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Pollution Monitoring, Dispersion Modeling and Proposed Siting Criteria for New brick Kilns

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Abstract: *Stack and ambient air quality monitoring studies were carried out for individual and clusters brick kilns and data was used for air dispersion modeling. Gaussian model was used to calculate the concentration of suspended particulate matter at ground level. The modeling was carried out assuming highly unstable conditions in day time (at 14.30 PM) and the night time modeling was carried out assuming highly stable conditions (at 2.30 AM). The results of modeling for ground level concentration (GLC) were utilized for developing the criteria for installation of new brick kilns in Uttar Pradesh, India. Different distances for orchard, hospital and school, buildings, residential area PWD road, National highway etc. were recommended for installation of new brick kilns. To reduce the ill effect of stack emission, on the buildings, human health, flora and fauna, good house keeping practices have also been proposed.*

Keyword: *Brick kiln, suspended particulate matter, pollution, ground level concentration, stack, ambient air quality, emission standards*

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I. Introduction

Brick making is a traditional, unorganized industry generally confined to rural and semi-urban areas and there are around one lakh brick kilns in India. India is the second largest producer of clays bricks in the world after china with an estimated production of around 140 billion bricks per year. The Gangetic plain of North India accounts for about 65% of the total brick production (Aslam et al. 1992). The basic raw material for brick making is clay and fuel required is coal and biomass. Brick making is a highly energy intensive process and consumes about 24 million tones of coal and 2.6 million tones of biomass per year.

As per data of U. P. State Pollution Control Board, Lucknow, there are about 10,000 brick kilns in Uttar Pradesh. At present mostly brick kilns are of bull's trench type with fixed chimney and constructed with gravitational settling chamber as pollution control device. The minimum stack height is 27 meter and the gravitational settling chambers are constructed as per CBRI, PSPCB and AMU designs. The main fuel used is coal and coal briquettes, wood, biogases, rice husk etc. The quality of coal used show large variations in calorific value, ash content, volatiles, sculpture content etc. Mostly the brick kilns are situated in rural areas or in sub urban areas. All the kiln operations right from digging of earth to unloading of fired bricks from the kiln are accompanied by evolution of dust which makes the whole workplace dusty. Air pollution in brick kilns is produced both through stack emissions as well as fugitive emissions. Practically, noise pollution is negligible from brick industry. Stack emission from brick kiln consists of mainly coal fines, dust particles, organic matter and small amounts of acidic gases such as SO_2, NO_2, NO_x, H_2S, CO etc (Aslam 1993 and Aslam et al. 1994). Other sources of pollution are solid waste generation from burning of fuel and fugitive dust emission mainly from unloading of fired bricks from the kiln. The effect of particulate matters emitted from the stack of brick kilns is more on the vegetation where kilns are constructed in clusters as compared to scattered brick kilns. Fugitive dust emission also affects the occupational health and surrounding vegetation (Minocha et al. 2001 and Jain et al. 2010). Present papers deals with a detailed study of brick kilns carried out in Uttar Pradesh, India regarding environmental status of brick kilns, monitoring of stack and ambient air quality along with air dispersion modeling. The objective of the study was to provide the recommendations regarding installation of a new brick kiln and adoption of good house keeping practices in and around the brick kilns.

II. Emission Standards

Ministry of Environment and Forests (MoEF), GOI issued a notification, S.No. 74 vide notification GSR No. 176 (E) dated April 03, 1996 on emission standards for brick kilns. The notification presents standards for maximum allowable suspended particulate matter (SPM) concentration in flue gases (Table 1) and minimum stack height for brick kilns (Table 2). These emission standards are mainly for Bull's Trench kilns and cover emissions of suspended particulate matter (SPM) which were considered to be major emissions from brick kilns.

It is mandatory for each brick kiln owner to construct a kiln with fixed chimney of stipulated height, to install gravity settling chamber (GSC) - a pollution control system to keep the SPM levels below the enforced standards.

Table 1. Emissions standards for brick kilns

Size	Kiln Capacity	Maximum concentration limit of SPM
Small	Less than 15,000 bricks per day (less than 15 ft trench width)	1000 mg/Nm^3
Medium	15,000 to 30,000 bricks per day (15-22 ft trench width)	750 mg/Nm^3
Large	More than 30,000 bricks per day (More than 22 ft trench width)	750 mg/Nm^3

Note: The above emissions limits are achievable by installing fixed chimney/high draft kilns and/or setting chamber

Table 2. Stack height regulations for brick kilns

Size	Kiln Capacity	Stack height
Small	Less than 15,000 bricks per day (less than 15 ft trench width)	Minimum stack height 22 (OR) Induced draft fan operating with minimum draft 50mm WG with 12 metre stack Height.
Medium	15,000 to 30,000 bricks per day (15-22 ft trench width)	Minimum stack height 27 metre with gravitational settling chamber (OR) Induced draft fan operating with minimum draft 50mm WG with 15 metre stack Height.
Large	More than 30,000 bricks per day (More than 22 ft trench width)	Minimum stack height 30 metre with gravitational settling chamber (OR) Induced draft fan operating with minimum draft 50mm WG with 17 metre stack Height.

Source: Ministry of Environment and Forests (MoEF), Government of India

III. Stack Monitoring

The air pollution monitoring at monitoring was carried out at kilns in different districts as per BIS methods. Stack Monitor (Envirotech model APM 610) was used for monitoring SO_2 and NO_x were determined spectrophotometrically. Flue gas velocity and temperature were measured with the help of water gauge manometer and Toshniwal thermocouple/pyrometer respectively. Isokinetic sampling was carried out and 3 samples were drawn for each parameter from each stack and average results are reported in Table 3 along with particle size distribution shown in Table 4. The stack monitoring results (Table 3) reveals that the SPM emissions are well below the prescribed limit of 750 mg/Nm_3 in all the kilns monitored. A perusal of Table 4 shows that bigger size particle (>30 µm) are not being emitted through stack and are retained by gravity settling chamber.

Table 3. Stack Emissions from Brick Kilns

Parameters	Kiln 1	Kiln 2	Kiln 3	Kiln 4
Flue gas temp (^oC)	73	68	80	76
Flue gas velocity (m/s)	3-4	3-4	3-4	3-4
Capacity of kiln (x 1000 per day)	25-30	30-40	25-30	30-40
Stack Height (Feet)	108	120	107	118
Fuel used	Coal	Coal	Coal	Coal
Additional Fuel	Fire wood	Fire wood	Fire wood	Fire wood
Consumption of fuel (Tonnes per Lakh of brick)	10-12	10-12	10-12	10-12
SPM (mg/Nm^3)	656	492	605	594
SO_2 (mg/Nm^3)	0.28	0.26	0.32	0.33
NO_x (mg/Nm^3)	2.20	1.98	2.65	2.50

Table 4. Particle Size Distribution of SPM

Particle size (µm)	% mass
> 1	95.2
> 2	90.3
>5	78.4
>10	53.7
>15	38.1
>20	25.6
>30	10.8

IV. Ambient Air Quality Monitoring

The SPM monitoring was carried out as per BIS methods using high volume sampler (Envirotech model APM 410). Respiratory Suspended Particulate Matter (RSPM) was also measured using mini volume sampler (Air Matrices 2.2). Acidic gases (SO_2 and NO_x) were measured using gaseous sensors. Ambient meteorological conditions like air temperature, relative humidity, and wind velocity and wind direction were also measured simultaneously. Two sites were selected (i) where brick kilns were scattered (ii) where kilns were in clusters in western UP for monitoring during summer and monitoring was carried out in day and night time at 3 locations at each kiln in down wind direction. The ambient air monitoring locations were selected at a distance 50-100 m from the kiln and sampling was done for 24 hours. The average results of both the kilns are given in Table 5.

Table 5. Ambient Air Quality Monitoring Data

Emissions	Value($\mu g/m^3$)	
	Site 1 (Scattered)	Site 2 (cluster)
RSPM	125	275
SPM	345	574
SO_2	26	45
NO_x	17	30

The results reveal that respirable suspended particulate matter (RSPM) emissions were exceeding the prescribed limits (100 µg/m^3) of National Ambient Air Quality Standards, CPCB, Delhi in both the kilns. The values are higher in site 2 of the cumulative effect of clustered kilns. The SPM values were also exceeding the prescribed standards for industrial area (500 µg/m^3) in site 2. The emission of acidic gases was below the prescribed standards limits (80 µg/m^3) for industrial/ residential/ rural / other area and ecological sensitive area notified by Central Govt.

AIR QUALITY DISPERSION MODELLING

The dispersion of stack gases and their impact on ground level concentration along the wind ward direction is a complex phenomenon due to turbulent atmospheric conditions and meteorological parameters which change from point to point and from time to time. The complexity of the dispersion process has been solved by using simulation modeling. The impact of stack emissions from different type of brick kilns on ground level concentration has been studied by using a mathematical model that has been developed for the present specific purpose. The model is based on the guidelines for micrometeorological techniques in air pollution studies (IS: 8829-1978). These guidelines have been used to formulate a model which will be useful to provide concentration profiles for a particular stack above a brick kiln. The model is a data based user friendly mathematical model and has been written in an interactive mode to make it suitable for use by all concerned. It makes use of the double Gaussian diffusion expression given below for the estimation of pollutant concentration X(g/m^3) at any location (x,y,z).

$$X(x,y,z) = \frac{Q}{2\pi\,\sigma_y\,\sigma_Z\,\mu}\, exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left[\exp\left\{-\frac{1}{2}\left(\frac{z-he}{\sigma_z}\right)^2\right\}+\exp\left\{-\frac{1}{2}\left(\frac{z+he}{\sigma_z}\right)^2\right\}\right] \quad \ldots(1)$$

In the expression (1), Q is the source strength (g/s), µ is the wind velocity at the source level (m/s) and h_e is the effective stack height, H and the height due to plume rise (h).

$$h_e = H + \Delta h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\Delta h = 0.84\,(12.4 + 0.094)\,\frac{Q_H^{\frac{1}{4}}}{H}\,,\ Q_H > 10^6 cal/s \quad \ldots\ldots\ldots\ldots\ldots(3a)$$

$$\Delta h = \frac{3\,W_0\,D}{H}\,;\ Q_H < 10^6\ cal/s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3b)$$

The quantities of σ_y and σ_Z are the standard deviations of distribution of concentrations in horizontal crosswind and vertical directions respectively. With the help of the above model estimation of SPM concentrations at various locations along the axis of the plume (x-axis) as well as in the crosswind direction (Y-axis) have been made. The modeling was carried out assuming highly unstable conditions in day time (at 14.30 PM) and the night time modeling was carried out assuming highly stable conditions (at 2.30 AM) The results of computation data are given in Fig. 1 and 2 and for day and night time respectively with variation of concentration with downwind distance. During the day time it has been assumed that sky was clear and the solar insulation was moderate to strong. During the night time, it has been assumed that since there is no solar insulation, and wind velocity is low so the atmosphere is moderately stable. Fig. 1 shows that the ground level concentration (GLC) becomes almost negligible after a distance of about 800 m from stack in day time while the GLC does not reduce even after a distance of about 1500 meter.

V. Recommendations

Based on the survey, monitoring studies and air quality modeling, following criteria has been proposed for installation of new brick kilns and recommendations have been given for adoption of good house keeping practices in the brick kilns.

Criteria for Citing the New Brick Kiln

Following criteria is proposed for installing a new brick kiln:

Distance from Residential Area/Population

Brick kiln shall be established at least 500 m away from residential area having a minimum population of 100-150 people or 20 houses including both kachcha and pucca houses in a perimeter of 1 mile, 1.0 km from a residential area having a population more than 150 or more than 20 houses including both kachcha and pucca houses in a perimeter of 1 mile. However the distance from notified municipal area will be 5.0 km.

Distance from Sensitive Areas

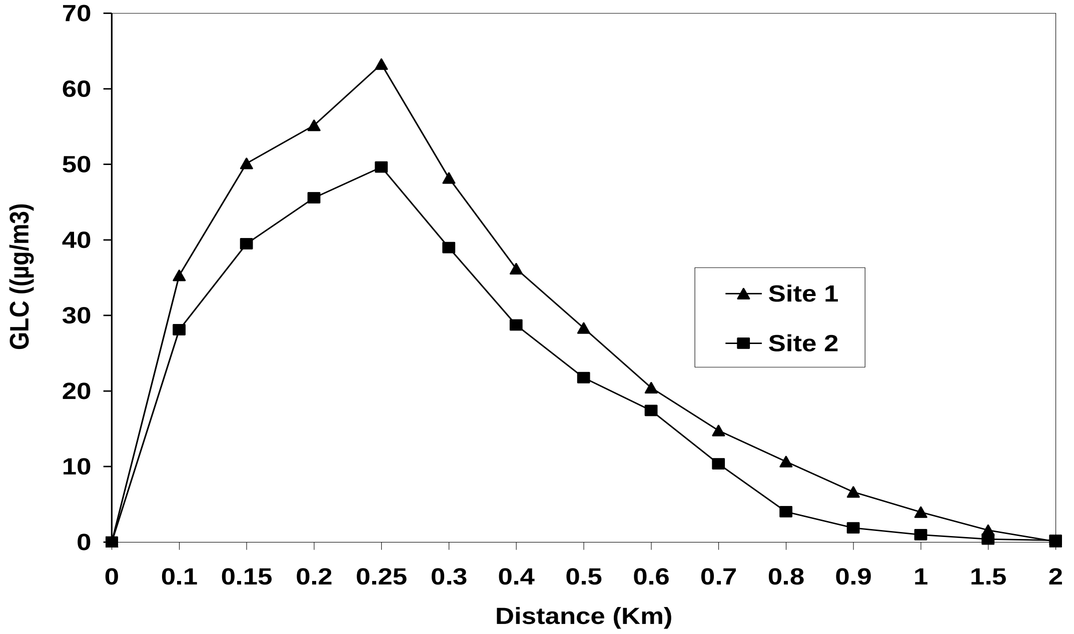

Fig. 1. Variation of GLC with Down Wind Distance (Day Time) at 14.30 PM

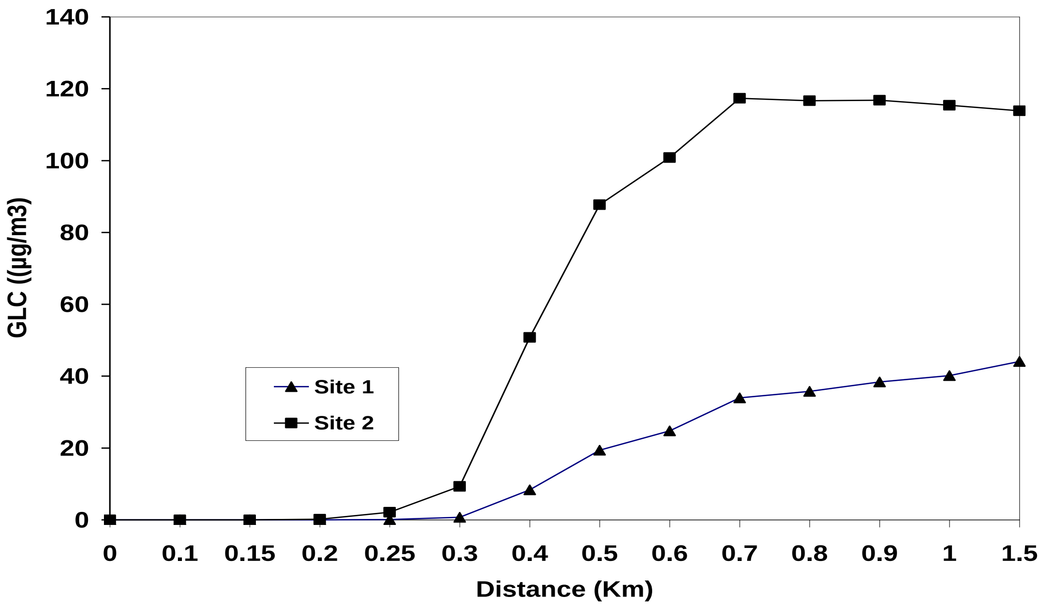

Fig. 2. Variation of GLC with Down Wind Distance (Night Time) at 2.30 AM

The distance of brick kilns shall be 1.0 km from the areas like registered hospital, school, public building, religious place or a place where flammable substances are stored. Brick kilns shall not be allowed with in a radius of 5.0 km in notified sensitive areas like Zoo, wild life sanctuary, historic monuments*, museum etc.
*These guidelines are not applicable for Taj Territory Zone (TTZ) in which honorable Supreme Court of India has given separate directions.

Distance from Railway Track, National/State highways and PWD /District Road

Brick kilns shall not be constructed within 200 m from the middle of railway tracks. The rick kilns shall be constructed at least 300 m from National and State highway from the middle of the road. Brick kiln shall be constructed at least 100 m away from middle of the main district road/PWD roads.

Distance between two brick kilns

The distance between two brick kilns shall not be less than 500 m to avoid clustering of brick kilns in an area if a new brick kiln is being installed.

Distance from Mango/fruits Orchard

Brick kilns shall not be allowed to install in the periphery of 1.6 km from a notified mango fruit belt area or the restriction made by concerning competent authority or decision of Hon'ble court on case to case basis if any.
Distance of mango orchard / Mixed fruits (mango and other) orchard (having at least 100 fruiting trees)/ joint nursery from brick kiln shall not be less than 800 m in each direction. The mentioned distances are applicable irrespective of the variety/type of fruit whose area individually or collectively should not be less than 2.5 acre.
Note: Distance will be measured from the chimney of the brick kiln to the first/nearest row of the tree of mango/fruit orchard towards the kiln.
Note:

1. The above siting criteria will be applicable to all Bull's Trench Kilns irrespective of their brick production capacity.
2. All the distances are in the above guidelines for installing a new brick kiln are from the stack of the brick kiln considering stack as the central point of the kiln to the outer periphery to orchid etc. or a human settlement.

Good House Keeping Practices

Brick kilns are usually dusty as they use clay as main raw material and powdered coal as fuel. Main solid waste being coal ash and fire burnt and unburnt clay particles keep the workplace extremely dusty especially with current practices of handling raw clay, coal, fired and unfired bricks etc. Some recommendations are given below for better housekeeping which, if followed, with sincerity could reduce considerable dust level in workplace of brick kiln.

Disposal of Coal Ash

It is observed that for disposal of ash produced from brick kiln, it is dumped on the kiln top or stocked along the side wall which is source of fugitive emission. It is recommended that the ash produced must be covered with a layer of fired bricks on special tiles. This practice would not only check disposal of dust but would also provide better thermal insulation to the kiln. This will also be helpful in the reduction of thermal discomfort for the workers working for a longer period on the bed of ash.

Provision of Double Wall

Presently, a solid brick wall is constructed around the kiln and excess ash is dumped around it to check heat losses. However, this mode of ash disposal is responsible for dust pollution in the surrounding passage. It is recommended that a double brick wall with a gap in between should be constructed around the kiln and the gap should be filled with ash produced from the kiln. This practice will provide thermal insulation to the kiln as well as would keep the outer wall and surrounding passage clean.

Brick Lining of Passage

It is recommended that the passage to should be paved by fired bricks. The rejected bricks (over burnt and deformed bricks) should be used for paving the passage. This practice will be helpful in improving the work efficiency in the kiln as well as reduce the ground dust level in workplace.

Use of Properly Graded Coal

Manufacturing of the bricks in India is s coal based technology and using low grade coal responsible for higher dust and smoke emission. It is recommended that brick kilns should use properly graded coal to improve the thermal performance as well as reduction of the fugitive dust emissions from the stacks.

Protection from Noise Pollution

Mixers, crushers, compressors, diesel generators may produce large unbalanced forces of couples. Anti-vibration mountings are required for such heavy machinery mountings. Also it would be nice if workers accept the ear muffs which may provide a reduction in noise level of about 30 dBA.

VI. Conclusions

Based on the results of air dispersion modelling, it is concluded that for siting of a new brick kiln, the recommendations should be followed strictly to reduce the impact of pollution on human beings, flora and fauna as well as on buildings. The brick kiln owners should take all the measures to save the people working on the kiln by adopting the good house keeping practices.

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