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Air Quality Impact of Sponge Iron Industries in Central India

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Abstract Emission load of particulate matter from 42 sponge iron industrial units located in clusters in the Indian State of Chhattisgarh was estimated to be 1,361 TPD. US EPA air pollution dispersion model ISCST-3 applied to predict the impact of the sponge iron industry emissions on ambient air quality showed contribution up to 546 μg/m^3 to the surrounding air basin causing the air quality exceeding the national ambient air quality standards. Electrostatic precipitator (ESP) has been suggested to all the above industrial units that would bring down the contribution to as low as 27 μg/m^3.

Keywords Sponge iron · Air quality · SPM · ISCST3

The sponge iron has of late come up as a major input material for steel making in India. As per the National Steel Policy issued by the Ministry of Steel – India will produce 110 million ton of steel by 2020 which will require 30 million ton of metallic sponge iron compared to 13.9 million ton produced in 2006 (Battacharjee 2007). Under the existing industrial policy regime of encouraging the growth of sponge iron industry in the country, the entrepreneurs are free to set up sponge iron plants anywhere in the country based on their commercial judgment. Such industries in India are located in clusters in the State of Chhattisgarh and utilize about one third of the total coal consumed in central India thus making it a major source of air pollution in the central India. As per the industries' data collected from Chattisgarh State Environmental Control Board (CSECB) Raipur, 100 TPD sponge iron plant consumes 160–175 ton of Hematite, 120–150 ton of coal, 3.5–5 ton of dolomite and 120–160 ton of water, everyday. In turn, it emits 180–200 ton of carbon dioxide, 1–10 ton of dust depending on working of electrostatic precipitator (ESP) and 25–30 ton of char every day.

The sponge iron industries cause potential health risk to the people living around them (Pandit et al. 2002). Air pollution impact of these units on the state capital city, Raipur, located 30 km south to these clusters became a high-profile issue for both the State and National governments. As a pre-requisite to suggesting an appropriate air pollution control strategy (Xue et al. 2003; Kim et al. 2002), the authors undertook a study in 2005 to make an assessment of the emissions from sponge iron industry and its impact on the ambient air quality of the area. The findings are discussed in this communication.

Materials and Methods

The area of interest was 30 × 30 km consisting of 3 industrial estates, viz. Siltara, Borjhara-Urla and Urla, and the capital city Raipur in the State of Chhattisgarh in central India. SPM emission load from the 42 sponge iron units clustered in the above three industrial estates were estimated using USEPA AP-42 emission factors (USEPA 1995). Data including fuel consumption for each sponge iron industry, air quality and meteorology in the region were collected from CSECB. CSECB regularly monitors ambient air quality at four sites, viz. Jai Stambh Square, Tatibandh & Birgaon and Woolworth representing

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Table 1 Status of air quality around the sponge iron industrial clusters

Location (year)	RSPM (μg/m^3)	SPM (μg/m^3)	SO_2 (μg/m^3)	NOx (μg/m^3)	AQI (mixed area)	AQI (industrial area)
Birgaon (rural residential area)						
1997	–	249.2	9.2	27.4	60	–
1998	–	265.7	9.8	35.4	66	–
1999	–	331.6	9.8	36.8	79	–
Tatibandh (urban residential area)						
1999	220.9	284.2	7.5	23.0	156	–
2000	210.2	415.9	11.3	37.5	182	–
2001	171.2	294.9	10.3	39.2	145	–
2002	189.3	306.2	8.9	35.4	152	–
2003	233.3	350.8	8.3	37.2	179	–
2004	268.6	394.1	10	37.5	202	–
2005	210.8	311.3	11.2	36.3	163	–
2006	165.1	271.5	11.7	33.5	136	–
Jai Stambha Square (urban commercial area)						
2005	176.2	259.6	11.3	34.8	139	–
2006	131.1	218.8	11.2	32.5	112	–
Woolworth (Industrial area)						
1999	201.8	329.4	9.2	33.4	–	78
2000	206.3	279.8	9.5	37.2	–	77
2001	171.9	262.4	9.3	39.6	–	69
2002	219.3	295.7	8.7	37.1	–	81
2003	239.4	349.8	8.3	38.3	–	89
2004	282.1	404.8	10.3	37.5	–	102
2005	234.0	345.1	10.8	36.3	–	87
2006	193.2	299.9	11.1	33.0	–	75

Source: CSECB, Raipur

commercial, residential and industrial area respectively. On site data were also collected from randomly selected sponge iron units by conducting stack emission monitoring. Ambient air quality was also monitored. The results were comparable to those obtained by CSECB.

Air quality index was estimated from the long-term air quality data as:

$$\mathrm{AQI} = 1/4 * \left(I_{\mathrm{SPM}}/S_{\mathrm{SPM}} + I_{\mathrm{RPM}}/S_{\mathrm{RPM}} + I_{\mathrm{SO_2}}/S_{\mathrm{SO_2}} + I_{\mathrm{NO_X}}/S_{\mathrm{NO_X}}\right) * 100$$

where I_{SPM}, I_{RPM}, $I_{\mathrm{SO_2}}$ and $I_{\mathrm{NO_X}}$ are annual average concentration of suspended particulate matter (SPM), respirable particulate matter (RPM), sulfur dioxide (SO_2) and oxides of nitrogen (NO_X) respectively, and S_{SPM}, S_{RSPM}, $S_{\mathrm{SO_2}}$ and $S_{\mathrm{NO_X}}$ are corresponding Indian National Ambient Air Quality Standards (NAAQS).

Emissions load were calculated as:

$$E = A \times \mathrm{EF} \times (1 - \mathrm{ER}/100)$$

where E is the emission load, kg per day; A the activity rate, production in ton per day; EF the emission factor, kg per ton of production, and ER is the overall emission reduction efficiency, %.

US EPA air pollution dispersion model ISCST-3 was used for predicting the particulate matter impact on the

Table 2 SPM emission load from different industrial estates

Industrial estate	Dust emission load (TPD)
Siltara	505.57
Borjhara-Urla	224.11
Urla	631.97

Table 3 Stack emission characteristic of sponge iron industries

Parameters	Range	Average
Stack height (m)	35–62	47
Stack diameter (m)	1.08–3.1	1.76
Exit gas velocity (m/s)	4.06–5.82	5.37
Exit gas temperature (K)	365–399	392.2
SPM emission rate (g/s)	0.26–3.91	1.57

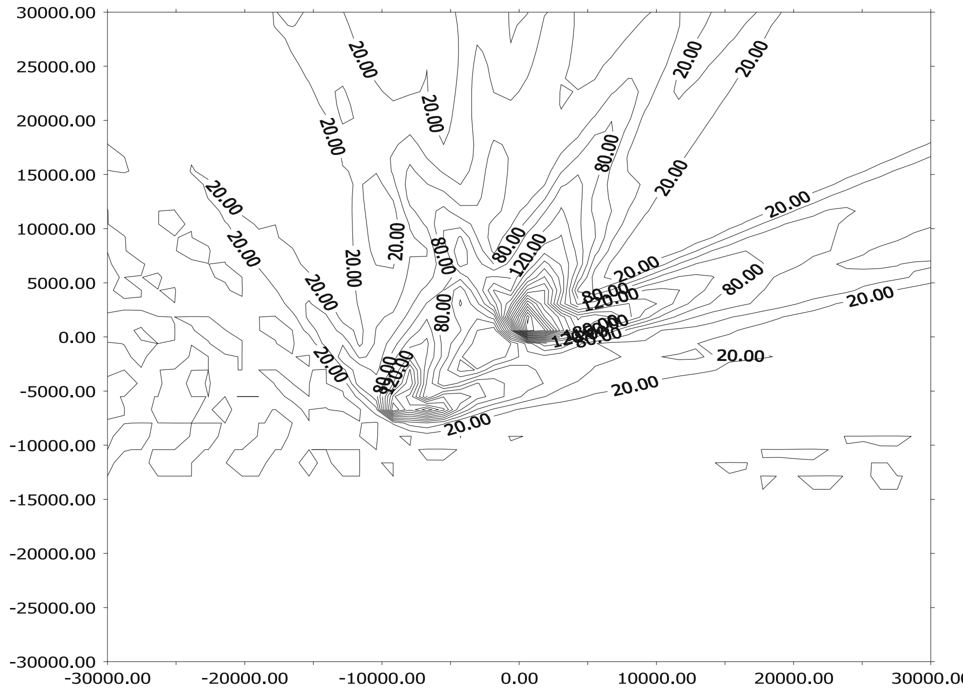

Fig. 1 Ground level concentration of SPM when no ESP is working (μg/m^3)

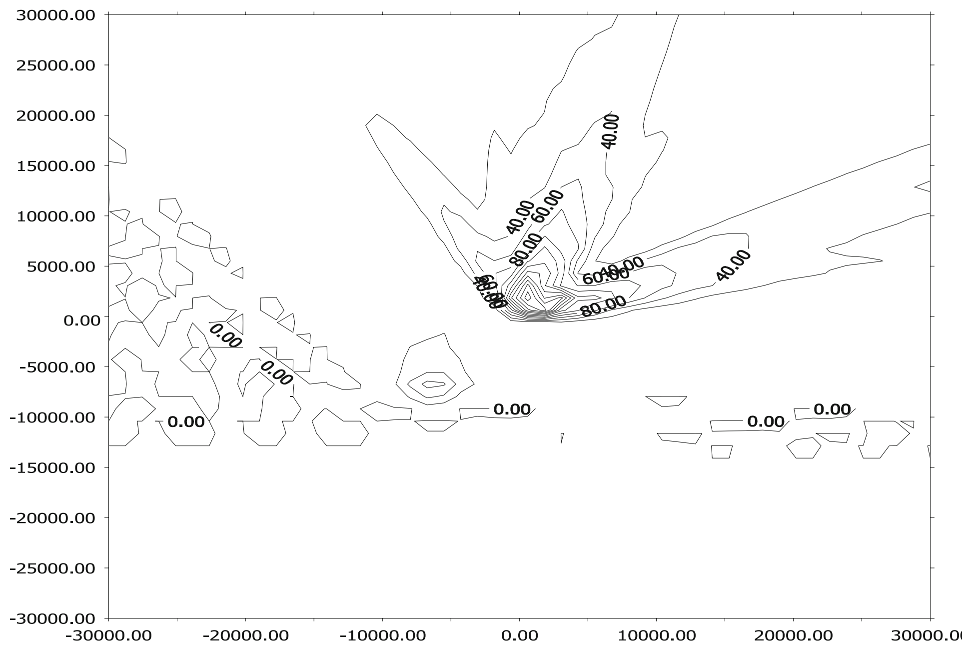

Fig. 2 Ground level concentration of SPM when 50% ESPs are working (μg/m^3)

ambient air of the surrounding air basin. Particulate emission control through electrostatic precipitator (ESP) was considered for the sponge iron units and following four scenarios were simulated:

1. None of the ESPs is working
2. 50% ESPs are working
3. 75% ESPs are working
4. All the ESPs are working

Results and Discussion

The air quality index was calculated for all the sampling stations (Table 1) and compared with the five categories i.e. 0–25, 26–50, 51–75, 76–100 and greater than 100 representing clean air, light, moderate, heavy and severe air pollution respectively (Mukumd Rao et al. 2004). The Birgaon rural residential area was moderate to heavily

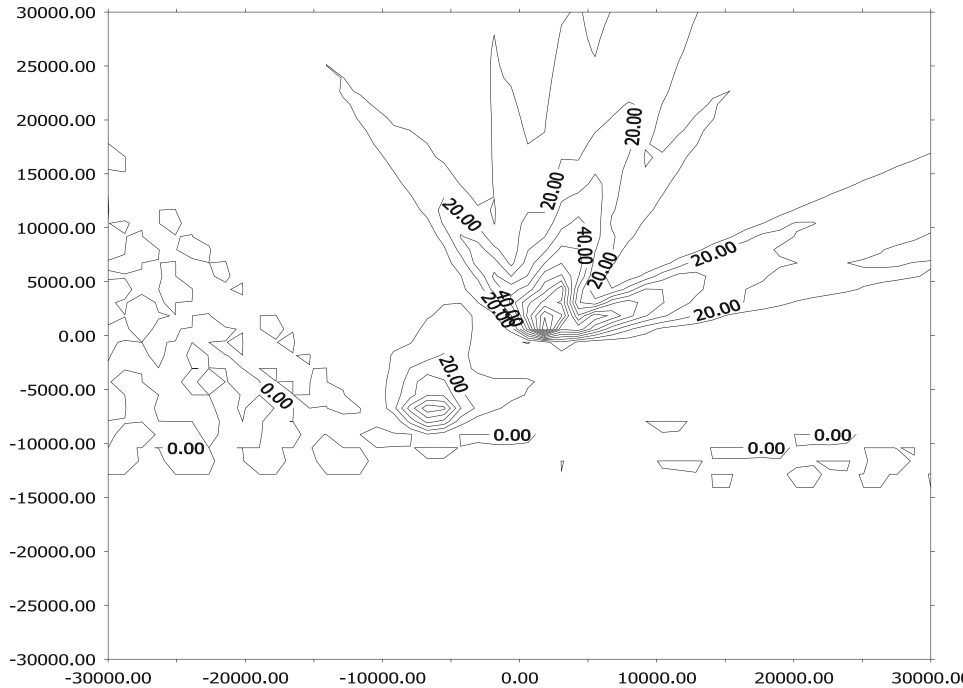

Fig. 3 Ground level concentration of SPM when 75% ESPs are working (μg/m^3)

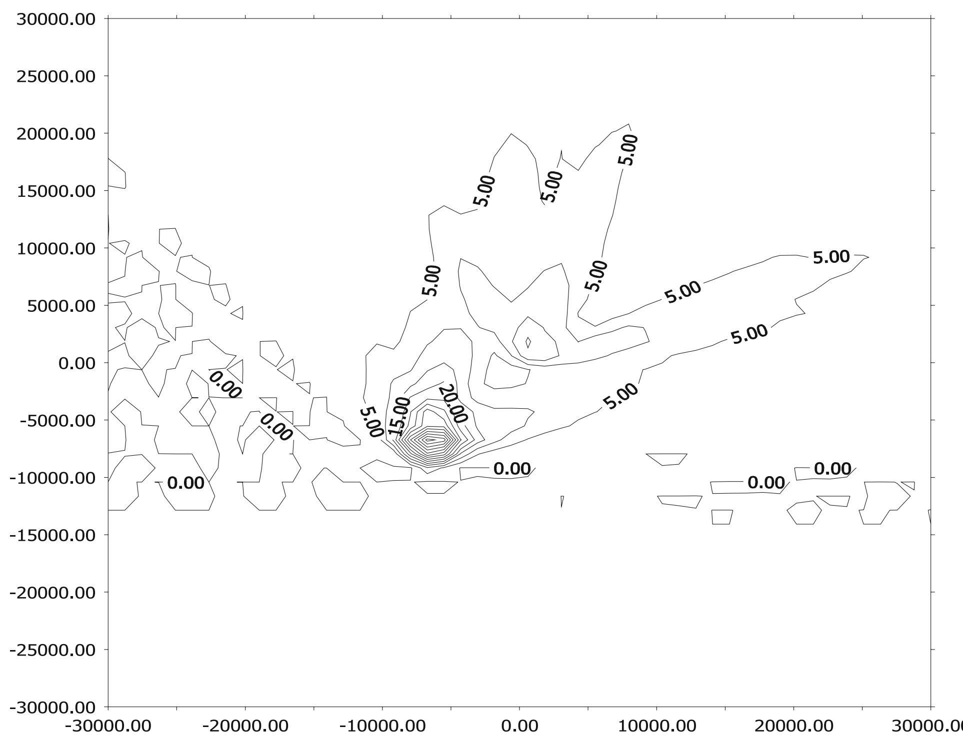

Fig. 4 Ground level concentration of SPM when all ESPs are working (μg/m^3)

polluted, Tatibandh urban residential area and Jaistambh square urban commercial area were severely polluted. The AQI for industrial area showed heavy air pollution except moderate in 2001. This is due to relaxed national ambient air quality (NAAQ) standards followed in India for industrial areas.

The SPM emissions estimates from the sponge iron industries in the 3 industrial estates are shown in the Table 2. Out of the total 1,361 TPD SPM emissions, 47% is contributed by the Urla industrial estates alone. The other two estates, Siltara and Borajhra-Urla contribute 37% and 16%, respectively. Impact of these emissions on

Table 4 Impact of SPM emissions on the surrounding air basin

Distance (m)	Direction	SPM concentration (μg/m³)					
		0.0	1,000	2,000	5,000	10,000	30,000
Scenario 1	N	201	546	309	181	82	28
	S		3	1	0	0	0
	E		165	184	0	0	0
	W		27	27	39	39	0
Scenario 2	N	43	449	221	99	52	17
	S		2	1	0	0	0
	E		8	91	0	0	0
	W		18	5	8	2	0
Scenario 3	N	13	47	30	19	12	7
	S		2	1	0	0	0
	E		8	91	0	0	0
	W		4	5	8	2	0
Scenario 4	N	7	27	17	10	4	3
	S		2	1	0	0	0
	E		8	10	0	0	0
	W		4	5	8	2	0

ambient air quality of the surrounding air basin was predicted using model ISCST3. The stack emission characteristics are shown in Table 3.

ISCST3 was run for 30 km × 30 km grid. The results of ISCST3 are shown in Figs. 1–4. The three industrial estates, Siltara, Borajhra – Urla and Urla are located at 0.5 km SE, 1 km SW and 20 km SW respectively. Distance and directions are with reference to the grid center coordinate (0, 0). Figure 1 represents the ISCST3 results for scenario 1 when none of the ESPs is working. The maximum ground level concentration of 546 μg/m³ SPM occurred at 1,000 mN. Other concentrations, their distances and directions are presented in Table 4. Figure 2 represents the scenario when 50% ESPs are working. In this case, 17%–45% reduction in the impact is achieved within 1–10 km N. However the ground level concentration exceeded the NAAQS of 200 μg/m³. Model results for scenario 3 in Fig. 3 showed an impact reduction of 55%–90% bringing down the ground level SPM concentration well below the NAAQS. This shows that at least 75% of the sponge iron industries must be fitted with ESP and their ESPs must be fully working for keeping the impact within the NAAQS. The model results for scenario 4 when all the ESPs are working, as presented in Fig. 4, show that the impact on ambient air quality could be brought down to 4–27 μg/m³ within 1–10 km N, creating space for capacity expansion. As far as the impact on the state's capital city Raipur is concerned, the wind direction distribution in the air basin showed that about 30% time during summer and 15% during winter (Thakur et al. 2004; Chaulya et al. 2001), the winds blow towards it. The model results for such conditions showed an impact of 28 μg/m³ in the absence of ESPs which could be brought down to an insignificant level of 3 μg/m³ by making all the ESPs working.

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