Particulate matter concentration in the microenvironment of wheat thresher

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In the present study three commercial wheat threshers of capacity 600–800, 800–1200 and 1200–1500 kg/h were operated and mean concentration of PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP was recorded at three locations, i.e. 3 m to the left, right and back of the blower outlet and compared with standard limits of 24 h mean of $PM_{2.5}$ and PM_{10} recommended by NAAQS, Central Pollution Control Board New Delhi, Environment Protection Agency and WHO air quality guidelines. PM_{10} concentration emitted from all threshers exceeded the desired limits. The thresher with the lowest capacity only exceeded the $PM_{2.5}$ concentration limits recommended by WHO, whereas the other two threshers exceeded all desirable limits of $PM_{2.5}$ concentration.

Keywords: Dust, microenvironment, particulate matter, standard limits, wheat thresher.

DUST is commonly associated with agricultural operations. It was in the 16th century that dust exposure in agriculture was first identified as a cause of respiratory diseases and has continued to be a major source of respiratory morbidity among farmers[1]. The agricultural field operations that cause dust production in conventional crop production systems include soil tillage and seed bed preparation, planting, fertilizer and pesticide application, harvesting and post-harvest processes. Since air pollution is commonly identified to be the result of industrialization and mechanization, agriculture is not considered as a major cause of air pollution. The emission trends, presented in Figure 1, estimated from all sources and from agriculture in the European Union show that agriculture is one of the major sources of emissions and should be studied further to improve the health and welfare of the rural community.

The emissions from agriculture may generate local and regional problems in Europe in terms of air quality. Such issues may include particulate matter (PM) exposure, eutrophication and acidification, toxics and greenhouse gas (GHG) emissions, causing numerous environmental impacts. Hence PM emissions should be studied not only for PM_{10} but also $PM_{2.5}$ with NH_3 as a precursor[2].

In India, the majority of air mass coming from the northwest to Delhi represents the downwind transport of pollutants from the agricultural biomass burning regions of Punjab and Haryana[3,4]. The dust emerging from the process of wheat threshing has been identified as the major allergen responsible for mid-April–May nasobronchial allergies seen in north India, that may cause asthma or other respiratory diseases over long exposure in the adult population[5]. Dust emissions from the wheat-threshing process specially with commercial wheat threshers and personal exposure to the generated particulates are two major issues to be addressed by both policy makers and researchers. India is currently one of the leading wheat-producing countries in the world, with 86.2% small and marginal farmers with land holding less than 2 ha (ref. 6). Many wheat farmers in India still incorporate commercial wheat threshers instead of combine threshers. There is limited research on dust emissions from wheat threshers. The present study aims to estimate the particulate matter emissions from three commonly used wheat threshers into their microenvironment.

Three commonly used commercial wheat threshers were selected for the present study in order to assess their particulate matter emissions. The study was carried out in the farmer's field, Udaipur, Rajasthan, India. The threshers of capacity 600–800 (T1), 800–1200 (T2) and 1200–1500 kg/h (T3) were operated at their recommended power take-off (PTO) speeds. Assessment of mean concentration of dust fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and total suspended particles (TSP) was made at three locations, i.e. 3 m to the left (L1), 3 m to the right (L2) and 3 m to the back (L3) of the blower outlet of the operating thresher.

A real-time dust monitor was utilized to quantify the mean dust concentration of PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP (Figure 2). Simultaneous measurement of the environmentally relevant mass fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP as well as particle number and particle size distribution in the particle size range 0.18–100 μm was done. By providing the fine dust values with a high time resolution, comprehensive information for the evaluation and assessment of fine dust pollution for the studied application was obtained using this dust monitor. The dust monitor communicated via WLAN with its wireless operators panel, i.e. Tablet, making it possible to take measurements at such locations where it is difficult for the operator of dust monitor to be present. The dust monitor was operated with a flow rate of 1.4 l/min and was equipped with sensors for environmental conditions, temperature, atmospheric pressure and relative humidity. The data sampling frequency of each simultaneous measurement was set at 10 sec and the total sampling period was 30 min.

The data collected in the experiments were analysed statistically in the two-factorial CRD model for the significance of difference, if any, among parameters at 1% and 5% level of significance. Three replications of each treatment were carried out, where three threshers (T1, T2 and T3) and three locations (L1, L2 and L3) at which

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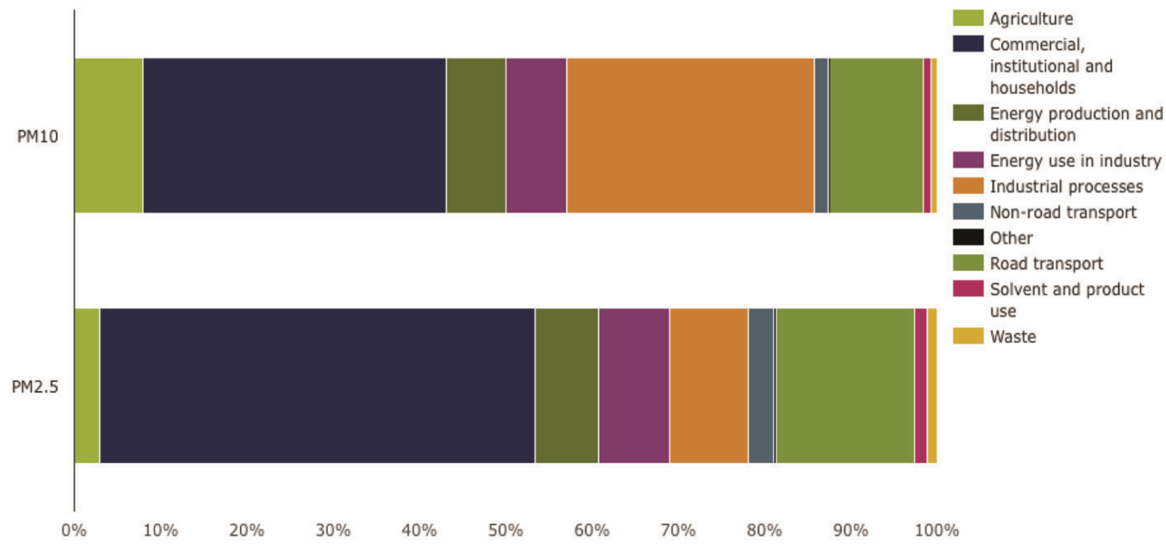

Figure 1. Sectoral share for emissions of primary particulate matter $PM_{2.5}$ and PM_{10} (source: European Environment Agency, May 2015).

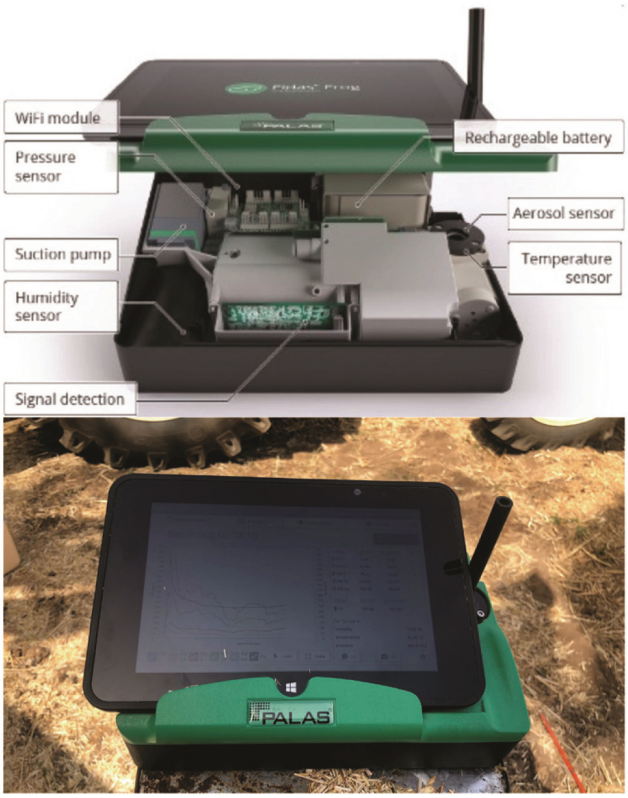

Figure 2. Real-time dust sampler (Fidas® Frog fine dust monitoring device).

measurements were taken, were considered as the independent parameters. The mean concentration of dust fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP was selected as dependent parameter in the present study.

Tables 1–3 present the results of this study. The mean dust concentration of both PM_1 and $PM_{2.5}$ during the operation of T2 and T3 remained the same, while T1 emitted lower concentration of PM_1. The mean dust concentration of PM_4, PM_{10} and TSP during the operation of T2 was observed to be the highest, whereas T1 emitted the lowest concentration of PM_4, PM_{10} and TSP. The mean concentration of PM_1 recorded at all the studied locations was observed to be similar, whereas the mean concentration of $PM_{2.5}$, PM_4, PM_{10} and TSP was highest at L3 and lowest at L1. This could be attributed to the difference in the construction of the threshers. The blower was close to the breathing zone of the farm workers in T2. Also, the blower speed of T3 was higher than that of T2, hence decreasing the likelihood of settlement of finer PM within the microenvironment of the thresher T3. The variation in the levels of dust concentration at different locations could be attributed to the variation in the direction of the wind in the open field, which cannot be controlled during any particular measurement.

The analysis of variance of the logged data revealed that a highly significant effect at 1% level of significance of the thresher was observed on mean dust concentration of PM_1, $PM_{2.5}$ and PM_4, and a significant effect on PM_{10} at 5% level of significance. No significant effect of the thresher was observed on the mean concentration of TSP recorded in this study. Thresher T2 was observed to be emitting overall higher PM emissions than the thresher T1 and T3. It was notable that varying the locations inside the microenvironment significantly affected only the mean concentration of $PM_{2.5}$ and PM_4 with a 5% level of significance, and had no significant effect on the mean concentrations of PM_1, PM_{10} and TSP. Among the locations L3 exhibited marginally higher value of mean concentration of $PM_{2.5}$, while both L1 and L2 had similar mean concentration of PM_4. The study also revealed that the combination of interaction of thresher and location had a highly significant effect on the mean concentration of PM_1, $PM_{2.5}$, PM_4 and PM_{10} at 1% level of significance and TSP at 5% level of significance. The highest mean concentration of both PM_1 and $PM_{2.5}$ was noted for the combination of T2 and L2 as well as T3 and L3. The highest mean concentration of PM_4 was observed for the combination of T2 and L2. The highest mean dust concentration of both PM_{10} and TSP was observed for the combination of T3 and L3. The lowest mean dust concentration of PM_1 was observed at all the locations where the data were recorded during the operation of T1. The lowest of mean dust concentration of $PM_{2.5}$, PM_4, PM_{10} and TSP was recorded at location L3 of the thresher T1.

The assessed mean dust concentration of $PM_{2.5}$ and PM_{10} within the microenvironment of various operating wheat threshers was compared with the standard limits of 24 h mean $PM_{2.5}$ and PM_{10} recommended by the National Ambient Air Quality Standards (NAAQS), given by the Central Pollution Control Board (CPCB)[7], New Delhi, NAAQS US EPA[8], and WHO air quality guidelines (AQGs)[9] (Table 4).

It was observed that the mean concentration of $PM_{2.5}$ from T1 did not exceed the limits given by NAAQS, US EPA and NAAQS, CBCP, but exceeded the limits given by WHO AQGs, whereas both T2 and T3 exceeded all the desired limits for the mean concentration of $PM_{2.5}$. The mean concentration of PM_{10} from all the threshers exceeded the desired limits. Hence, it can be stated that the commonly used wheat threshers emit hazardous amounts of PM into their microenvironment, which may prove to be dangerous to the health of wheat thresher operators.

The results of the present study show that the operation of commercial wheat threshers poses danger to the respiratory health of the operators. PM concentration emitted by the most of the commercial wheat threshers exceeds all the recommended standard exposure limits. Hence it is required to design and develop appropriate technologies which may help in curbing this issue of PM pollution within the microenvironment of the operating wheat threshers.

Table 1. Mean concentration (mg/m^3) of dust fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP emitted by the studied threshers

Level	PM_1	$PM_{2.5}$	PM_4	PM_{10}	TSP
T1	0.01	0.03	0.07	0.17	0.32
T2	0.02	0.14	0.25	0.93	1.86
T3	0.02	0.14	0.24	0.89	1.63

Table 2. Mean concentration (mg/m^3) of dust fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP at various locations studied

Level	PM_1	$PM_{2.5}$	PM_4	PM_{10}	TSP
L1	0.02	0.06	0.10	0.41	0.90
L2	0.02	0.12	0.23	0.62	1.22
L3	0.02	0.13	0.23	0.95	1.70

Table 3. Mean concentration (mg/m^3) of dust fractions PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP emitted by the studied threshers at various locations

Level	PM_1	$PM_{2.5}$	PM_4	PM_{10}	TSP
T1L1	0.01	0.06	0.13	0.35	0.59
T1L2	0.01	0.03	0.05	0.11	0.33
T1L3	0.01	0.02	0.03	0.04	0.05
T2L1	0.02	0.05	0.07	0.39	0.85
T2L2	0.03	0.31	0.61	1.70	3.27
T2L3	0.02	0.05	0.07	0.70	1.46
T3L1	0.02	0.07	0.11	0.50	1.26
T3L2	0.02	0.03	0.04	0.05	0.07
T3L3	0.03	0.31	0.58	2.12	3.58

Table 4. Standard limits of 24 h mean $PM_{2.5}$ and PM_{10} concentrations (mg/m^3)

	$PM_{2.5}$	PM_{10}
NAAQS, CPCB, New Delhi, 2009 (ref. 7)	0.06	0.10
NAAQS, EPA, US, 2020 (ref. 8)	0.035	0.15
WHO AQG, 2006 (ref. 9)	0.025	0.05

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