is required by hand. Further, the gap is also useful to make the air flow.

Selection of blower

A dust capturing system was designed to collect the air borne dust from sieving and feeding section of a rice mill. The overall dust collecting system is shown in Fig. 4. The blower capacity was calculated on the basis of required air velocity at feeding plus sieving section. As per literature¹³, the minimum required velocity to capture air borne dust is 0.5 m/s.

Calculation for feeding section

From trial and error method in a laboratory experiment it was observed that air velocity of 6.5 m/s at suction inlet creates minimum air velocity of 0.5 m/s throughout the

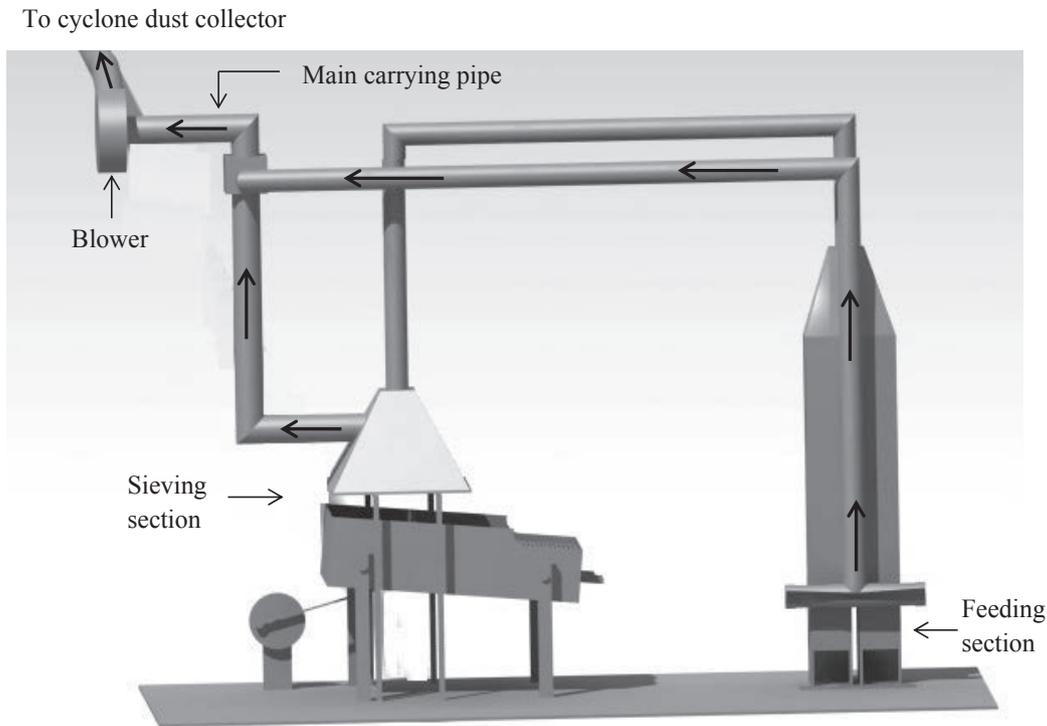


Fig. 4. Overall view of dust collection system.

feeding zone. To get the better air flow uniformity, the suction inlet cut in venture shaped as shown in Fig. 2a. Further, the calculated area of opening of venture shaped cylinder is 0.075 m^2 .

Therefore, air suction rate at feeding section = $0.075 \text{ m}^2 \times 6.5 \text{ m/s} = 0.488 \text{ m}^3/\text{s} = 29.25 \text{ m}^3/\text{min}$.

Calculation for sieving section

The opening face of designed hood is 1 m^2 against the sieve size of 1.8 m^2 . By trial and error method, it was calculated that the required average air velocity at opening face of hood should be 1.2 m/s to create the minimum 0.5 m/s speed at remotest corner of the sieve.

Therefore, air suction rate at sieving section = $1 \text{ m}^2 \times 1.2 \text{ m/s} = 1.2 \text{ m}^3/\text{s} = 72 \text{ m}^3/\text{min}$.

Total required capacity of blower = $29.25 + 72 = 101.25 \text{ m}^3/\text{min} = 3,576 \text{ CFM} \approx 3,600 \text{ CFM}$

Hence, a blower operated by 3-pashe electric motor with specification of $3,600 \text{ CFM}$ flow rate, $2,800 \text{ rpm}$ speed, 152 mm of water column static pressure, and 5 hp rated power was selected to get the desired air suction at sieving as well feeding section.

Measurement of air velocity

After installing a designed blower, the air velocity cre-

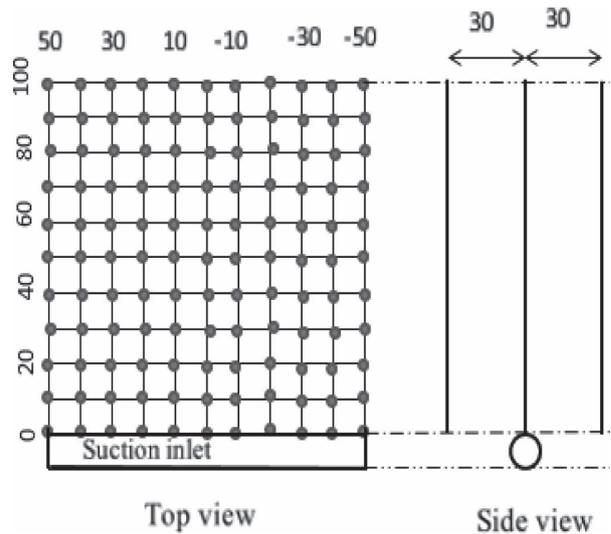


Fig. 5. Grid points of air velocity measurement at feeding section.

ated by the blower at feeding and sieving section was measured to identify the zone creating air velocity more than 0.5 m/s . The velocity of air was measured by Portable Thermal Environment and Heat Stress Monitor (Make: Quest Technologies). The velocity was measured in the grid developed at $10 \text{ cm} \times 10 \text{ cm}$ at feeding and sieving section. The developed grid at feeding and sieving section is shown in Figs. 5 and 6, respectively.

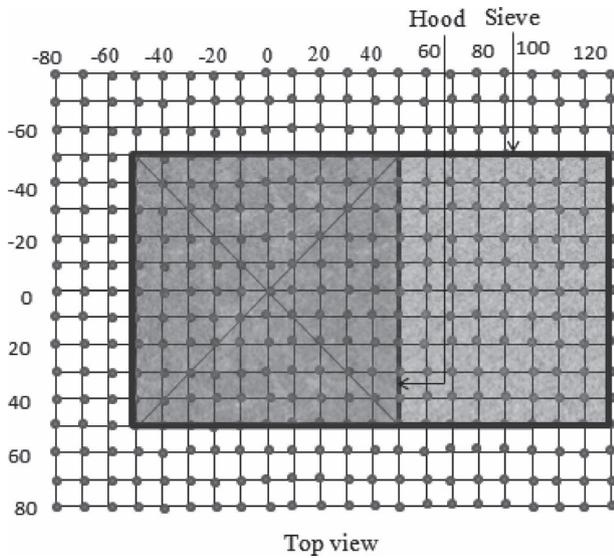


Fig. 6. Grid points of air velocity measurement at sieving section.

Results and Discussion

Velocity profile at feeding section

The measured velocity at feeding section as per the grid was used to develop contour plot as shown in Fig. 7. It is revealed that air velocity more than 0.5 m/s was observed at about 0.7 m distance from the middle of opening cylinder. The contour of 0.5 m/s speed is indicated by bold line in Fig. 7 which is fully dust free zone. Further, at 0.3 m above and below the line of opening, 0.5 m/s air speed was observed up to 0.4 m only (Fig. 8). The air speed of 0.5 m/s is referred to discuss because this is the minimum required velocity to blow the airborne dust of less than 10 μm as per the WHO¹³). The working area of worker in feeding zone was witnessed 1 m × 1 m but it was observed that most of the time, workers work within 0.7 m × 0.7 m area where measured air speed was more than 0.5 m/s.

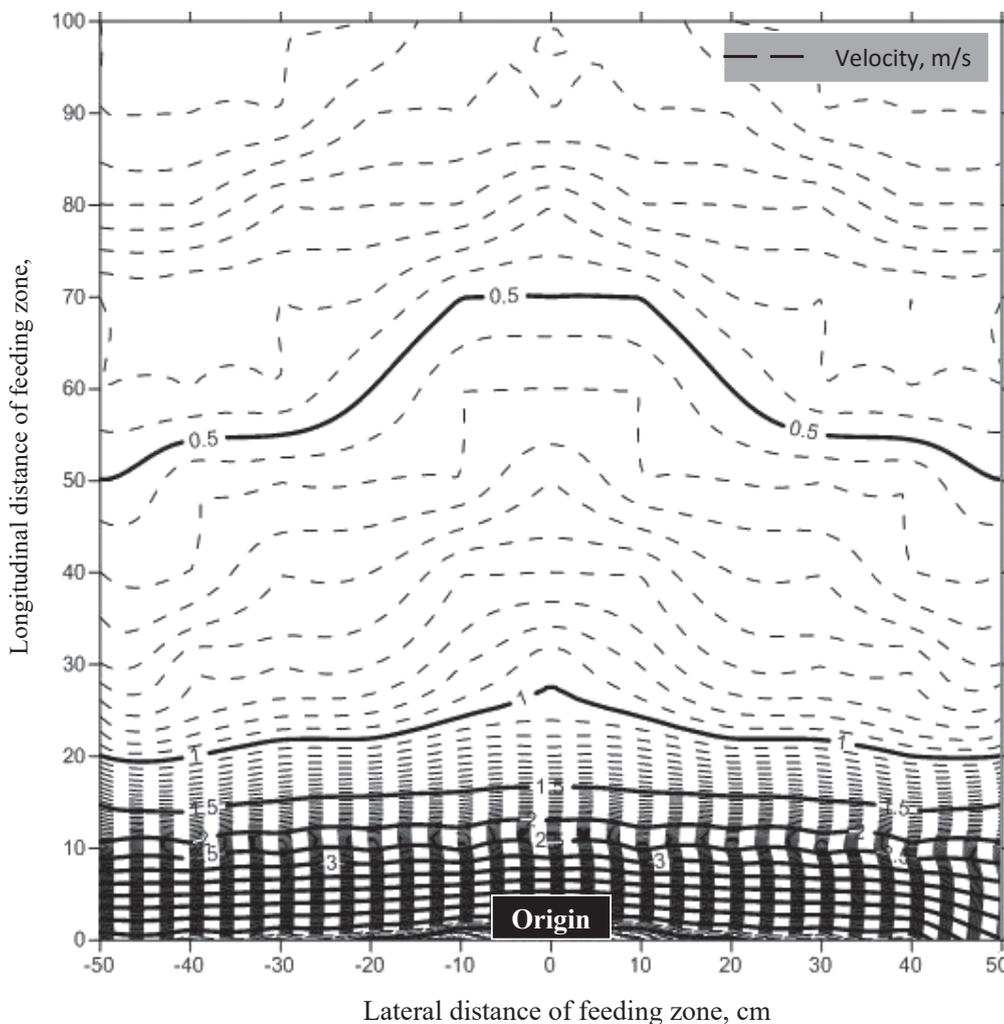


Fig. 7. Velocity profile at feeding section in the line of air opening of cylinder.

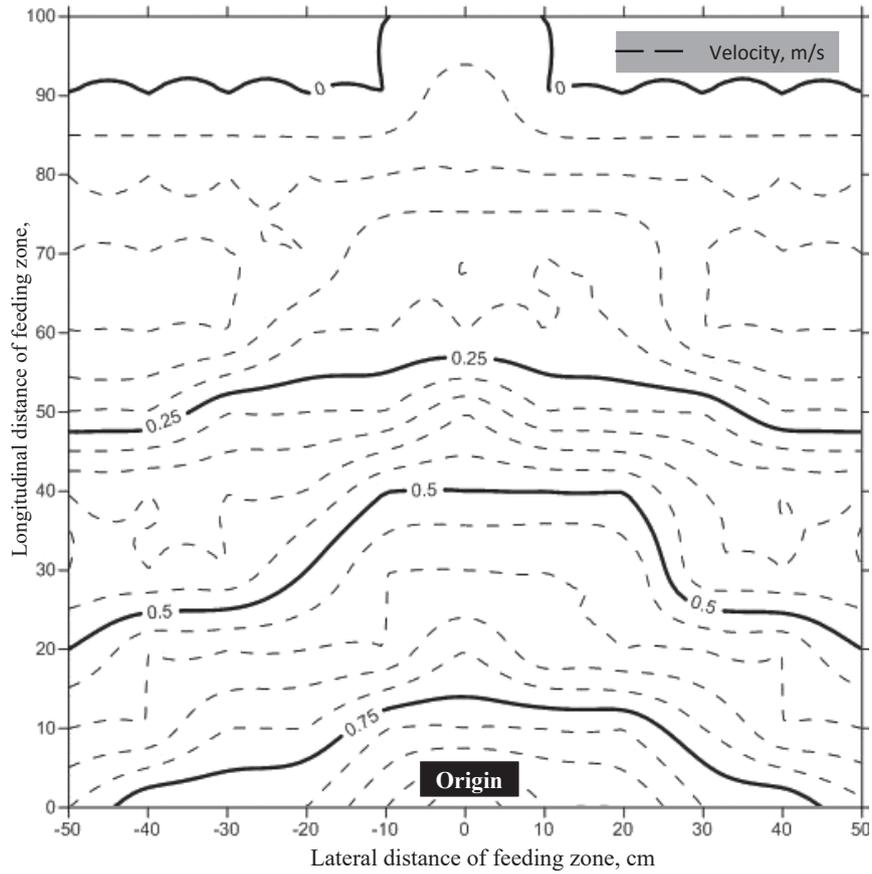


Fig. 8. Velocity profile at 0.3 m up and down from the central line of opening.

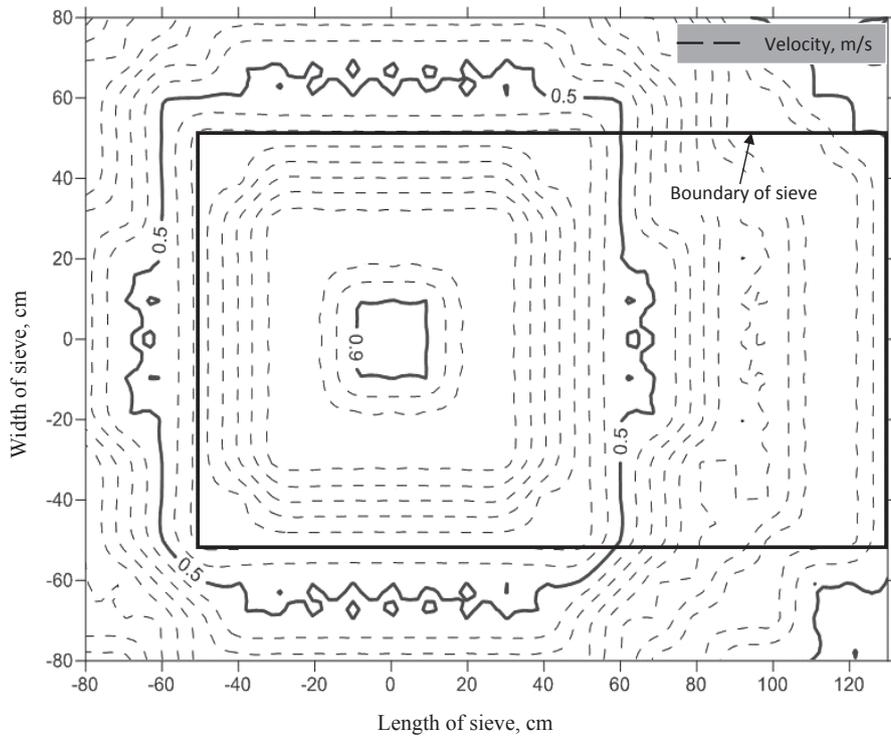


Fig. 9. Velocity profile at sieving section on the sieve.

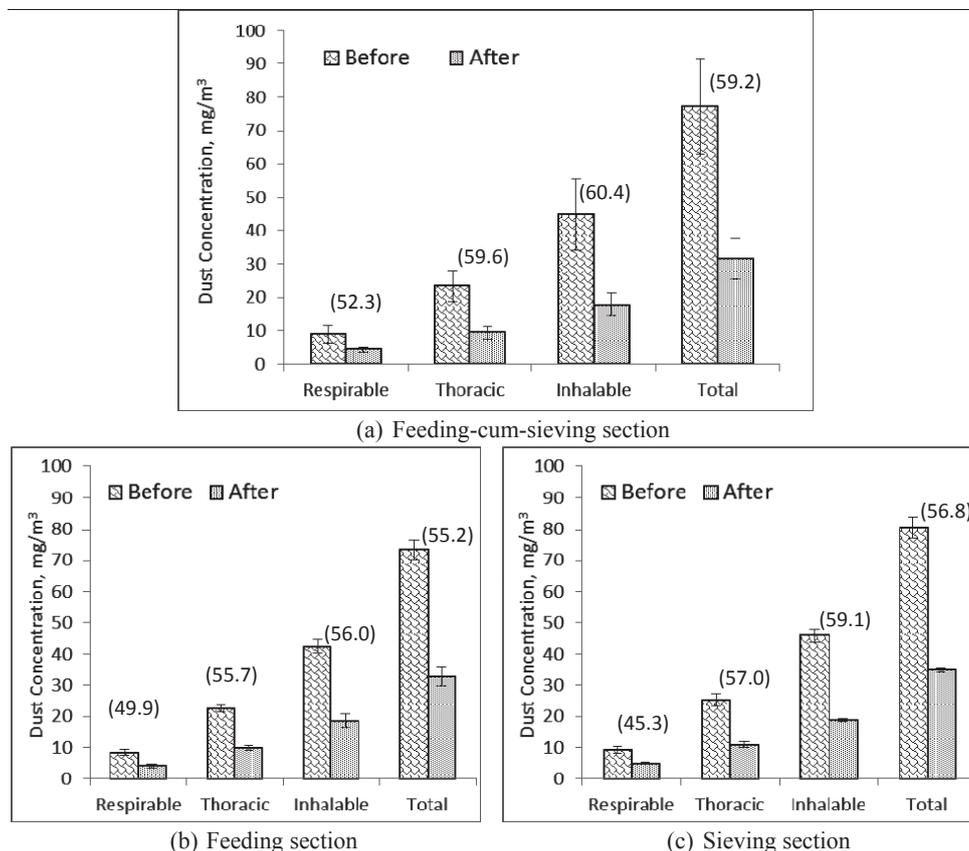


Fig. 10. Comparison of various dust concentration before and after modification.

Velocity profile at sieving section

The air velocity created by blower above the sieve was also measured at sieving section. The contour of air velocity is shown in Fig. 9. The straight continuous lines indicate the boundary of the sieve. From the figure, it is clear that air velocity is more than 0.65 m/s above the sieve. Further, the air velocity was more than 0.5 m/s outside the sieve up to 20 cm in three sides which is working zone of the workers.

Dust concentration

The dust concentrations at feeding, sieving, polishing and packaging were measured before and after modification at feeding and sieving section by fixing particle dust sampler at one place. However, dust was also measured by mounting the sampler in the breathing zone of worker who was working at feeding as well as sieving section which is presented as dust at feeding-cum-sieving section.

A comparison of dust concentration (respirable, thoracic and inhalable and total dust) before and after modification at feeding, sieving and feeding-cum-sieving is represented in Fig. 10. The figure in parenthesis above the bar graph

indicates the percentage reduction in dust concentration due to modification. It is revealed that there is significant reduction in total dust concentration 55 to 59 percent. The total dust concentration after modification at feeding-cum-sieving section varied from 31–34 mg/m³ compared to that of 73–80 mg/m³ before modification. The respirable dust is reduced to the lower than recommended limit of 5 mg/m³ at all the sections. The developed system is very much feasible and cost effective for traditional rice mills of Assam. From the subjective analysis it was also observed that workers' working hour enhanced by 18–20% with the adaptation of dust reduction system which interns as financial benefits. All the previous trial for dust separation was to enhance the quality of final rice product not to reduce the air borne dust. This system is typically for reducing the air borne dust which was affecting the worker health. This technology can also be used in other similar industry.

Further, the effect of modification at sieving and feeding section was also observed at polishing and packaging because dust was propagating to these sections mainly from feeding and sieving section only. It was observed that respirable dust reduced up to 52 per cent at polishing and

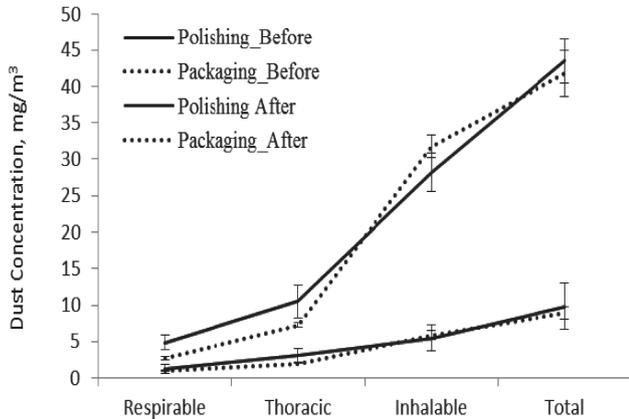


Fig. 11. Effect of modification on polishing and packaging section.

packaging sections. The effect of modification at polishing and packaging is presented graphically in Fig. 11.

Conclusions

A dust collection system was incorporated in feeding and sieving section of rice mill by creating an air stream to capture the air borne dust. This modification reduced the total dust concentration in the range of 56 to 58% at feeding-cum-sieving section. The respirable dust concentration reduced to 4.24 from 8.89 mg/m³ after modification which comes under the recommended limit of 5 mg/m³. Further, significant effect of modification was also observed at the polishing and packaging section. The same technology may be used in others similar industry for the betterment of workers for their health and efficiency.

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