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Assessment of Dispersion, Retention Time and Fraction of PM10-20, and PM0.23-1 in Iron Ore Mines

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***Abstract*— The measurement study of the generation, dispersion and retention was carried out at Kiriburu (KIOM) and Meghahatuburu (MIOM), iron ore mines, Odisha state of India. The six days' average concentrations of particulate matter (PM) with two wide size ranges (PM10-20, and PM0.23-1) were monitored in two iron ore opencast mines. Monitoring was done for three days at the same location at each mines. The increment average concentrations ranged from 15.48-16.74 µg m-3 for PM10-20 and 13.03-29.35 µg m-3 for PM0.23-1 in KIOM and 88.65-92.8 µg m-3 for PM10-20 and 7.89-9.54 µg m-3 for PM0.23-1 in MIOM respectively. Require them to reach the surface are monitored on average 1-2 minute for PM. The retention time of fine PM varies 4-8 minute for KIOM and 1-12 for MIOM, while coarse PM varies 4-5 minute for KIOM and 1-10 for MIOM. The good relationship was obtained between retention time and retention fraction in both KIOM and MIOM. Fine PM shows the higher retention time as compared to coarse PM. The results of this study reveal that relationship between retention time and retention fraction with mining activity and gives the roughly information about time require by PM to reach the surface.**

Keywords*— *Dispersion, Retention Time, Fraction, Iron Ore Mines

I. Introduction

Field study of the generation of particulate matter (PM) from different mining operations was found to know contribution of PM through mining activities are done earlier in different countries [1, 2]. Some earlier research done on health effects due to generation of PM in and around mining activities [3]. This paper deals with measurement of PM with two size ranges (PM10-20, and PM0.23-1) in two iron ore opencast mines. Some studies show that coarse PM was obtained higher in concentration as compared to fine PM during mining operations [4]. However, this all studies not shown the retention time, retention fraction and require time of PM to reach the surface when mining activities running on the bottom area of mines.

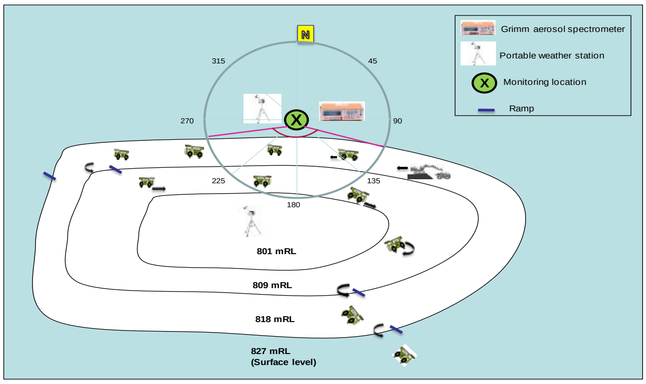
Earlier studies indicated concentrations generations due to individual mining operations and assessment of PM in and around the mining area [5,6]. Few dispersion pattern studies of PM in opencast mines are found to show the pit retention time [7,8]. Wings [7] given expression of particulate deposition, fraction of PM with result varies from 0.14 to 0.73, while Fabrick [8] proposed expression with wind speed, width and particle deposition velocity with results varies from 0.23 to 1.0 for 10 µm to 95 µm respectively. Recent no studies could not find to know pit retention studies in opencast mines. There is some gap to estimate the retention time and travel time of PM inside the opencast mines. The paper represents a wide ranging dust generation and dispersion of study in two iron ore opencast mine in India. This study aimed at estimating the incremental contribution of PM during mining activities inside the mines and to estimate travel time, retention time, and a retention fraction of PM to know how much concentration of PM comes from bottom to top, and require time to stay in the mines with concentration.

II. Methodology

A. Study Area

The research work on PM was carried out in two iron ore opencast mines, namely Kiriburu iron ore mines (KIOM) and Meghahatuburu iron ore mines (MIOM). It has a general trend N70E to S 70W with an average dip of 600 to the West for KIOM and N 370 E direction for MIOM.

(a)



(b)

Figure 1. Mine layout sampling location at KIOM; (a) pictorial view and (b) schematic diagram.

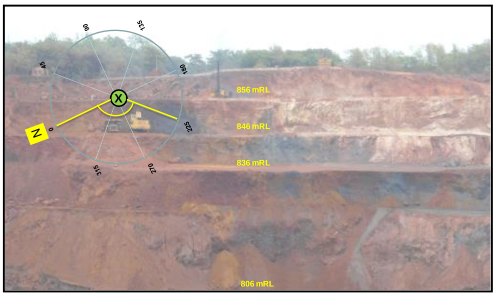


Figure 2. Mine layout and sampling location at MIOM

In KIOM, surface RL is 827 m. It has 3 benches with first and second bench 9 m high and the bottom third bench is 8 m high. The pit bottom RL is 801 m (Figure 1). In MIOM, At MIOM, the bench height is 10 m. At the experiment site surface RL is 856 m and RL of pit bottom is 806 m (Figure 2). The Grimm portable aerosol spectrometer 1.108 is used for measurement of PM concentration. The standardized dust mass/count measurement is in accordance with U.S Environmental Agency, (USEPA) or European approval for equivalent measurement EN 12341. For Meteorological measurement, WatchDog 2000 series portable weather stations of Spectrum Technology were used. During the study, PM and meteorological data were recorded at 1 min interval. The concentration is measured at surface level in both KIOM and MIOM. Sampling point X is located on the surface at the surface at 827 mRL in KIOM and 856 mRL in MIOM (Figure 1 & 2). The main source of PM generation is a shovel and dumpers is obtained. For a wind direction between E and SE for KIOM and SW-W-NNE for MIOM, dust generated due to mining activities by shovel also could be a prominent source, therefore recorded more closely the PM contributed from the mining activities.

III. Results

The meteorological (wind speed and wind direction) studies were carried out in two iron ore opencast mines with the help of the portable weather station, at the selected location in KIOM and MIOM. The maximum time (67%) of field study the wind speed is observed in calm condition in both KIOM and MIOM (Table 1).

Table 1. Statistical analysis of wind speed in KIOM and MIOM

Mines	Date	Wind Speed ($m\ s^{-1}$)		Percentiles		
		High	Low	25^{th}	50^{th}	75^{th}
KIOM	22/05/2013	6.11 $m\ s^{-1}$	0 $m\ s^{-1}$	0 $m\ s^{-1}$	0.83 $m\ s^{-1}$	1.66 $m\ s^{-1}$
KIOM	23/05/2013	8.33 $m\ s^{-1}$	0 $m\ s^{-1}$	0.27 $m\ s^{-1}$	1.11 $m\ s^{-1}$	2.5 $m\ s^{-1}$
MIOM	04/06/2013	3.06 $m\ s^{-1}$	0 $m\ s^{-1}$	0.28 $m\ s^{-1}$	0.83 $m\ s^{-1}$	1.11 $m\ s^{-1}$
MIOM	06/06/2013	3.89 $m\ s^{-1}$	0 $m\ s^{-1}$	0.00 $m\ s^{-1}$	0.28 $m\ s^{-1}$	1.11 $m\ s^{-1}$

Table 2. Statistical analysis of wind direction in KIOM and MIOM

Mines	Date	Wind directions	Favourable direction	Percentiles		
				25^{th}	50^{th}	75^{th}
KIOM	22/05/2013	5 to 353^0	From 112^0 to 247^0	224^0	251^0	298^0
KIOM	23/05/2013	5 to 358^0		210^0	252^0	292^0
MIOM	04/06/2013	12 to 348^0	From 225^0 to 360^0	69^0	90^0	116^0

MIOM	06/06/ 2013	0 to 360^0	266^0	300^0	324^0

In KIOM, the wind direction varied from 5 to 3530 and 5 to 3580, while 12 to 3480 and 0 to 3600 are recorded in MIOM (Table 2). The favourable wind direction to carry the PM from the source to the sampler are from 1120 to 2470 and from 2250 to 3600 for KIOM and MIOM respectively.

A. Background concentration of PM

To collect the information about background concentration, monitoring was started at about 20-30 minute before the start of mining operations. On 22 May 2013, background concentrations of PM at the mine were 17.87 µg m-3 for PM0.23-1, and 0 µg m-3 for PM10-20. On 23 May 2013, background concentrations were 14.51 µg m-3 for PM0.23-1, and 0 µg m-3 for PM10-20 for KIOM. On 4 June 2013, background concentrations of PM at the mine were 8.3 µg m-3 for PM0.23-1, and 0 µg m-3 for PM10-20. On 6 June 2013, background concentrations were 6.85 µg m-3 for PM0.23-1, and 0 µg m-3 for PM10-20 for MIOM.

B. Salient features of enhance concentration due to mining

The enhance concentration are monitored for different particle size (PM10-20, and PM0.23-1) during the field study in two iron ore mines (Table 3). The concentration of background shows a higher concentration in fine particles instead of coarse PM. However, the coarse PM is generating huge in quantity as compared to fine PM during mining activities. Earlier studies indicated the concentration of coarse PM generation in higher quantities during mining activities [4].

Table 3. Increment concentration profile of PM

Study site	Date of study	Incremental concentration of PM			
		First phase		Second phase	
		$PM_{0.23-1}$	PM_{10-20}	$PM_{0.23-1}$	PM_{10-20}
KIOM	22/05/13	1.97	5.08	6.2	9.70
KIOM	23/05/13	29.35	15.48	13.03	16.74
MIOM	4/6/2013	0.94	1.5	7.93	2.6
MIOM	6/6/2013	7.89	92.8	9.14	88.65

C. Travel Study

1) Travel time

The movement and dispersion of PM depend on their settling velocity (size) and meteorological condition. Generally fine size of PM takes more time as compared to the coarse size of PM due to their settling velocity. The travel time is measured when the PM reaches the surface and concentration are increasing simultaneously after the start of mining activities. Further, the coarse and fine PM took same travel time throughout the study period in both KIOM and MIOM. The results are shown PM with same size take more or less the same time to reach a higher bench from the source. The measured values of travel time of different size of PM are mentioned in Table 4.

Table 4. Time estimates for particle movement

Date	Time (Start of mining)	Time when elevated concentration was observed		Time when PM reaches the surface (minutes)	
		$PM_{0.23-1}$	PM_{10-20}	$PM_{0.23-1}$	PM_{10-20}
22/05/13	7:24	7:26	7:26	2	2
23/05/13	7:20	7:22	7:21	2	1
4/6/2013	7:53	7:55	7:54	2	1
6/6/2013	7:10	7:12	7:11	2	1

2) Retention time

The retention time of coarse and fine PM is measured during the fieldwork in two iron ore opencast mines (Table 5). Higher values of retention time indicate the higher exposure of PM of mine workers. In results, the fine PM shows the higher retention values as compared coarse PM that is indicated the exposure of fine PM is very high on mine worker as compared to coarse PM. However, the irregular results are obtained from this research, but the comparison of retention time for coarse and fine gives the information that fine PM takes more time to escape from the mines whereby it takes more time to remain inside the mines.

Table 5. Retention time of PM

Date	Time (When mining activities closed)	Time when particle concentration reached background concentration		Retention time (minutes)	
		$PM_{0.23-1}$	PM_{10-20}	$PM_{0.23-1}$	PM_{10-20}
22/05/13	7:44	7:48	7:48	4	4
23/05/13	7:58	8:06	8:03	8	5
4/6/2013	8:59	9:00	9:00	1	1
6/6/2013	8:48	9:00	8:58	12	10

3) Relationship between mining duration, particle travel time and retention time

Figure 3, indicated that the relationship between mining duration and particulate travel and retention time. The result of KIOM and MIOM clearly indicated that the retention time of PM is higher as compared to travel time of PM that shows PM takes more time to escape from the mines for both coarse and fine sizes of PM. However, particle retention time can be fluctuated with mining operations and duration of activity

(Figure 3).This result gives information about the movement / dispersion of both coarse and fine PM inside the mines, where the travel time, increase during mining operations, then it takes less time to escape from the mines and decrease the retention time.

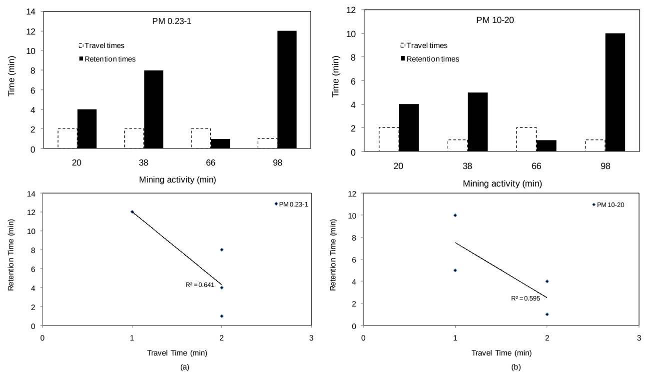


Figure 3. Relationship between mining duration vs. retention and travel time and Travel time vs. retention time; (a) PM0.23-1; (b) PM10-20

4) Relationship between retention fraction and retention time

The relationship between retention fraction and retention time indicated that retention fraction depends on retention time (Figure 4). Good relationship found in both coarse and fine PM in mines during field work in KIOM and MIOM. When the retention time increases, then the retention fraction of PM increase simultaneously (Fabrick, 1982; Winges, 1981).

IV. Conclusion

The measurement of travel time in both KIOM and MIOM gives the information about the movement and dispersion of PM from bottom to surface of the mines. The results showed that the travel time of coarse PM is higher as compared to fine PM during mining activities. The results are verified by other earlier research that measured higher concentration in coarse PM during the mining operations.

The retention time of PM varied from 4 to 8 minutes and 4-5 minutes in KIOM for PM0.23-1 and PM10-20 respectively, While 1 to 12 minutes and 1 to 10 minutes in KIOM for PM0.23-1 and PM10-20 respectively. The result of retention time is indicated that fine PM takes more time to escape from the mines as compared to coarse PM. The measurement of travel time and retention time is very important inside the mines, because long travel time and high retention time results in higher exposure of the PM inside the mines. Therefore, in opencast mines, the chances of exposure to PM on mine worker are very high when higher retention time occurs. In the case of fine PM, the retention time is very higher as compared to coarse PM that results in high potential to enter in lungs of mine workers. The relationship between retention fraction and retention time shows the good relationship with R2 of 0.976 and 0.973 for PM0.23-1 and PM10-20 respectively. That is indicated that retention fraction depends on retention time for both PM0.23-1 and PM10-20 size of PM. Therefore, higher retention fraction and time increases higher exposures of PM on mine worker that have higher possibility to enter into the lungs. The results presented in this research are focused on dispersion, retention time and travel time of PM with different size in two iron ore mines. The authors propose more studies in different type and deeper mines to know about dispersion, retention and travel time of PM with different sizes.

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