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Work zone noise levels at Aarti steel plant, Orissa and its attenuation in far field

S. Kerketta[1], P.K. Dash[2] and L.T.P. Narayan[2]

[1]Ministry of Environment and Forests, Eastern Regional Office, Chandrasekharpur, Bhubaneswar - 751 023, India
[2]Aarti Steels Limited, Ghantikhal, Cuttack - 754 029, India

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Abstract: *The outdoor noise levels from the various work places of the integrated steel plant were measured. The average noise level (L_{eqst}) at the outdoor was found between 59-84 dBA. The combined noise level (L_{eq}) of the plant was 90 dBA and 92 dBA on 1.12.2006 and 16.12.2006, respectively. The noise levels in the far fields were found between 43-70 dBA for daytime and meet the noise quality for industrial (75 dBA) area and residential (55 dBA) areas. Maximum attenuation of 47-49 dBA of noise level was found at worker's colony and may be attributed mainly to the ground absorption. As the air quality standards of the area in respect of noise in the ambient is tending to increase, engineering control measures suggested to the noisiest equipments for better economically viable and higher payback period.*

Key words: *Outdoor noise, Far fields, Attenuation, Ground absorption*
PDF of full length paper is available online

Introduction

Substantial research works have been carried out on rail and road traffic noise, aircraft noise (Arnberg *et al.*, 1990; Babisch *et al.*, 2005; Babisch, 2008; Banerjee *et al.*, 2008; Bluhm *et al.*, 2004; Bolt *et al.*, 1969; Brooker, 2006; Griefahn *et al.*, 2000; Jabben and Potma, 2004; Jarup *et al.*, 2005; Landon *et al.*, 2005; Lecher and Bottledooren, 2006; Ouis, 1999; Raggam *et al.*, 2006) and their impact to the dwelling communities (Clark *et al.*, 2006; Franssen *et al.*, 2004). Noise pollution has also been studied in cities (Kisku *et al.*, 2006; Pandya *et al.*, 1997; Singh *et al.*, 2000; Sobotova *et al.*, 2006) and industries like paper mills (Toppila *et al.*, 2001), textile plants (Bedi, 2006), thermal power plants (Kisku and Bhargava, 2006; Parzych *et al.*, 1995; Putnam *et al.*, 1996), refineries (Wachasunder, 2004), saw mills, printing presses (Boateng and Amedofu, 2004) and mines (Kanchan *et al.*, 1998; Kisku *et al.*, 2002; Mandal and Srivastava, 2006; Pal and Saxena, 2000; Vardhan *et al.*, 2004). Research work has also been done on noise generation (sources), it's values have been compared with the Indian conditions (Murthy *et al.*, 1999; Prasannakumar *et al.*, 2008) and impact on the workmen. Therefore, regular training and awareness programme (Parikh and Saiyed, 2003) should be imparted on safety (Kazi, 2003; Melamed *et al.*, 2001) and health hazardous (Babisch, 2006; Boman *et al.*, 2005; Ising and Kruppa, 2004; Williams *et al.*, 2004; Willich *et al.*, 2006) due to noise exposure both to the industrial workers (Boateng and Amedofu, 2004) and to the residential communities (Ahmed *et al.*, 2004; Datta *et al.*, 2006; Pal *et al.*, 2000; Holgers and Pettersson, 2005).

Worldwide, 16% of the disabling hearing loss in adults is attributed to occupational noise, ranging from 7-12% in the various sub-regions. The effects of the exposure to occupational noise are longer for males than females in all sub-regions and higher in the developing countries (Nelson *et al.*, 2005). Similarly, traffic noise received by the inhabitants living at roadside mainly depends on distance from road, diurnal variation and character of the traffic and street configuration (Leong and Laortanakul, 2003). 25% of the European population is exposed to transportation noise at over 65 dBA and more than 30% are exposed at night to noise levels exceeding 55 dBA and disturbing to their sleep (Lambert and Vallet, 1994; Griefahn and Spreng, 2004; Maschke *et al.*, 2004). There are evidences that a small number of individuals are highly susceptible to noise (Archibald, 1964; Michaud *et al.*, 2005; Picard *et al.*, 2008). Studied on animal behaviour (Rabat *et al.*, 2006; Samson *et al.*, 2007) like little Cotton rats and Sigmodon hispidus, living closer to the airport, are more timid and less social then their counterparts farther from the noise (Kavaler, 1975). Physiological responses that wildlife generally experience when introduced to human-made noise include an increase in heart rate and alteration of metabolism and hormonal balance (Busnel and Fletcher, 1978).

In our country, all the integrated steel plants have been set up in the rural areas because of availability of coal, cheap labourforce, plenty of surface water and abundance of land. As the industries grow up, it leads to development of large-scale habitations in the area. Noise pollution, one of the environmental pollutions, remains unattended and ignored because its impact to the community is not felt immediately. Therefore, a study was planned on noise generation from the various sources of the plant and their attenuation in the far fields.

Materials and Methods

M/s Aarti Steel Ltd. (Steel and Power) is an Integrated Steel plant of 0.5 MTPA installed capacity and 50 MW Captive Power Plant located at village Ghantikhal, Athagarh, Cuttack, Orissa, India. It is located between 20°30′30″ to 20°31′15″ North latitude and between 85°44′15″ to 85°44′45″ East longitude over an area of 283.40 ha. The local climate is hot and humid and temperature varies between 10°C to 48°C throughout the year. It is 6.5 km away from NH-42 and the East Coast Railway line is passing near to the project. River

*** Corresponding author:** suna1466@rediffmail.com

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Mahanadi controls the entire drainage system of the area. It is in a small hillock. One side of the hill slope is towards Mahanadi drainage *i.e.*, in NE-SW direction where the project site is located. Other side is towards NH-42 where workers colony and two villages *i.e.*, Ghantikhal and Gourangapur (of total population 1100) are located. At present, the total numbers of employees are 2000 including contractual workers. The major plant facilities of the project are atmospheric fluidized bed combustion (AFBC) boiler, coal washery, direct reduced iron (DRI) kiln, waste heat recovery boiler (WHRB), turbine generator (TG) set, submerged arc furnace (SAF) (Ferro Alloys Plant), steel melting shop (SMS) with induction furnace (IF) and laddle furnaces (LF).

Electric generators, venting steam, mechanical fans, water falling in cooling tower, loading/unloading of raw materials, crushing and screening of coal, *etc.*, do produce noise in the plant. A total of 9 stations were taken in the work zones to evaluate the present noise status of the power plant. Similarly, 4 stations representing industrial (time office, purchase department main gate and central store house) and one station representing residential areas (worker's colony) were taken to measure the present ambient noise.

All the measurements were carried out outdoors. Sound Level Meter (Model SL-4005, Metravi make) was used for monitoring noise levels. The sound level meter was placed at 1.2 to 1.5 m above the ground surface, one meter away from each sides of the source and free from any obstacles or any reflecting objects. Since, the main objective of this paper is to obtain attenuation of noise levels at the far fields, a single point source model was approximated for all the industrial facilities and measured the noise levels at a distance closest to the source (Parzych, 1999). Measurement was carried out in clear sky weather and sustained wind to avoid background noise level difference of more than 10 dBA (Heimann, 2003). The details of noise monitoring stations were given in Table 1.

The sequence of operation of all the process units is as per the Station code *i.e.* from N1 to N9. Monitoring of noise level was carried out for two days *i.e.* on 01.12.2006 (1st) and 16.02.2006 (2nd) as per the time mentioned in columns 4 and 5 of Table 1. Measurements of noise for duration of 15 minutes were carried out for 20 seconds interval in each direction. Thus, the data measured were evaluated for L_{eqst} (average noise level in each direction and at each location) (Parzych, 1999) and L_{eq} (combined noise level of the plant). The following equations were used to evaluate L_{eqst} and L_{eq} (Irwin and Graf, 1979):

$$L_{eqst} = 10 \log_{10} [1/N\Sigma 10^{Li/10}] \quad \ldots (1)$$

$$L_{eq} = 10 \log_{10} \Sigma 10^{Li/10} \quad \ldots (2)$$

Where,

L_{eqst} = Average noise level, dBA

L_{eq} = Combined noise level, dBA

L_i = the i^{th} sound pressure level, dBA

i = 1, 2, 3, ...N

N = number of monitoring stations

Results and Discussion

The intensity and propagation of combined noise level (L_{eq}) of the power plant may depend on angle of incidence of the sound waves, acoustic properties of the ground, geometry of the inclined surface (which may act as barrier) and meteorological parameters (Padmnabhmurthy and Mishra, 2000). The wind direction on both the days was found to be NW-SE and it was the most dominant direction on the day of conducting noise survey. As per Irwin and Graf (1979), the wind direction varies in each and every moment and thus, sound wave may propagate in various other directions. The alignment of each unit is also different and this factor may also influence the refraction of sound wave in outdoors. So, the Directivity Factor (Irwin and Graf, 1979) was evaluated to ascertain the propagation of sound wave in different direction as provided in Table 2. The Directivity Factor was found to be from 0.63 to 2.0 and the highest values were obtained in South and East directions. It was noticed that NW-SE was the prevailing direction of the sound wave of the combined noise of the plant as if an entertainment loudspeaker is placed in the plant facing SE direction.

Table - 1: Name of the monitoring stations

Station code	Station name	Category of area zone	Time of monitoring	
			1st	2nd
N1	Coal washery	Work zone	06.00 am	10.00 am
N2	AFBC boiler	Work zone	08.00 am	11.00 am
N3	DRI kiln	Work zone	10.00 am	12.00 noon
N4	DRI bag filter	Work zone	12.00 noon	01.00 pm
N5	WHRB boiler	Work zone	02.00 pm	02.00 pm
N6	TG set	Work zone	04.00 pm	03.00 pm
N7	SAF (FAP)	Work zone	06.00 pm	04.00 pm
N8	SMS (IF)	Work zone	08.00 pm	05.00 pm
N9	SMS (LF)	Work zone	10.00 pm	06.00 pm
N10	Time office	Industrial	07.00 am	10.00 am
N11	Purchase department	Industrial	09.00 am	12.00 noon
N12	Main gate	Industrial	11.00 am	02.00 pm
N13	Central store house	Industrial	01.00 pm	04.00 pm
N14	Workers' colony	Residential	03.00 pm	06.00 pm

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Table - 2: Outdoor work zone noise level

Station code	Average noise level (L_{eqst}), dBA								Average noise level (L_{eqst}) at each station, dBA	
	East		West		North		South			
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
N1	82	81	83	81	83	79	82	79	82	80
N2	84	85	83	84	84	85	84	84	84	84
N3	82	74	81	76	82	76	82	75	82	75
N4	84	75	84	75	84	77	84	78	84	76
N5	81	73	82	74	81	74	81	76	81	74
N6	85	84	84	83	85	84	85	84	84	84
N7	67	59	68	57	70	60	70	58	68	59
N8	82	79	81	79	82	78	82	80	82	79
N9	82	78	81	79	81	80	81	78	81	79
L_{eq} of the plant, dBA									**90**	**92**

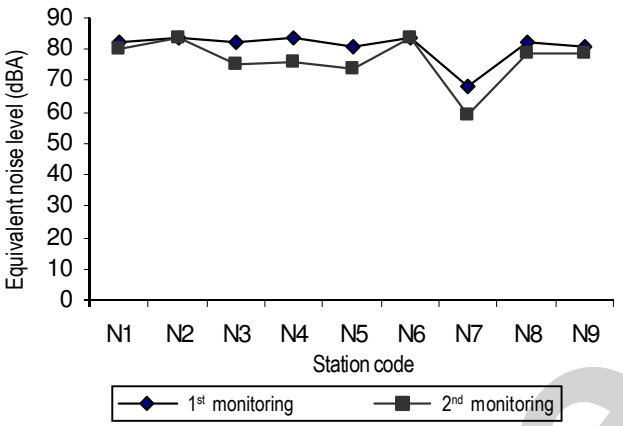

Fig. 1: Work zone noise levels at outdoors

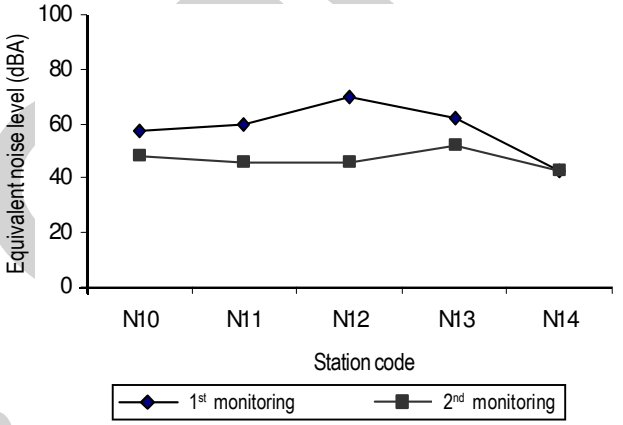

Fig. 2: Ambient noise levels

All the equipments are of different sizes and thus, do not radiate sound wave uniformly from its entire surface area. Therefore, average noise level (L_{eqst}) at each location was evaluated which much depends on its overall surface area, radiates to the far field and reaches the community. By using equation (2), the combined noise level (L_{eq}) of the plant was arrived as 90 dBA and 92 dBA on 1st monitoring and 2nd monitoring, respectively. The noise levels at stations N10 to N13 (industrial areas) were found to be from 46 to 70 dBA. The highest noise level was recorded to be 70 dBA at station N10 and may be attributed to high vehicular traffic (including plying of two wheelers, light motor vehicles and a high percentage of heavy trucks) instead of L_{eq} of the plant alone. The noise level at station N14 (residential area) was 43 dBA. All the industrial stations and residential station meet the Ambient Air Quality standards in respect of noise (NPR, 2000) for daytime in the industrial (75 dBA) and residential (55 dBA) areas, respectively. In similar situation, Naik and Purohit (2003) studied the noise levels in the residential areas due to development of industries around it. The finding reveals that average noise level in the residential areas varies from 55.03 to 67.35 dBA during daytime and it is attributed mainly to the development of industries like Rourkela Steel plant and growing of other downstream industries (Naik and Purohit, 2003). Similarly, Leong and Laortanakul (2003) find that noise level at various traffic zones of Bangkok Metropolitan Region varies from 72.8-83.0 dBA during daytime and is mainly due to heavy vehicular traffic. He also points out that older adults of 46-55 years living in the urban sites were found to have highest risk of traffic noise induced hearing loss (Leong and Laortanakul, 2003). Pandya and Srivastava (1999) also agree that in the residential areas adults having age more than 40 years are highly affected due to noise exposure. Thus, the present development in the vicinity of the project may result in significant increase in noise levels in future. Therefore, the project requires to take appropriate control measure at source, path and receiver end, so that the stipulated standards of air quality in respect of noise at far fields are complied.

Larsson (1998) studied that the wind and temperature gradients cause refraction of the sound rays, and hence influence the sound level and is also agreed by Tanaka and Shiraishi (2008). As depicted in Fig. 1, 2 the noise levels in the work zone areas and in the far fields were found to be lower on 1st monitoring than 2nd monitoring. Harris (1966) also agrees that the difference of outdoors sound levels for both at high and low frequencies vary both over the day and year and thus this noise level difference noticed may be due to the variations in the atmospheric temperature and Relative Humidity on both the days (Kneser, 1933). The attenuation in the far fields was found to be from 22 to 49 dBA on 1st monitoring and that was from 42 to 47 dBA on 2nd monitoring and is shown in Fig. 3, 4.

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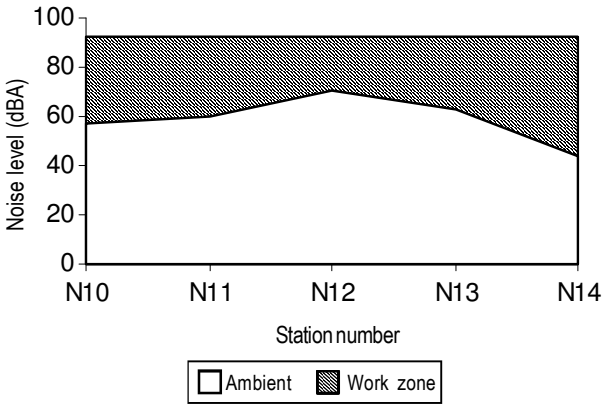

Fig. 3: Attenuation on 1st monitoring

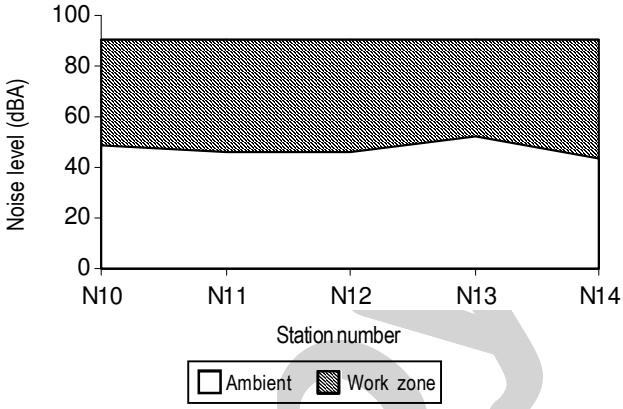

Fig. 4: Attenuation on 2nd monitoring

This may be attributed to the factors like acoustical properties of the ground, geometry of the inclined surface which may be acting as barrier, propagation of noise through a number of buildings, meteorological parameters, *etc.* (Heimann, 2003; Ingard, 1953). Lyon (1973) also reveals in his paper that attenuation of 10 dB due to spreading, 1 dB due to air absorption and 10-15 dB due to absorption by ground may be accounted in the propagation of highway noise. Therefore, if these problems are approached systematically, accurate prediction of the effects of noise sources and accordingly necessary control measures may be taken and thus, control the distribution of noise levels in the far field areas.

The previous study reveals that attenuation due to ground absorption is negligible within a distance of 30 to 70 m of the source. In the range of 70 to 700 m, attenuation can be referred to a unit distance of, say, 100 m unless the total attenuation exceeds 30 dBA (Kurze and Beranek, 1988). An attenuation of 5 to 10 dBA over a distance of 250 m has been observed in the frequency range from 100 Hz to 6.3 kHz (Ingard, 1953) with values as high as 50 dBA in the range of 3 to 6 KHz (Harris, 1963; Wiener *et al.*, 1965). Except station N14, stations N10 to N13 are located within 100 m distance from the plant. So, the ground effects may be neglected for stations N10 to N13. However, attenuation of 47-49 dBA at N14 was found and this affect may be due to the ground absorption, because thick undergrowth has come up between the power plant and the Workers' colony.

Thus, the distances of the noise sources very at sensitive receptor location, in other words when the sound wave propagates into the far fields, the presence of buildings/structures in the area introduces attenuation and thus, experiences low noise level. Bolt *et al.* (1969) studied that attenuation of 2 to 10 dBA is found within 100 m of sidewall of a highway that is elevated. Beyond 100 m, the noise radiation by elevated ground level is the same. As the stations N10 to N14 are located at relatively elevated ground surface from the noise source, this attenuation may also be attributed to ground elevations as experimented by Shaw and Olson (1969) in a busy highway to find out the attenuation due to the presence of the intervening buildings and was found to be 15 to 20 dBA at a distance of 600 m.

The L_{eq} of the power plant is evaluated to be 90 dBA and 92 dBA on 1st monitoring and 2nd monitoring, respectively and stations N2 and N6 have the largest contribution to the combined sound level of the facility, while N7 has the least impact on the combined sound level on both the days. If engineering control measures are adopted and a constant noise reduction of 6 dBA is applied to each unit then the L_{eq} of the plant would achieve 85 dBA noise criteria. But, if further noise control criteria is applied to all the sources then it is unnecessary, economically not viable and thus, higher payback period. Moreover, the values of noise level at industrial and residential areas are less than 75 dBA (for daytime) and 55 dBA (for daytime), respectively. Therefore, it may not be a wise decision forcing additional noise control to other units by adopting engineering control to reduce noise levels below the standards. However, it is better to treat N2 and N6 (noisiest equipments) so that the L_{eq} would fall below 85 dBA criteria and far fields levels may be further reduced.

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