Assessment and Simulated Estimation of Emissions from Selected Brick kilns in Suburbs of Islamabad

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بسم الله الرحمن الرحيم

IN THE NAME OF ALLAH, THE MOST BENEFICIENT, THE MOST MERCIFULL

Dedication

I would like to dedicate this dissertation to sweet and lovely feelings of my husband Khawaja Abid, whose motivation, encouragement and support enabled me to reach this destination and who has been a constant source of love, inspiration and success for me.

DECLARATION

I hereby declare that this thesis entitled "Assessment and simulated estimation of emissions from selected brick kilns in suburbs of Islamabad" is the result of my own research. I also declare that, as required by the rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Date:

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FORWARDING SHEET

The thesis entitled "Assessment and simulated estimation of emissions from selected brick kilns in suburbs of Islamabad" submitted by Salma Khurshid in partial fulfillment of MS in Environmental Science has been completed under my guidance and supervision. I am satisfied with the quality of student's research work and allow her to submit this thesis, for further processes per IIU rules and regulations.

Dr. Tahira Sultana

Table of Contents

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LIST OF ABBREVIATION

EPA	Environment Protection Agency
CLEAN	Central Laboratory for Environmental Analysis and Networking
CAA	Civil Aviation Authority
JICA	Japan International Cooperation Agency
WHO	World Health Organization
GDP	Gross Domestic Product
BTK	Bull Trench Kiln
MM5	Mesoscale Model 5
SO_2	Sulpher Dioxide
CO	Carbon Mono-oxide
CO_2	Carbon Dioxide
NOx	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
VOC	Volatile Organic Compound
NH_3	Ammonia Gas
H_2S	Hydrogen Sulphide
HNO_3	Nitric Acid
ICT	Islamabad Capital Territory
PM	Particulate Matter
TSPM	Total Suspended Particulate Matter
FCBTK	Fixed Chimney Bull Trench kiln
SPSS	Statistical Package for Social Sciences

SMART	Self Monitoring and Reporting Tool
NAAQS	National Ambient Air Quality Standard
VSBK	Vertical Shaft Brick Kiln
$CaCl_2$	Calcium Chloride
USGS	United States Geological Survey
USNCEP	United States National Center for Environment Prediction
NCAR	National Center for Atmospheric Research

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Urban air pollution is one of the rising environmental issues in major cities of Pakistan. The traditionally practiced bricks production sector is considered as a significant contributor to air pollution. This unorganized and unregulated sector of the economy is developing rapidly to meet the construction demands. Combustion of low grade coal along with other fuels (as starters) results into emission of hazardous pollutants into air posing serious environmental and health hazards. The present study focuses on the assessment of the baseline and emission data (stack as well as ambient) of the selected operational brick kilns in the capital city of Islamabad. Moreover, an integrated modeling system comprising of diagnostic meteorological mesoscale model (MM5) coupled with California puff dispersion model (CALPUFF) was employed to identify the dispersion pattern and simulate the ground level concentration of SO_2 and NOx emission from a brick kiln cluster located at Tarlai Kalan. The 3 hours (11:00 am to 14:00 pm) simulations were performed. The brick kiln baseline inventory was developed through questionnaire survey, including a number of aspects like number of bricks production unit, fuel type and daily consumption, daily production capacity, chimneys height etc. The stack emission monitoring exercise was carried out to monitor the concentration of gaseous pollutants like CO, CO_2, SO_2, NO_2 using a compact gas analyzer and isokinetic sampling procedure/technique was applied to measure the suspended particulate matter (SPM) in the flue gas (combustion gases inside the stack before release). Ambient air quality constituting gaseous pollutants and metrological parameters such as (wind speed, wind direction and ambient temperatures) were assessed by using mobile air quality monitoring station provided by Pakistan Environment Protection Agency (Pak-EPA). The results of study indicated that total of three hundred and one (301) brick enterprises with sixty five (65) feet averaged stack height were categorized into seventy eight (78) functional and twenty four (24) non-functional units confined to the suburbs of Islamabad. The coal fired operational brick enterprises employed total (9112) workers while covering 10118 kanal of land area, 82% of which is taken on lease by the brick kiln operators/entrepreneurs. Combustion of approximately 5-6 tonnes daily coal consumption results into production capacity of 20,000 bricks per day. The profile of stack emission characteristic revealed that the flue gas velocity of monitored fixed chimney brick kilns varied from 0.21 - 0.53 meter per second. The stack gas monitored values of

temperature and flow rates of flue gas at two sampling points ranged from 60.2- 67.8 °C and 3182 – 14910 cubic meters per hour (m^3/h). The hourly averaged concentration of stack emissions observed within the permissible limits except, Particulate Matter (PM). The CALPUFF model predicted that wind with well defined southeasterly wind component dominating the chosen physical domain of the brick kilns cluster was mainly responsible for dispersion of SO_2 and NOx emissions towards southeast direction up to 4 km and 8.5 km area respectively. The predicted maximum hourly averaged ground level concentration of SO_2 exceeds $10\mu g/m^3$ whereas more than $60\ \mu g/m^3$ of NOx was the maximum hourly concentration at ground level simulated by model.

1. INTRODUCTION

Air pollution has emerged as a serious environmental issue, mainly due to the presence of pollutants in the atmosphere as a consequence of rapid industrialization and increased transportation (Shah *et al.,* 2006). In the recent times, introduction of undesirable materials by natural or anthropogenic activities into atmosphere has put the survival of mankind on risk. Air pollution may be defined as any atmospheric condition in which substances are present at concentrations high enough above their normal ambient level to produce a measurable negative effect on humans, animals and plants (Khurshid and Bibi, 2003).

Pollutant is any substance released in atmosphere from either anthropogenic, biogenic or geogenic sources and exist in higher concentration and may cause short or long term adverse impacts. Air pollutants can be categorized as primary and secondary pollutants. The primary pollutant are the substances directly emitted into atmosphere from their sources such as carbon compounds (CO, CO_2, and Volatile organic Compounds), nitrogen compounds (NO, N_2O and NH_3), sulpher compounds (SO_2, H_2S), halogens and Particulate Matter (PM) or aerosols (solid or liquid form), which are usually categorized into different groups based on aerodynamic diameter of the particles. The primary pollutants after introduced into atmosphere undergo different chemical reactions (physical and chemical transformation) resulting into the conversion of precursor pollutants to secondary pollutants as ozone, NO_2 and HNO_3 (Daly and Zannetti, 2007).

Pollutants in the atmosphere come mostly from anthropogenic activities, though significant quantities are also released naturally through dust storms, volcanic activities and decomposition of organic matter (Trivedy and Goal, 2005). However the pollution in atmosphere from manmade activities is contributed either by stationary sources like fuel combustions (such as electric utilities and boilers in industries), industrial activities (petroleum refineries, manufacturing facilities, cement kilns and metal smelters), and power plants, or mobile sources including highway transportation and non-road sources (such as recreational and construction equipment, aircraft, and locomotives (Fenger, 1999). Tobacco smoke, building construction materials, insulation materials, house dust, furnishings, and cleaning agents are included in the category of indoor pollution sources. The use of cooking stoves and biomass fuel such as wood, coal and cow dung for heating and cooking purposes is considered the largest source of indoor air pollution particularly in rural areas of developing countries (WHO, 2004).

Air pollution has been recognized long back as a source to effect animals, damage plants, buildings and materials leading to irreparable physical and economic loss. It may also contribute to reduce visibility, changes in solar radiation and affect climatic/weather conditions (Arva, 1999). It was proved by research studies conducted worldwide that air pollution leads to effect public health causing chronic cardiovascular and respiratory diseases. Enhanced mortality and morbidity are also associated with air pollution. Similarly in America and Europe, various cases of acute respiratory morbidity, including hospital admissions, exacerbation of respiratory symptoms, lung functions changes, and school absenteeism were also reported in last few years (Chen, 1998). Air pollution may also result into increased deaths, pulmonary functions disorder and cardiovascular and neurobehavioral effects (Mace, *et al.*, 1996). WHO reported that the pollution in urban areas is responsible for an estimated 60% of 865,000 premature deaths annually in Asia (WHO, 2007).

In the past few decades, air pollution has emerged as a most challenging problem before mankind. Although it existed in the prehistoric times but variety of factors today accelerate the proportion of air pollution menace to much higher level than past (Sethi, 2007). Environmental conditions are rapidly altering at global and national level due to recent increased industrialization and urbanization (Khan and Jaffar, 2002). The population and economic growth accompanied by the increased living standards and prosperity give rise to expansion of construction industry. The construction sector may be regarded as one of the backbones of development process mainly because of its multiplier effect on other sectors of economy. Many developing countries have geared their construction efforts towards the establishment of infrastructure needed for economic development in the form of highways, major townships, irrigation works, bridges, office buildings, etc., for which building materials particularly clay bricks are needed (Rahman, *et al.*, 2000). Urbanization trend especially in bigger cities has resulted enhanced activity of construction of houses and dwellings. Houses are generally built from fired clay bricks, which are produced in the brick kilns located in suburbs of big cities (Tahir, *et al.*, 2010).

The brick making industry is developing at rapid rates in order to meet the construction demands. In China the total brick output is about 800 billion pieces annually while the Indian brick industry produces nearly 140 billion bricks per year (Co, *et al.*, 2009). Brick kilns can be classified into small (less than 15000 bricks), medium (15000 to 30000 bricks) and large (more than 30000 bricks) on the basis of daily bricks production (Maithel, *et al.*, 2003). The process of clay brick making can be generalized into six main steps consisting of clay extraction, clay preparation, drying, firing, grading and finally dispatch. Although the establishment of brick kilns in areas results into overall development and prosperity such as better roads, improved transportation, and employment opportunities for the people resided nearby (Singh and Asgher 2005). However, wide range of significant adverse environmental impacts are also associated with the making of clay bricks which could not be disregarded. These includes agricultural soil degradation, reduce soil fertility due to removal of nutrients and humus from top layer of soil resulting into reduced crop production (Khan, 2007), and changes in the land cover (Singh and Asgher. 2005).

The brick production is a small scale traditionally operated industry in Pakistan which represents an unorganized and unregulated sector with an estimated contribution of 1.5% contribution to Gross Domestic Product (GDP) and appears to be growing at an annual rate of about 3% resulting in establishment of numerous new factories (SDPI, 2009). In Pakistan no realistic data on the exact number of brick kilns in country is available as no license or registration is required for initializing brickwork. However, approximately over 6,000 brick kilns are clustered into small enterprises in rural and suburban areas of the country with an estimated brick production of 11 million annually (Rana, 2006). Different types of fuels such as waste oils, scrap rubber tires, wood and coal are used for backing of clay bricks. Mostly low quality coal is used for firing green bricks while the wood, waste rubber tires etc. are used as starter of firing process. Mainly the technology employed for brick making is fixed chimney Bull's Trench Kiln (BTK) based on the design of Mr. Bull, although other types of technologies also exists in country (SDPI, 2009).

The 2010 -2011 report issued by economic survey of Pakistan revealed that 56.6 percent of supplied coal is consumed by brick kilns. As the brick kilns are operating without any pollution control devises therefore, the amount of pollution released is directly linked to combustion of fuel type, mainly coal. Large number of hazardous pollutants release from fuel combustion mainly coal used for brick firing share their contribution to the deteriorations of air quality (Co, *et al.,* 2009). Burning of coal mobilizes the release of several harmful air pollutants into the atmosphere such as, carbon dioxide (CO_2), carbon monoxide (CO), sulpher dioxide (SO_2), nitrogen oxides (NOx) and particulate matter (PM). At local level (in the vicinity of a brick kiln) some of these pollutants are injurious to human health, animal and plant life while pollutants like CO_2 contributes to the phenomena of global warming and climate change (Maithel, *et al.,* 1999). Therefore it can be generalized that air pollution from brick making comprising of stack emissions and fugitive emissions, poses severe environmental and health impacts. Furthermore, the air quality of the adjacent areas can also be declined due to the dispersion of these pollutants in the atmosphere (Le and Oanh 2009).

Like other major cities of the country, Islamabad, the federal capital is also facing the menace of air quality degradation over the last few years. Pakistan Environment Protection Agency (Pak-EPA) under assistance of Japan International Cooperation Agency (JICA) conducted air assessment study in Lahore, Islamabad and Rawalpindi. It indicated elevated levels of average Suspended Particulate Matter (SPM) which is 6.4 times higher than WHO guidelines (Shigeta, 2001; Pak. EPA, 2001). The tremendous bulk of vehicles on road coupled with increased industrial activities in the center of the city greatly contributed to declining air quality. Moreover, the problem of air pollution in the city is compounded by huge number of brick production enterprises operating in suburban areas particularly located in zone II and IV of Islamabad, recognized as prime source of atmospheric pollution (Qadir, 2002). The major clusters of brick kilns, at the entrance point of the city (along the motorway intersection) and within 20 km radius of Benazir Bhutto International Airport Islamabad, are operating currently. The brick kilns have been considered as a major source of air pollution in the capital city posing a severe threat to Civil Aviation Authority (CAA) because of the reduced visibility resulting from the black smoke emitting from these kiln operation serving as an obstacle in the movement of air planes (Pak. EPA, 2005). On the repeated concerns expressed by CAA on the prevailing air pollution from brick kilns around the Benazir Bhutto International Airport. Pak-EPA has dismantled 27 brick kilns spreading over an area of 2,000 kanals in Loi Bher, for the sake of environmental protection (Pak. EPA, 2005; Mian, 2010).

Monitoring/measurement and modelling are the two widespread applications applied to assess the air quality and estimate air pollutants. Measurement involves sampling and analysis. As ambient pollutants are present in different forms in atmosphere with varying concentration and physical states, therefore cannot be monitored by same methods. Different devices and methods are available which can be employed for measuring air pollutants. Filtration, sedimentation, electrostatic precipitator, and impingement in liquids are techniques applied for particulate matter sampling. The use of high volume sampler is mostly practiced worldwide to monitor the suspended particles in the range of 1-10 μm which do not settle by gravity. On the other hand, gaseous pollutants are sampled by using bags or containers (for sampling large quantity of air) and this technique is suitable for those samples which allow determination through instrumental techniques. Sampling of gaseous air pollutants can be performed by absorbing gases in suitable liquid absorbent using bubblers, impingers and scrubbers and then the resulting liquid is subjected to chemical analysis for particular pollutant. In addition portable digital analyzers are available for quick and spontaneous monitoring of ambient gaseous pollutants (Trivedy and Goal, 2005).

Air pollution modelling is the most advance technique used to describe and predict the diffusion, transport, fate and dispersion of air borne particulate matter, gases, and their ground level concentrations downwind of pollution sources (Spellman, 1999; and Wahab, *et al.*, 2010). The air quality models are used widely to assess the ambient air quality of desired region due to different sources as regular monitoring of pollutants both temporally and spatially is not always feasible due to high cost and experimental difficulties involved (Krishna, *et al.*, 2005). There are various atmospheric dispersion models available in literature such as Industrial Source Complex (ISC3), California Puff Modelling System (CALMET/CALPUFF) and Simulation of Air pollution From Emissions Above Inhomogeneous Regions (SAFE_AIR). These models are often required for regulatory purposes and use either a simple surface-based meteorological file or a diagnostic wind field model based on available observation (Hurley, *et al.,* 2005).

The approach to use modelling system using CALPUFF dispersion model integrated with the Mesoscale Meteorological Model generation Fifth (MM5) is well known and has been practiced worldwide in various studies for simulation and prediction of atmospheric pollutants at ground level. MM5 is the latest and prognostic meteorological modeling system extended to broad range of applications as it is characterized by non-hydrostatics dynamics, multiple nesting capability and assimilation capability of four dimensional data as well as improved physics options combined with portability to a wider range of computing platforms (Pfender *et al.,* 2006; Yang *et al.,* 2006).

MM5 modeling system is supported by several pre and post- processing programs. The main programs incorporated into MM5 modeling package include TERRAIN, REGRID, INTERPF and MM5. The program TERRAIN is used for defining model domain. It extracts the input data of terrain elevation, land use /vegetation, land-water mask, soil types, vegetation fraction and deep soil temperature from global data set and interpolates it onto a defined mesoscale model grid. The global data of terrain and land use are available for resolutions of 1 degree, 30 minutes, 10 minutes, 5 minutes, 2 minutes, and 30 seconds. MM5 is the numerical weather prediction part of the modeling system and can be used for a wider spectrum of theoretical and real-time studies, including applications of both predictive simulation and four-dimensional data assimilation to monsoons, hurricanes, and cyclones. On the smaller scales (2-200 km), MM5 can be applied for studying mesoscale convective systems, fronts, land-sea breezes, mountain-valley circulations, and urban heat islands (MM5 tutorial).

The physics and assumptions in MM5 limit its applications on fine resolution, thus MM5 simulations were used as initial-guess field in CALMET to simulate the wind fields of fine resolution over the brick kiln cluster. This data was used by CALMET model as input to adjust the meteorological fields to reflect the high-resolution terrain and land use data in the brick kiln cluster. The meteorological fields from MM5/CALMET then drove the CALPUFF for the gaseous pollutants simulation.

According to United States Environmental Protection Agency (USEPA), CALPUFF is a multi-layer, non-steady-state puff dispersion model that can simulate the effects of unstable meteorological conditions on transport of pollutants (both particles and gases) in atmosphere and their dry and wet deposition (USEPA, 2005). The CALPUFF modeling system is an inclusive modeling tool that incorporates various pre/post processors for analyzing the geophysical, meteorological and emissions data. It includes a diagnostic meteorological model, CALMET, a puff-based dispersion model CALPUFF and a post-processing module CALPOST (Wahab, *et al.,* 2010). The meteorological model CALMET produce hourly based three dimensional meteorological data (wind and temperature field) on a defined model domain of fine resolution (Zhou, *et al.*, 2003) while the CALPUFF dispersion model (Scire, *et al.*, 1999b; Levy *et al.*, 2002) is employed to predict hourly surface level pollutant concentrations. The model has capability to simulate or predict the effects of varying (spatial and temporal) meteorological conditions on pollutant transport in air. Apart from providing estimates of emitted pollutants concentration in air, CALPUFF can also simulate wet and dry deposition of pollutants and transformation of pollutants through different chemical reactions taking place in atmosphere (MacIntosh, *et al.*, 2010).

CALPUFF may be applicable for near-field (less than 50 km) regulatory applications when temporal and spatial assumptions of steady state straight-line pollutants transport are unsuitable (USEPA, 2008). The model simulates continuous puffs of pollutants entered into the ambient air flow after releasing from a source. Dispersion of pollutant puffs follows Gaussian distribution and concentrations are based on the contributions of each puff as it passes over or near a receptor point (Scire, *et al.,* 2000). Grid system of CALPUFF dispersion model consists of an arranged horizontal grid cells and multiple vertical layers. Two grids (meteorological and computational) must be defined in the CALPUFF. The meteorological grid is used to define the meteorological variables and the extent of the concentration calculations is set by computational grid which must be identical to or a part of meteorological grid (Elbir, 2003).

Ainslie and Jackson in 2009 determined air emission source regions adversely influencing the city of Prince George, British Columbia, Canada from potential burning of isolated piles of mountain (beetle-killed lodge pole) pine by employing the CALPUFF atmospheric dispersion model, covering 40×40 km domain centered over the city of Prince George area. CALMET atmospheric dispersion model was used to calculate the impact of burning slash piles placed around the city on local PM concentrations. Meteorological input data (hourly temperature, wind speed and direction measurements) from six surface stations and one upper air station was used to drive the dispersion. The Model results showed that the location and extent of influence regions was found to be sensitive to wind speed, wind direction, atmospheric stability and a threshold used to quantify excessive concentrations.

Another study estimated the intake fraction of power plant emissions like primary fine particles, sulfur dioxide, sulfate and nitrate from a power plant in Beijing for health impact purposes by using a long range air pollution dispersion model CALPUFF. There was noted a good agreement between the modeled and observational fraction estimate for SO_2 (Zhou, *et al.*, 2002). Similarly, Levy evaluated the particulate matter impacts across a selected grid in the Midwest by applying CALPUFF modeling system to a set of nine power plants in Illinois (Levy, 2002).

The research work applying CALMET/CALPUFF modeling system was carried out to investigate and evaluate the aggregate air quality impact of six local power plants having total generating capacity of 2920 Mega Watt (MW) in the Beijing area and it was estimated that about 48% of the total electricity consumed in Beijing in 2000 and 2008 was provided by these power plants. The intake fraction of SO_2, NOx and PM emissions from the power plants was also calculated for the years of 2000 and 2008 considering the existing mitigation measures keeping in view, the public health risks associated with the exposure to toxic emissions from these plants (Hao, 2007).

1.1 Significance of the Study

Urban pollution is one of the most significant environmental problems faced by our cities. Ambient air quality status of capital city Islamabad is degrading day by day due to either natural calamities (forest fires on Margalla hills and pollen grains) or number of anthropogenic sources. In addition to industries and transportation, the small scale unorganized brick production enterprises mainly clustered in the suburbs of the city have aggravated the situation with pollution level rising to four times higher than the prescribed limit. Bricks in these units are produced by simple conventional methods using variety of cheap and low graded fuels such as plastic refuse, used tires, wood and coal. Consequently, leading to higher air pollution level posing severe health hazards to the communities living around the brick kiln operating areas.

At present, the environmental status of the brick kilns in Pakistan is largely unknown. Though there are many studies reporting the health hazards from brick kilns sector but scarce literature/data on the ambient air assessment and emissions from brick kiln sector is available. Even though brick kilns are one of the important sources of air quality degradation in the Islamabad city, but the research on the assessment of air quality from the brick kiln emission remains a most neglected and rarely attempted domain till to date in the area. Therefore, the present study was designed to develop the baseline and stack emission information of the brick kilns, and to investigate the ambient air quality of selected brick enterprises in the vicinity of federal capital. Moreover, ground level concentration of stack emissions (particularly SO_2 and NOx) from a cluster of brickworks at Tarlai are simulated by using an integrated modelling system comprising MM5 coupled with CALPUFF.

1.2 Objectives

The objectives of the study were:

- Collection of the baseline data regarding the existing brick kilns operating in Islamabad.
- Stack emission monitoring of selected brick kilns operating in the Islamabad territory.
- Simulated estimation of brick kiln emissions by using an integrated modelling system.

2. METHODOLOGY

The study was undertaken in collaboration with Pakistan Environment Protection Agency (Pak-EPA) in order to generate the baseline inventory of the brick kilns and assess the stack emissions and ambient air of selected brick production units operating in suburban areas of Islamabad. Furthermore, an advance California Puff air quality modelling system, CALPUFF coupled with latest diagnostic Metrological Mesoscale Model MM5 was employed to evaluate the dispersion of pollutants from brick kilns and to predict the concentrations of emitted pollutants particularly SO_2 and NOx at ground level.

2.1 Equipment and apparatus

Different instruments were used to monitor the stack as well as ambient pollutants released from the operational brick kilns during the study. The instruments used to fulfill the needs of experimental section of the research work are mentioned below in a sequential way.

2.1.1 Stack emissions monitoring

The equipments used for monitoring of stack emission and ambient air quality were provided by Central Laboratory for Environmental Analysis and Networking (CLEAN) of Pak-EPA. Thermometer known as Thermocouple-k of SATO Company, wet gas meter along with suction pump of Shinagawa Corporation (Japan), pitot tube (two faced), all types of probes, shefilled tubes containing ($CaCl_2$ and glass fibers), digital manometer and pretreated system (PS-200) were supplied by Nigrorikawa Rikakogyo Go.Ltd. (NRG) Japan. The Horriba Company (Japan) provided single compact gas analyzer PG-250 and cylindrical filter paper also known as micro fiber thimble of Whatmann In.Ltd was used.

2.1.2 Ambient air quality monitoring

In order to monitor and assess the status of ambient air quality around the chosen brick kilns in study area, the facility of mobile air quality monitoring station (Horriba Company) of Pak-EPA at federal level was utilized. There were different monitors installed in mobile station to measure the instantaneous concentration of different air pollutants. Ambient CO monitor (APMA-370), ambient SO_2 monitor (APSA-370), ambient NOx monitor (APNA-370) and particulate monitor

(APDA-370) were applied to determine the ambient air gaseous pollutants. Similarly the main meteorological parameters such as temperature, wind direction and wind speed were monitored by digital anemometer installed in the mobile air quality monitoring station.

2.1.3 Integrated dispersion modelling

Dispersion and prediction of ground level concentration of stack emissions from a selected brick kiln cluster was performed at Tarlai kalan in Islamabad by using an integrated modelling system comprising puff dispersion model namely CALPUFF which was coupled with a latest diagnostic Mesoscale Meteorological Model (MM5).

2.2 Study area

The study was conducted in Islamabad which is the capital of Pakistan. It is situated at height of 500 m above sea level within the geographical coordinates 33°49' N Latitude and 72°24' E Longitude. Total area covered by the city is about 900 km^2. According to master plan, Islamabad Capital Territory (ICT) is divided into 5 planning zones (I, II, III, IV, and V) categorized as urban area (I, II, V) and rural periphery (III, IV) *(*Adeel, 2010*)*. The city is characterized by a tropical climate with two extreme seasons, hot summers (April-September) and somewhat cold winters (October-March). The mean value of annual rainfall recorded in the city is 1143 mm (Parekh, *et al.,* 2001). The Population of study area has risen from 0.340 million to 1.124 million in 25 years with an annual growth rate of 6 % (Pak-EPA, 2008). The temperature ranges from a minimum of -4 °C in January to a maximum of 45 °C in June. The average daily maximum temperature is 16°C (Shah and Shaheen, 2007). The main water bodies draining the area are the Soan and Kurang Rivers dammed at Rawal and Simbli Lakes, respectively, serving to supply water for the urban area. Their primary tributaries are the Ling River, Gumreh Kas and Nala Lei (Sheikh, *et al.,* 2010).

The occupied land in Islamabad is divided into residential, industrial, and commercial sectors. The main industrial units are located in sectors of I-9 and I-10, while numerous brick production units are clustered in the northwestern and southeastern suburbs of Islamabad resulting into air quality deterioration of the city. Two major clusters of brick kilns, one at the entrance point of the city (around the motorway intersection) while the other near Benazir Bhutto International airport at Tarlai area, are present. Whereas, major concentration of brick kilns is found in the Tarnol area taking Islamabad and Rawalpindi districts together (Pak-EPA, 2005).

As study area is located on plateau and enclosed by mountains on two sides, it traps the air pollutants to the lower layers of the area, resulting into increased amount of air pollution including dangerous pollutants particularly Total Suspended Particulate Matter (TSPM), NOx, CO and SO_2, posing serious environmental as well as health implications (Waheed, 2008).

The simulated cluster of brick kilns is located in the vicinity of "Tarlai kalan" at south eastern suburbs lying in zone-IV of ICT. The said cluster consists of total 34 coal fired brick kilns employing Fixed Chimney Bull's Trench Kiln (FCBTK) technology for brick firing.

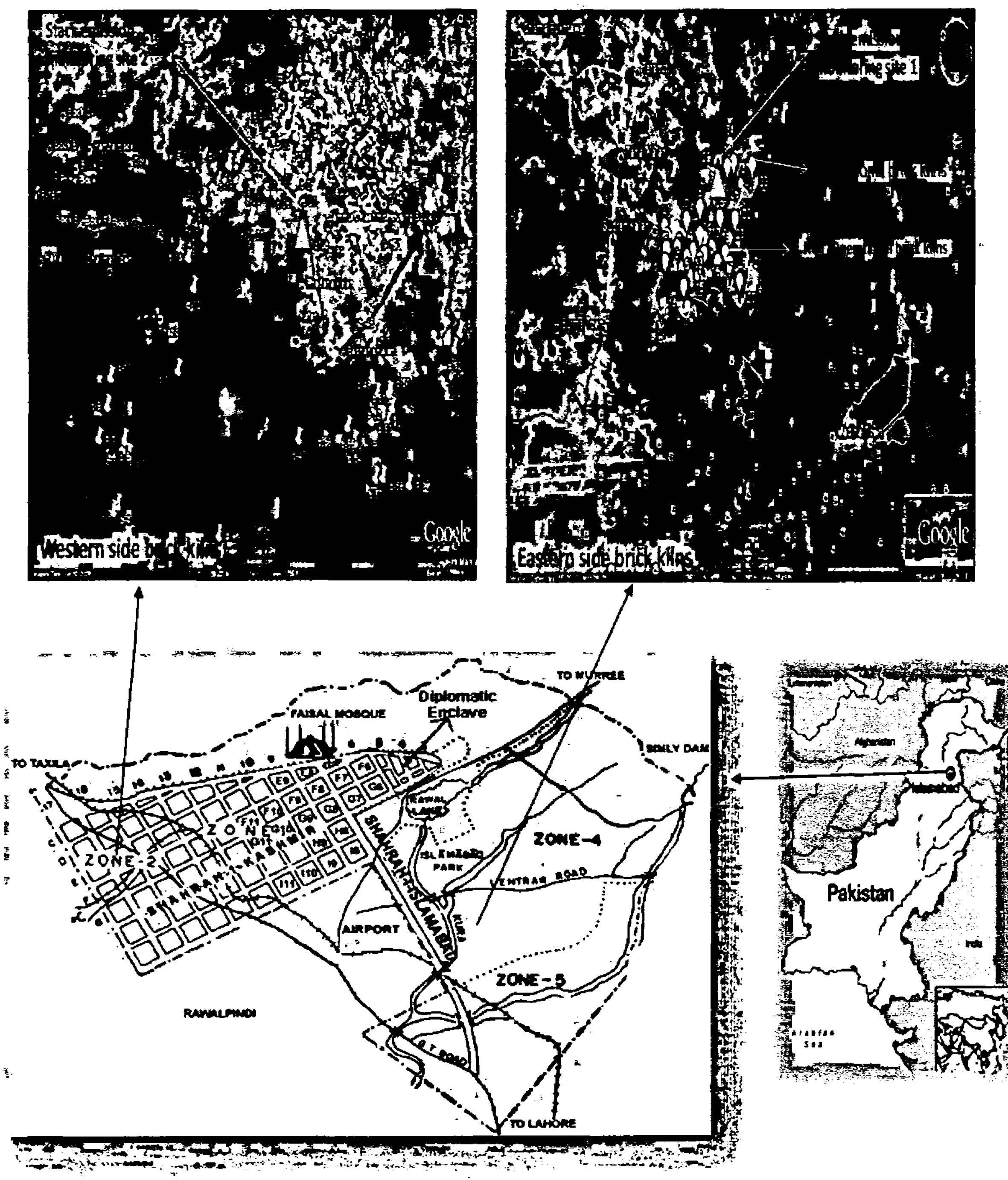

Figure 2.1 Map of study area showing brick kiln clusters located in zone II and IV of Islamabad

2.3 Baseline Data collection of brick kilns

Baseline data was collected from 78 coal fired brick kilns operating in sub urban area included in zone II and VI of Islamabad. To ascertain the feasibility of data collection, the location and the number of brick kilns within the area under jurisdiction of the ICT were identified in consultation with the officials of Pak. EPA and with the help of Google earth software showing the clustered brick enterprises in the study area. For baseline data collection, a structured questionnaire comprising of location and establishment date of brick enterprises, ownership status, trade mark, total covered area, type and source of fuel and daily consumption, daily production capacity, chimney height, manpower employed etc. was designed. The baseline information was collected through questionnaire survey of the identified brick production units located at eastern and western sides of study area. In addition, interviews of the munshi/owner (depending on availability) were conducted during field visits. Discussion with a key person Chuadary Ikram-ullah, chairman brick kiln association and with workers and interviewee proved really helpful in the process of information collection. Besides interviews and discussion, personal observations were made particularly during survey on real situation of the brick production units.

2.4 Sample preparation

Silica glass microfiber thimble (cylindrical filter paper) was heated in a furnace at 120 °C for two hours and stored in desicator for the next day PM sampling. Before sampling filter paper was weighed and labeled with proper identification number. Similarly, water was used as liquid medium in wet gas meter to find out the flow rate of stack flue gases.

2.5 Stack Emission Monitoring

Two sites one at Tarlai area having 22 operational brick kilns and another at Budhana village having 20 bricks production units were selected randomly to monitor the concentration of different pollutants such as CO, CO_2, SO_2, NO_X, and total suspended particulate matter (TSPM) from the stacks of brick kilns posing a serious health hazards to the communities residing near these brick kilns. A sampling port (hole) at right angle to the stack wall at height of 5 feet from the roof of the kiln was selected for monitoring of stack emissions from selected brick kiln at each sampling site. The monitoring was conducted during operational conditions of the kiln especially each measurement was made after coal feeding process to evaluate the concentrations of pollutants within the flue stream accurately. Isokinetic sampling procedure/technique was applied for the measurement of particulate matter from the stack gas stream of the brick kiln in the study area. It is based on the principal that the velocity of gas stream in the stack and passing through the sampling nozzle should be equal. Therefore, before Particulate sampling there was determined flow rate of the flue gases.

2.5.1 Stack Gas Temperature

The stack temperature was measured by using temperature probe known as thermocouple which was inserted in the port generated at the stack of selected brick kilns and the port opening was closed tightly in order to avoid the air interference.

2.5.2 Stack Gas Velocity

Pitot tube was connected with digital manometer for determination of velocity pressure comprising dynamic and static pressures of stack flue gases.

2.5.3 Flue Gas Moisture Content

The moisture content was determined by using a set of two sheffield tube containing glass fibers and $CaCl_2$ as moisture absorbent. The marked and pre-weighed sheffield tubes were connected with each other and placed in water port supported by a water stand, in such a way that sheffield tubes were connected with the heated probe through a suction pump so that moisture from the flue gases can be withdrawn in to the probe. The wet gas meter (containing water as a liquid) was set at flow of 2 L/ min of gases for 5 min duration and reading were noted before and after the sampling. The sheffield tubes were weighed after the sampling of the moisture content of the stack gases. The difference in the weight of sheffield tube provided the total mass of moisture absorbed. After the completion of sampling, the moisture of the flue gases was calculated by the following formula;

$$Xw = \frac{22.4}{18} \times ma \div \left(Vm \times \frac{273}{273 + \theta m} \times \frac{Pa + Pm - Pv}{101.3} + \frac{22.4}{18} \times ma \right)$$

Where

Xw= volume of water vapors in gas (%)

ma= mass of moisture absorbed (ma_2- ma_1) (g)

ma_2=weight of shefilled tube after sampling (g)

ma_1=weight of shefilled tube before sampling (g)

Vm= volume of gas sucked (reading of wet gas meter) (L)

Θm= temperature measured by the gas meter

Pa= atmospheric pressure (K-Pa)

Pm= gauge pressure of the gas in the gas meter (K-Pa)

Pv= saturated water vapor pressure at Θm (K-Pa)

2.5.4 Gaseous pollutant sampling

Heated probe attached with pretreatment system analyzer was connected with the wet gas meter and electric pump as shown in figure 2.2. The wet gas meter was set at 6 liter per minute of flow and gas analyzer was set on for 45 minutes to get start. On the completion of startup period, a sampling probe was inserted in the hole to monitor the concentration of gaseous pollutants in the flue gas stream. The readings of gases constituting the stack gas stream were noted when there was visible black smoke emitted from the stack.

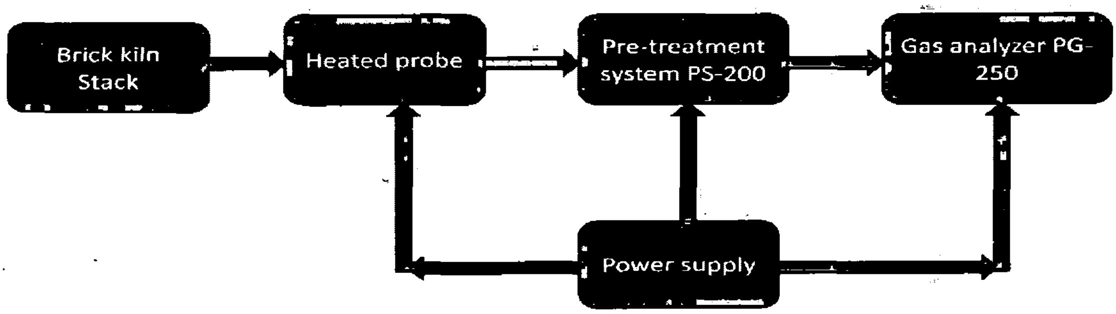

Figure 2.2 Assembly of instrumentation used for flue gases

2.5.5 Particulate Matter (PM) Sampling

Prior to PM sampling, flow rate of the gases in the flue gas stream was determined so that the same flow rate can be maintained during particulate matter sampling. The calculations performed for determination of flow rate were given below.

A-Calculation of sampling flow rate:

The velocity pressure and sampling flow is determined by the following formula,

1. **Velocity Pressure of flue gases**

$$V = \frac{C\sqrt{2Pd}}{P}$$

Where

V= velocity of flue gas in m/sec.

C= Pitot tube coefficient which is 0.85 in our case

Pd= dynamic pressure of flue gases

p= density of flue gases

2. **Density of flue gases determination**

$$p = P^{\circ} \times \frac{273}{273 + \theta s} \times \frac{Pa + Ps}{101.3}$$

and

$$P^{\circ} = \frac{1}{22.4} \times 100 \left\{ (M1X1 + M2X2 \ldots\ldots MnXn)\left(1 - \frac{Xw}{100}\right) + 18Xw \right\}$$

Where

Өs= stack gas temperature

p = Density of flue gas (g/m^3)

M1= molecular weight of the gas

X1= gas concentration (ppm)

3. **Flow rate of stack gases:**

$$Qm = \frac{\pi}{4d^2v}\left(1 - \frac{Xw}{100}\right)273 + \frac{\theta m}{273} + \theta s \times Pa + \frac{Ps}{Pa} + Pm - Pv \times 60 \times 10^{-3}$$

Where

Xw= moisture content

Pm= gauge pressure of wet gas meter

Pv= saturated vapour pressure in the gas meter

Pa= atmospheric pressure

Ps= static pressure

Θs= stack gas temperature

d= diameter of the nozzle in millimeter

Θm= temperature measured by the gas meter

4. **Flow rate of the dry flue gases:**

$$Q^{\circ}m = Qm(1 - Xw/100)$$

Where

Q°m = flow rate of the dry flue gases (m^3_N/h)

Qm = flow rate of wet flue gases (m^3_N/h)

Xw = moisture of the flue gases (%)

B- Setting and Procedure:

The thimble was dried in oven for about 2 hours at 120 ^{0}C before and after sampling so as to maintain to the same conditions. To sample the PM from the stack flue gas stream, a sampling train containing probe with filter box, pre-treatment system (PS), electric suction pump and wet gas meter was assembled after the fitting of proper nozzle and placement of a clean pre-weighted thimble/filter in the filter holder of the probe and tighten securely. The initial gas meter reading were recorded when the equipment was ready in all respects. The sampling probe was inserted in the sampling port on the stack wall carefully. During sampling the nozzle was facing in the upstream direction and flow rate was adjusted on the wet flow meter for isokinetic condition. At the completion of the test, the nozzle was turned in the downward direction and final wet gas meter reading were recorded. Afterwards, the sampler was removed from the sampling port carefully and quickly nozzle was plugged to prevent the loss of the sample. After cooling, the dust on the inside of the nozzle was carefully brushed down into the thimble using a small brush. The filter paper was placed in the dust tight container for transportation to the weighing room where the final weight of the filter paper used was determined. The weight of dust collected in the thimble was determined by subtracting the noted initial weight from the final weight.

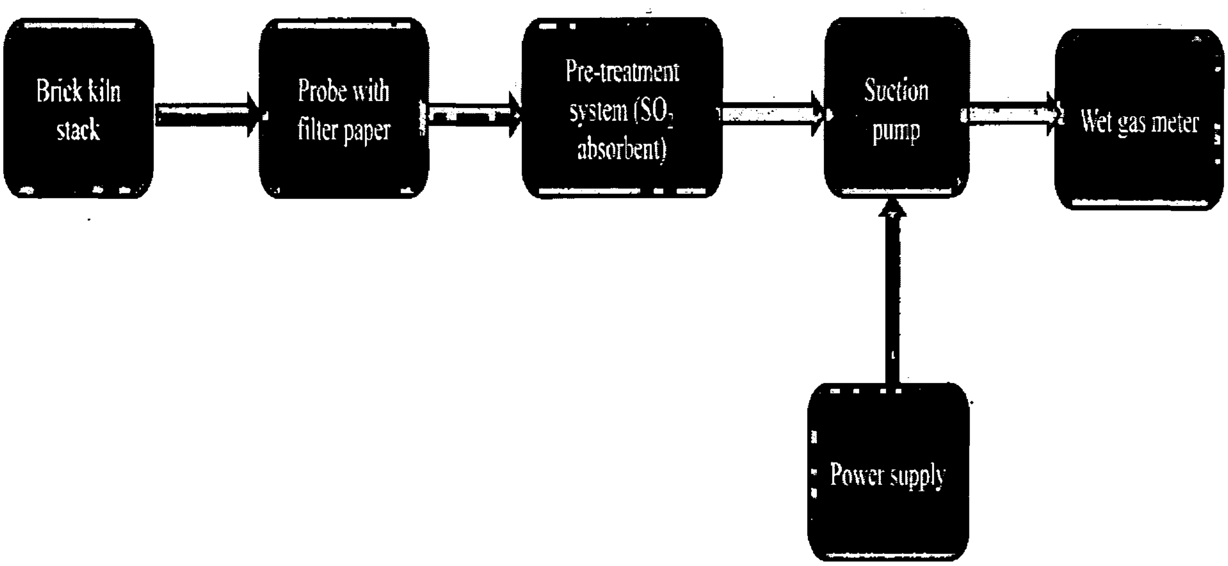

Figure 2.3 Assembly of instruments used for PM sampling

2.6 Ambient Air Monitoring

Ambient air quality of brickworks was monitored in a cluster located at Tarlai area. Mobile ambient air monitoring Van provided by Pak-EPA was used to capture the status of air quality in the cluster of brickworks. Two sampling sites within the cluster were selected for monitoring of ambient pollutants as well as metrological parameters. The readings of PM, ambient air pollutants (CO, SO_2, and NOx) and metrological parameters (ambient temperature, wind speed and wind direction) were recorded at height of 18 feet from the ground for 2 hours after 10 minutes at each sampling site. The monitoring was performed in the cluster when there were 22 brick kilns operational and about 10 units were non-operational. For the measurement of ambient air pollutants (SO_2, NOx, CO and PM) specific monitors were installed in the mobile ambient air monitoring station. Digital anemometer was used for monitoring of wind speed and wind direction.

2.7 Integrated Dispersion Modelling

In present study, an integrated modeling system comprising of an advance diagnostic mesoscale meteorological model (MM5) and Lagrangian puff dispersion system CALPUFF was employed to simulate the gaseous emissions from a cluster of brick kilns and to predict their ground level concentrations. The three hours (11:00am-14:00pm) simulations were performed on 21 September, 2011. To validate the models performance the surface meteorological data along with the ambient air quality data were collected on 21 September, 2011 with the help of mobile ambient air monitoring station of Pak-EPA.

2.7.1 Mesoscale Metrological Model (MM5)

To generate meteorological data for the dispersion model CALPUFF, a limited-area, non hydrostatic and terrain-following sigma-coordinate mesoscale model MM5 was employed. In the present study MM5 model was used to generate the necessary meteorological data which was used as a first guess for further processing. MM5 was configured with single domain centered at Latitude 33.62 N and longitude 73.16 E. The selected grid points in X and Y direction were 11 with grid spacing of 5 km. The vertical layers taken in Z direction were 23. Map projection of Lambert Conformal was selected for model domain. The global input data having spatial resolution of 2 minutes (approximately 4 km) for terrain and land use were taken from database of United States Geological Survey (USGS). The global meteorological input data of 1 degree spatial and 6 hours temporal resolution were taken from database provided by United States National Center for Environment Prediction (USNCEP). This data provided global information regarding horizontal and vertical winds, temperature etc.

2.7.2 CALPUFF Dispersion Model

In the present study, the CALPUFF modeling system was applied to study the dispersion pattern and predict the ground level concentration of emissions from a cluster of brick production enterprises. The CALPUFF model was configured with shared common domain of 10×10km centered at latitude 33.618N longitude 73.168E.The horizontal grid resolution is kept at 1km and in the vertical dimension, 10 layers corresponds to the physical height of 0m, 20m, 40m, 80m , 160m, 320m, 700m, 1300m, 1700m, 2300m, 3000m were selected above ground level.

The source characteristics and emission data needed to incorporate into the CALPUFF dispersion were derived from monitored stack emission. It was assumed that all the brick kilns have the same stack physical characteristics and emission values as shown in table 2.1. The X and Y Coordinate values of emission sources (brick kilns) in km are given in annexure-III.

Table 2.1 Source characteristics and emission data of modeled brick kilns

Parameters	Values
NOx concentration	296 ppm
SO_2 concentration	44.8 ppm
Temperature of flue gas	60.2 ^{o}C
Velocity of the Flue gas	0.21 m/sec
Stack height	65 feet
Stack exit diameter	0.762 m
Exit temperature	334 °C
Stack exit velocity	0.21 m/s
NOx emission rate	1.183 g/s
SO_2 emission rate	1.183 g/s

Prior to calculate the emission rates in g/sec, unit conversion calculations were made for the gaseous pollutants as SO_2 and NOx by the following formula;

$$mg/m^3 = (ppmv)(Mw)/(273.15 + °C)$$

Where

mg/m^3= milligrams of gaseous pollutant per cubic meter of ambient air

ppmv= ppm by volume (i.e., volume of gaseous pollutant per 10^6 volumes of ambient air)

Mw= molecular weight of the gaseous pollutant

°C= ambient air temperature in degrees Centigrade

The following formula was used to determine the emission rates of the gaseous pollutants in g/s.

$$\text{Emission rate} = Em \times Qs$$

Where

Em= Emission value of the pollutant

Qs= Flow rate of the flue gases

2.8 Data Analysis and Interpretation

In the present study, Microsoft Excel 2007 was applied primarily to compile and generate the data sheet for collected baseline information of existing brick kilns in the study area and to analyze and plot the measured and predicted meteorological data of the modeled domain in a graphical format was the second application of Exel-2007. Data acquired through questionnaire survey was analyzed and processed through Statistical Package for Social Sciences (SPSS) software version-16 in order to find out the descriptive statistics presenting the main findings regarding the baseline data of the brick kilns and for bar graph making.

3. RESULTS and DISCUSSION

3.1 Baseline data of brick kilns

A questionnaire survey of existing operational brick kilns located in the federal capital was conducted to generate baseline inventory comprising of brick enterprises location, establishment date, trade mark, daily production capacity, fuel type and source with per day consumption, manpower employed, total covered area etc. The collected datasheet of 77 brick production units is appended at annexure-1 while one brick kiln operator refused to provide information. In order to check the variability in the collected data SPSS (Statistical Package for Social Sciences) version 16 software was used to process and analyze the data. The basic descriptive data/figures obtained are presented in table 3.1.

Table 3.1 SPSS baseline data results of brick kilns in Islamabad

	Establishment date	Area covered (kanal)	Total number of workers	Daily fuel Consumption (tones)	Production capacity/day	Chimney height (ft)	Working days/week
Mean	1997	132.08	107.89	5.01	21575.00	65.75	6.01
Median	2000.00	127.50	80.00	5.00	20000.00	65.00	6.00
Mode	2001	150	100	5	20000	65	6
Std. Deviation	9.437	39.516	84.677	1.400	6598.548	4.419	.200
Variance	89.048	1561.487	7170.175	1.960	4.354E7	19.523	.040
Minimum	1978	40	20	2	2200	55	5
Maximum	2010	300	500	10	40000	85	7

3.1.1 Distribution of brick kilns

The results of survey indicated that majority of brick kilns existed in suburban areas leading to atmospheric pollution in the capital city. Brick producing enterprises are categorized into two types, one producing face brick used for outdoor decoration purposes in building construction while others produce structural bricks, the main building blocks required for construction activities. Table 3.2 indicates the location wise distribution of total brick kilns in Islamabad showing that total of 103 brick making units were clustered at Loibair, Karal town, Tarlai kalan, Khanna pull, Kirpa, Sher Damial, Budhana village, Benazir chowk of Tarnol area, Noon village, Dhoke Hameedan, Bajnail and Noughazi village near the motorway. Moreover the Tarlai kalan and Budhana village were the areas with two major clusters having 34 and 30 brick kilns respectively. There was only one enterprise producing face bricks located at kirpa.

Table 3.2 Distributions of brick kilns in Islamabad

Serial no	location	Number of brick kilns Located
1	Loibhair	1
2	karal	3
3	Tarlai	34
4	Khanna bridge	1
5	Kirpa	3
6	Sher damial	2
7	Budhana village	30
8	Banazir chowk Tarnol	7
9	Noon village	2
10	Dhoke Hameedan	10
11	Bajnail village	3
12	Nou ghazi village	7
	Total	**103**

There are 78 operational brick kilns situated in the suburban area of zone II and IV of Islamabad. Out of total functional brick production units, 77 enterprises were producing structural bricks while a single brick kiln was reported for face bricks production during the survey. The number of brick kilns in vacinity of the study area is clearly illustrated in figure 3.1 which depicts that out of total 103 units, 78 enterprises were functional/ working, whereas 25 enterprises were non-functional due to taking over of the their owners and operators to some more profitable businesses although the required infrastructure for the brick kilns existed. In addition, as clay bricks production in most of developing countries is a seasonal activity therefore few of units were closed due to off season during the survey period which was carried out in the months of November and January 2010. Another reason for non-functionality of the brick making units in the areas near Benazir Bhutto international airport representing the east of city, can be the strict action (demolishing and closing of brick kilns) of the Pak-EPA on this environment polluting sector within 20 km radius of airport due to worsen air quality resulting in decreased visibility during takeoff and landing of air planes.

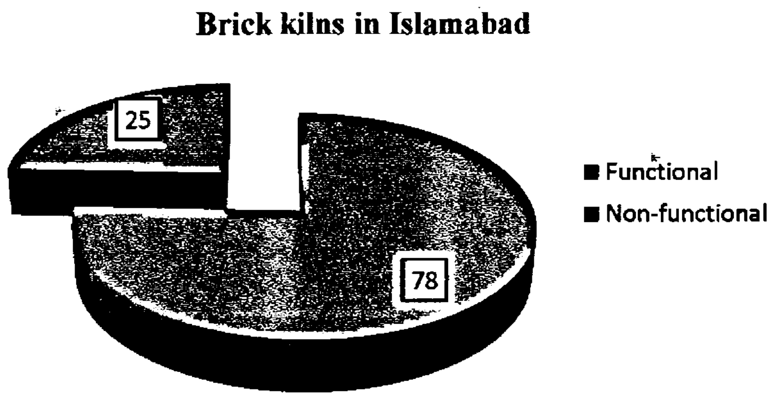

Figure 3.1 Brick production units in Islamabad

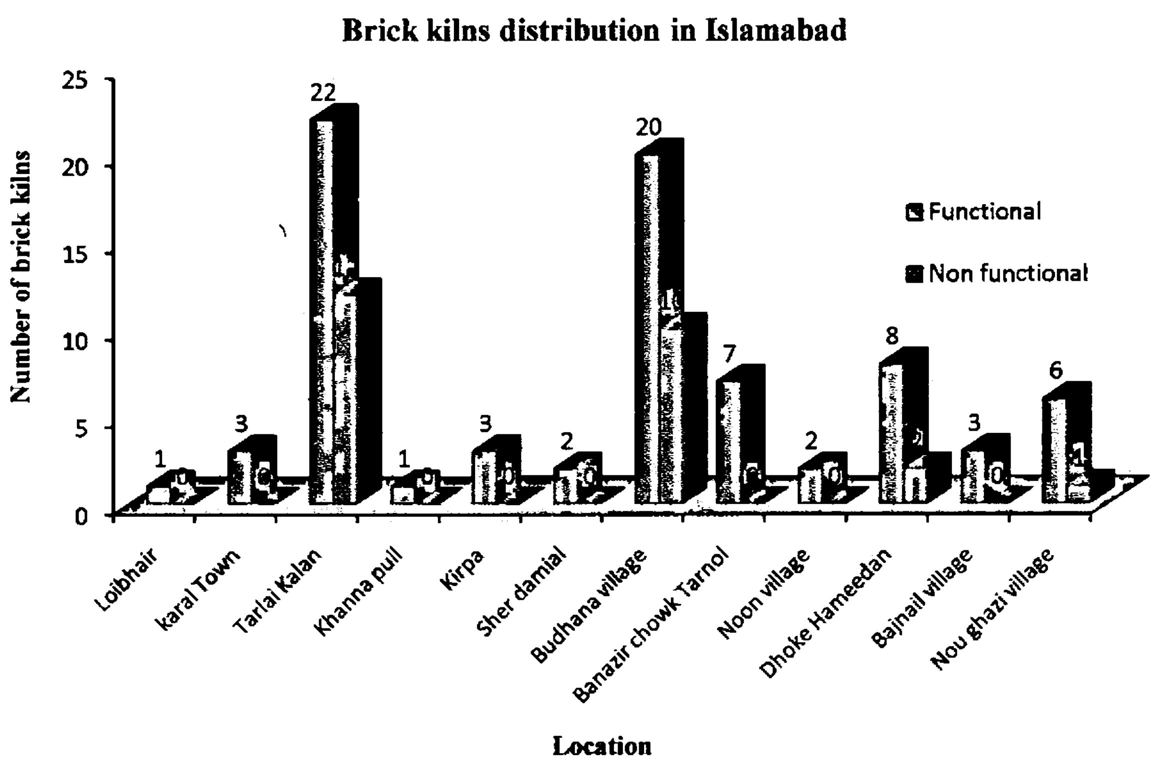

Figure 3.2 Location wise functional and non-functional brick kilns in Islamabad

The location wise distribution of functional and non functional brick kilns in the study area is depicted by figure 3.2 which clearly illustrated that the majority of brick kilns were operating at Tarlai kalan located at the left side of lehtrar road (near Benazir Bhutto international airport Islamabad) and Budhana village (near Tarnol) because there is easy availability of main resources required for brick making such as land for establishment of brick kilns and clay quarrying, man power (Pak-EPA, 2005).

Location of brick producing enterprises can also be categorized along the eastern and western directions in the study area as depicted in figure 3.3a and 3.3b. There were total of 30 enterprises in operation on the eastern side at Karal town, Loibair, Khanna pull, Kirpa and Tarlai kalan, lying within 20 km radius of Benazir Bhutto international airport. Tarlai kalan area is considered as a major cluster having maximum concentration on the southeastern suburbs of Islamabad. Similarly, on the western side which comprised areas around Islamabad Motorway intersection and Tarnol, a huge number of operational brick kilns (48 out of 78) were distributed in small clusters in Sher damial, Budhana village, Noon village, Dhoke hameedan, nou ghazi and bajnail area.

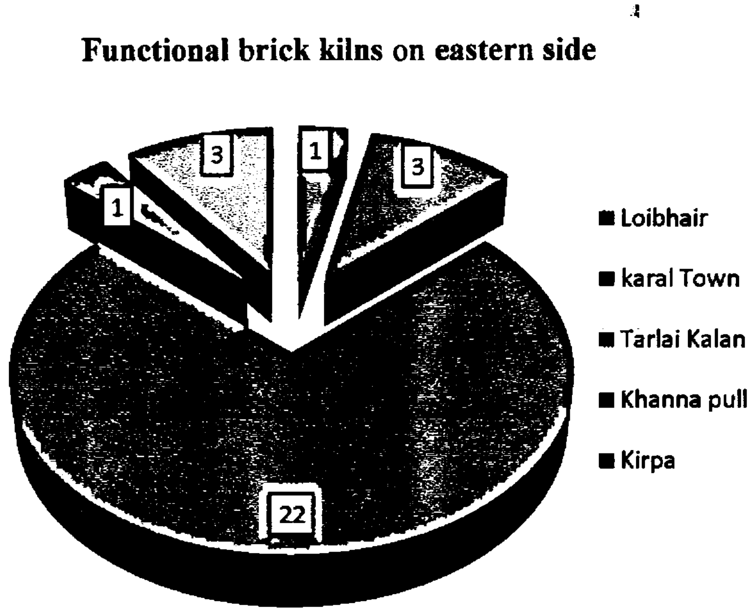

Figure 3.3a Functional brick kilns on the eastern side of Islamabad

Functional brick kilns on the western side

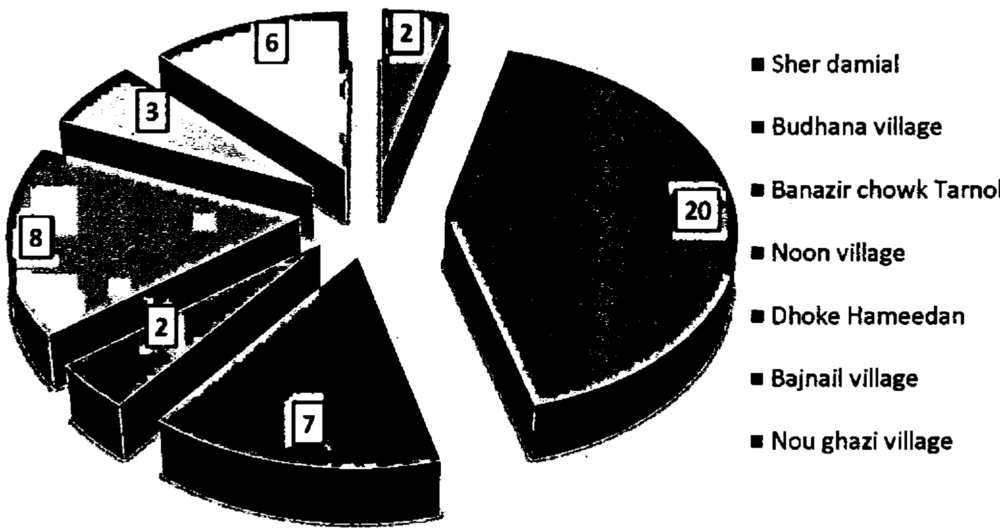

Figure 3.4b Functional brick kilns on the western side of Islamabad

3.1.2 Ownership status of the brick kilns

In Pakistan, land required for brick kiln development and soil resources is either owned by their owners or taken on lease for short time period of no more than few years (NWFP-EPA, 2004). The percentage and frequency of ownership status of the visited operational brick kilns in the study area premises is presented in figure 3.4. It is evident that most of the brick kilns (82.89 %) were operating on land acquired by brick kiln owners/operators on lease for specific time span usually for 5- 10 years on average because mostly the top soil of 3 meters is suitable for shaping and molding of clay bricks, which becomes utilized in leased period (Awan, 2010). The 13.16 % of the total land is fully owned by brick kilns operators. The reason for low ownership of the brick enterprises was high initial investment involved in land purchasing process. Apart from personally owned and leased, few nearly (4%) of brick kilns were working under the category of partially owned and partially leased land.

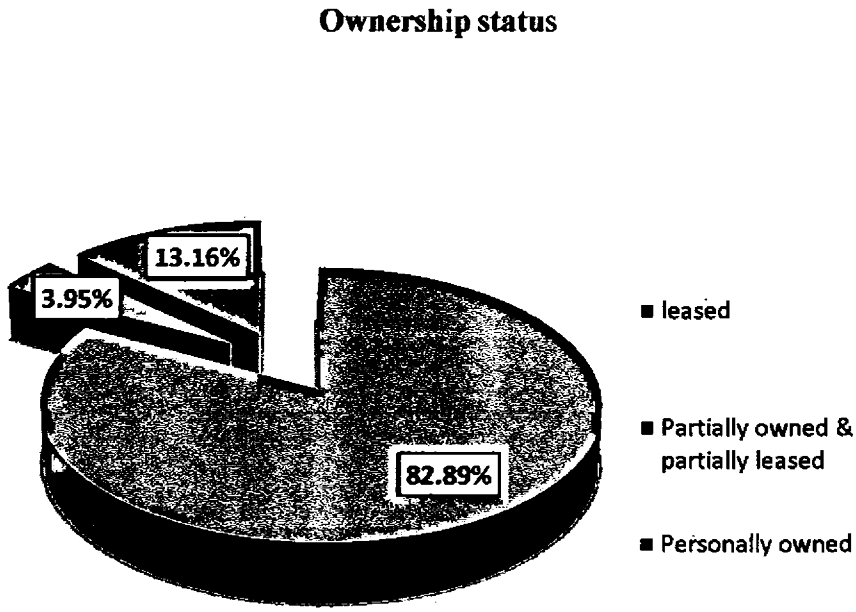

Figure 3.5 Ownership status of the operational brick kilns in Islamabad

3.1.3 Area covered by brick kilns

Widespread land area is occupied by the unorganized small scale brick enterprises in the suburban areas of zone (II and IV) in the capital city. Total area of 10118 kanals is occupied by the existing operational brick kilns in the premises of study area. The ranges of area covered by different brick making units are presented in figure 3.5 (extracted from table 3.2) indicating out of total 78 operational brick kilns, 30.3 % brick enterprises units covered an area of about 150 kanals and the second highest averaged range of 120 kanal is occupied by the 18.4% brick kilns while 14.5 % of the operational brick production units are estimated to spread over the land of average 120 kanals.

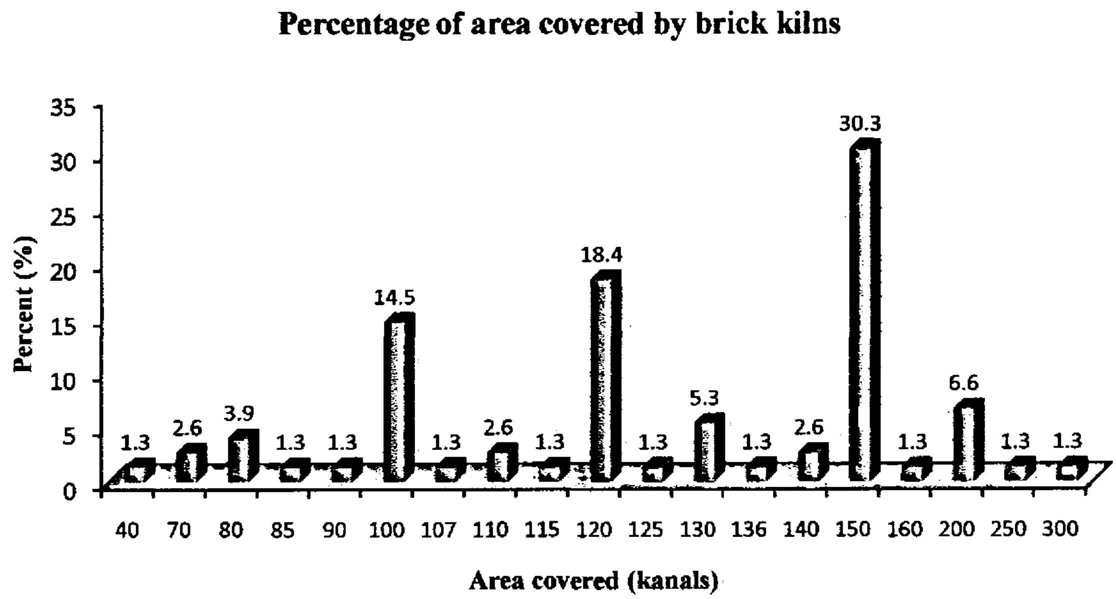

Figure 3.6 Area (kanals) covered by operational brick kilns in Islamabad

3.1.4 Manpower employed

Though a large numbers of workers are employed on forward and backup linkages in functioning of the brick kilns, but only the labor force have been taken into account in this study. Moreover, the strength of manpower employed in the brick enterprises varies and ranged from 20-500 as depicted by fig.3.6. The total number of employees can be assess through table 3.4 which shows that total of 8200 workers are being serving in the brick enterprises with higher contribution of male workers that is 89.87%. The very low involvement of females can be observed from figure 3.7 that is 10.12 % which may be attributed to their domestic jobs and unwillingness of brick kiln operators to employ females for work.

Table 3.3 Workers employed in the brick kilns in Islamabad

	Number	Percentage
Female workers	923	10.12%
Male workers	7277	89.87%
Total	**8200**	

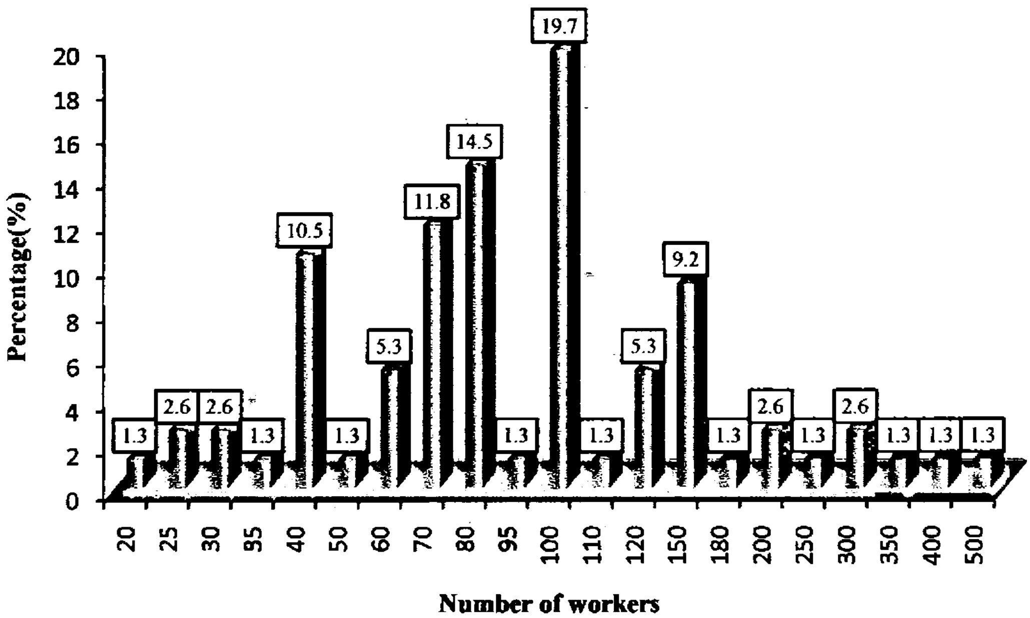

Figure 3.7 Total number of workers in operating brick kiln in Islamabad

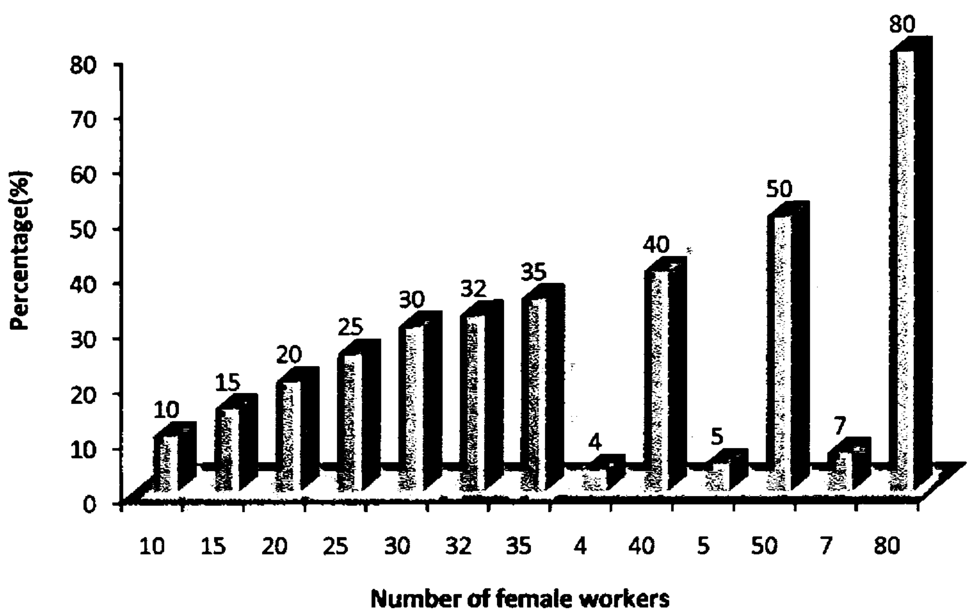

Figure 3.8 Number of female workers in operating brick kilns in Islamabad

3.1.5 Fuel type

Fuel is the main component for firing of unbaked clay bricks. Various fuel types such as coal, wood, rubber and scrap tires are used in different proportions for brick making in Islamabad. The percentages of fuel types consumed during brick firing and backing process in the study area are presented in figure 3.8. It is clear from figure that 80.26% of coal as major fuel is used by almost all the operational bricks production units. The collected data revealed that 14.5% of coal and wood are being used as a fuel for brick production. The single face producing enterprise structured at kirpa relies on wood for brick backing process in the study area.

Fuel wood is obtained from domestic forest in the area which is available on cheaper rates (Tahir *et al.*, 2010) but its share seems to be less as wood is not considered suitable for firing and strengthening of the bricks as reported by brick kiln owners therefore coal is used as a prime fuel type although bear high cost than wood. Apart from coal and wood, other combinations of fuel type like (coal and tire) which shares 1.32% and (wood, coal and rubber) contributes 3.95% are used by few enterprises in the production of clay bricks as clearly shown in figure 3.9.

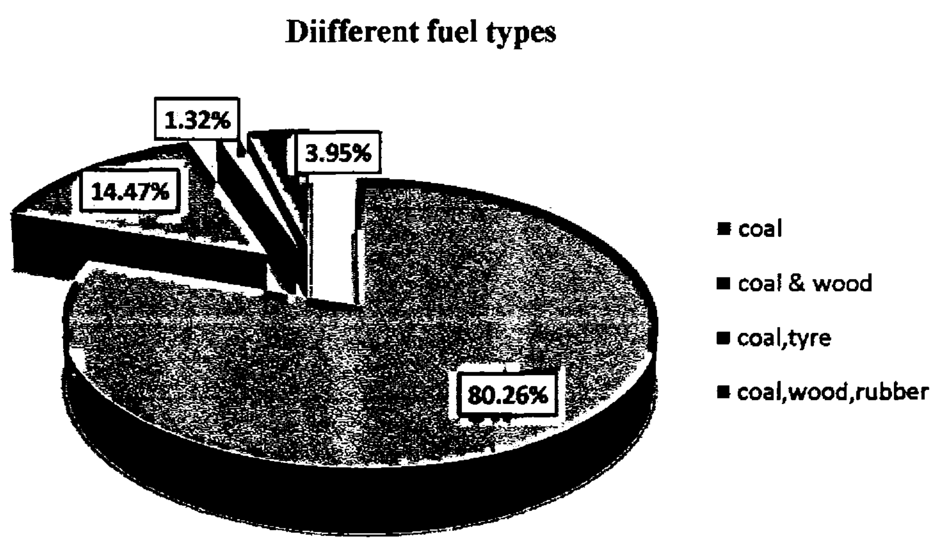

Figure 3.9 Percentage of different fuel types used in brick kilns in Islamabad

The fuel types as discussed above for brick production are purchased from different cities of the country. The Chakwal and Khushab areas in Punjab province and Quetta (Baluchistan) are the main cities of concern regarding fuel while fuel wood is mostly purchased locally. The percentage of fuel along with different suppliers are shown in figure 3.9 which illustrates that the 38.16% fuel (coal) is obtained from Chakwal district of Punjab and only Quetta supplied 18.42 % of fuel (coal) for bricks baking process in the study area. The share of 2.63% is contributed by Chakwal and Khushab together while 14.47% from Quetta and district Punjab collectively.

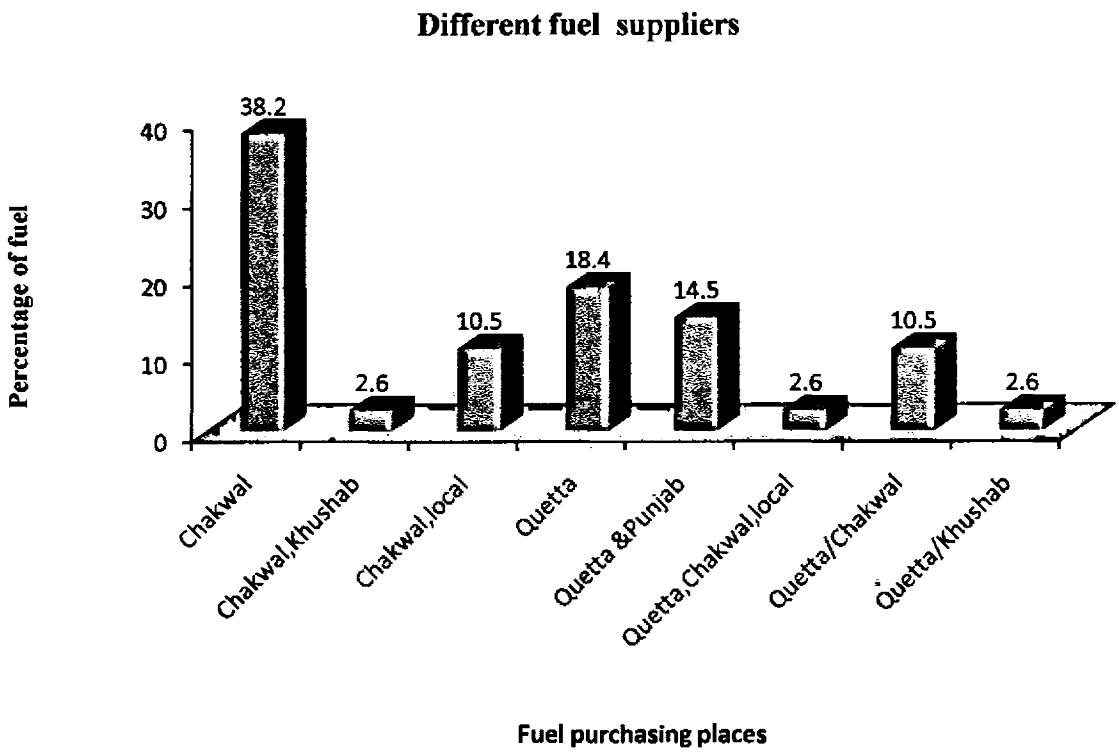

Figure 3.10 Percentage of fuel purchased by brick kilns from different places

3.1.6 Daily fuel consumption

The most important cause of air pollution in brick kiln sector is the use of energy inputs for combustion process. The clusters of brick kiln under study mainly use coal and other biomass, firewood as combustion fuel for bricks making. In some cases rubber and tires are also being used for power generation. Coal consumption by the brick kiln sector in Pakistan during

2007-2008 is reported to be 37.2 % of the total 10.11 million tons by (Sheikh, 2010). The per day consumption of fuel mainly (coal) by the brick kilns in the study area is indicated by fig. 3.10. It is clearly depicted by the results that averagely 5 tonnes of fuel mainly fuel wood and coal are consumed by approximately 25-35 % brick kiln daily for firing of clay bricks while 23.7% brick enterprises consume 6 tonnes of fuel per working day as indicated by results.

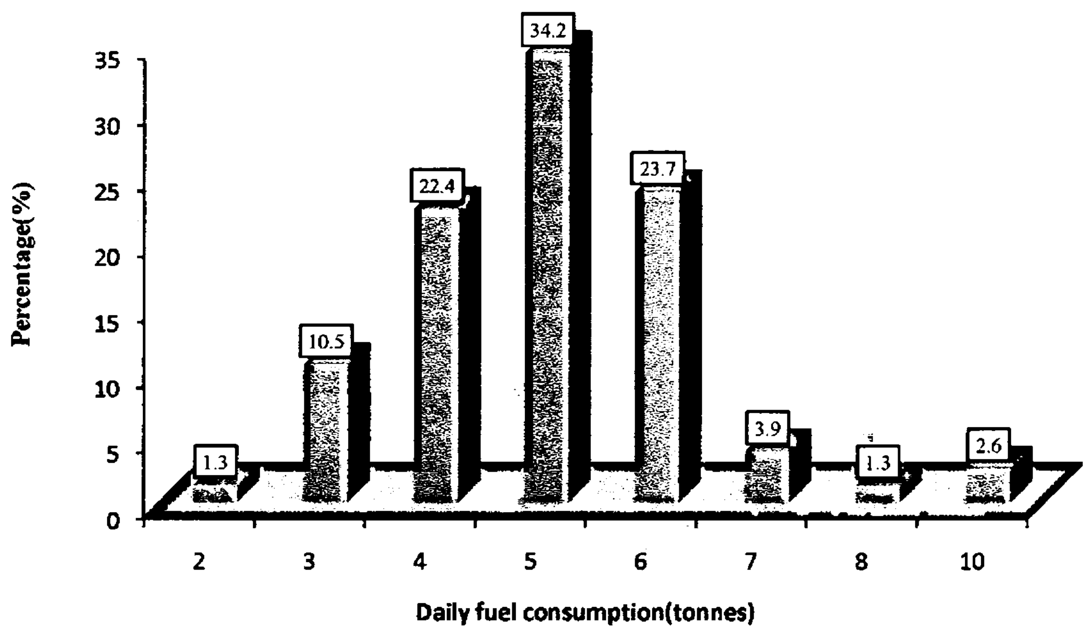

Figure 3.11 Daily fuel consumption of operating brick kilns in Islamabad

3.1.7 Production capacity

The bricks industry in Pakistan is estimated to produce 11 billion bricks annually which is mainly contributed by the large factories with 3-4 millions bricks per annum (FAO, 1993). The production capacities of the brick factories distributed in and around the federal capital are presented in figure 3.11 clearly indicating that bricks for construction activities in the area are majorly provided by the factories with daily brick production ranges from 10,000-40,000. The major contribution is shared by 37.7% factories having production capacities of 22,000 bricks per day to cater the public demands.

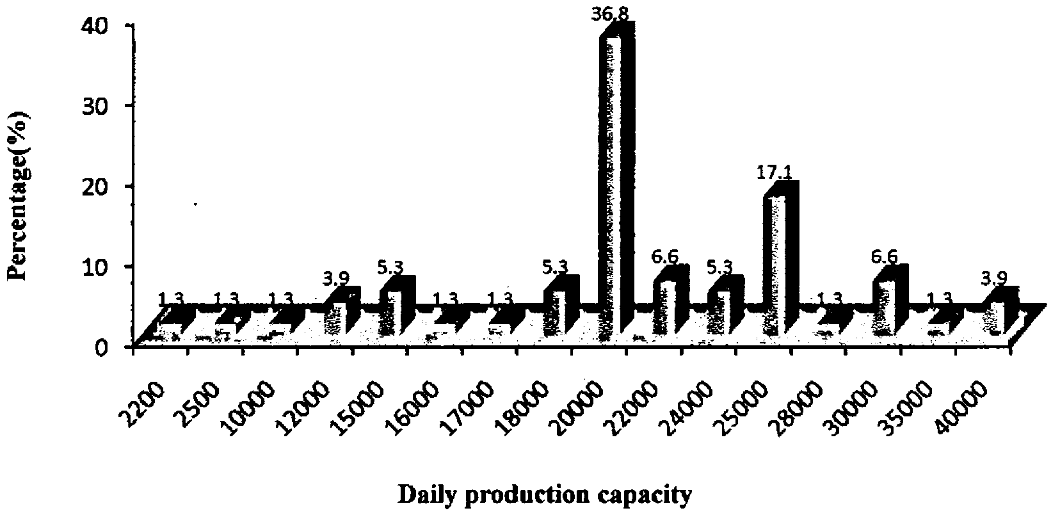

Figure 3.12 Daily production capacity of the operational brick kilns in Islamabad

3.1.8 Chimney height

It was observed that chimneys are made of cement in masonry work in the middle of the each kiln being oval in shape. The visited brick kilns in the study area were found having one fixed chimney with varying heights as shown in fig.3.13. However, the chimney height of 65 feet is observed in most (more than 50 %) of the visited (78) brick kilns as there is no specific limit for chimney height recommended by concerned government authorities.

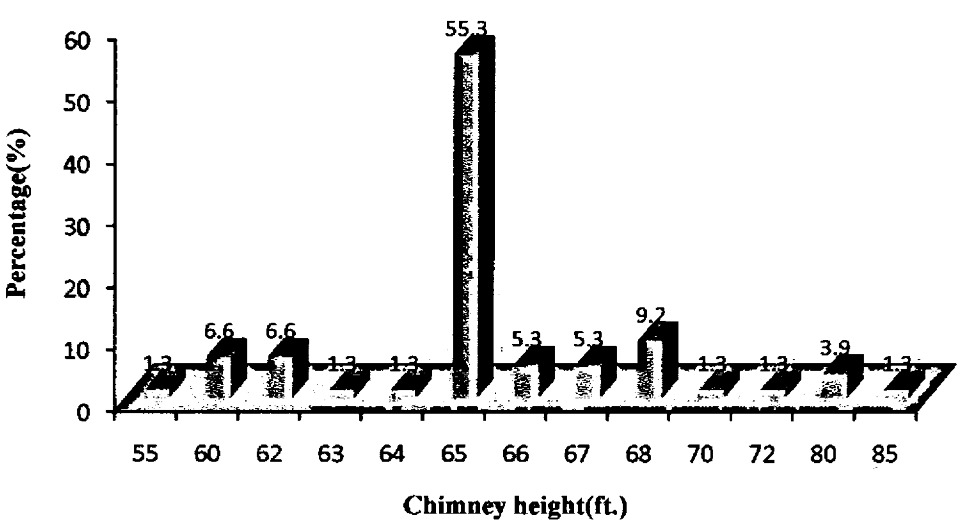

Figure 3.12 Chimney height of the brick kilns operating in Islamabad

3.1.9 Working days

Analysis of questionnaire data through SPSS shows that there are 6 working days per week in most (nearly 75) of the bricks enterprises operational in capital area and the only off day for workers is Thursday or Friday. Moreover, even no weekly holiday is offered to workers in few cases.

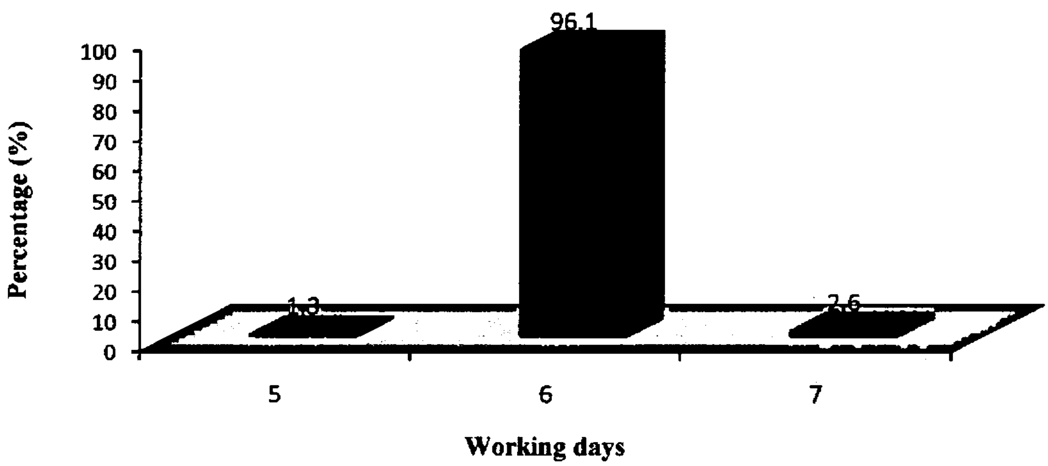

Figure 3.13 Weekly working days of operational brick kilns in Islamabad

3.2 Stack Emissions Monitoring

Two randomly selected brick kilns of fixed chimney in the suburbs (one at zone II and one at zone IV) of Islamabad were monitored for their stack emissions. The monitoring of stack gas emission (PM, CO, CO_2, NOx, and SO_2) was conducted during the firing batch of April 2011. Stack emissions of the monitored brick kilns along with industrial emission standard adopted for such type of units or emission source in the country are given in table 3.4.

The profile of stack emission characteristics given in table 3.4 reveals that flue gas velocity of the fixed chimney kilns varied from 0.21 - 0.53 m/s and temperature of flue gas at two sampling points ranged from 60.2- 67.8 °C. The obtained range of flue gas flow rates was found from 3182 – 14910 m^3/h. The results of monitored brick kiln stack emissions at two sampling sites in the study area, indicates that 676.78 mg /m^3 of PM concentration was observed at first sampling site (Tarlai) and concentration of PM for fixed chimney brick kiln at 2nd sampling point (Budhana

Table 3.4 Stack emission results of the monitored brick kilns

Parameters	Results		Standard value
	sampling site# 1	sampling site# 2	
PM	676.78 mg/ m^3	1000 mg/ m^3	500 mg/ m^3
NOx	296 ppm	25 ppm	400 ppm
SO_2	44.8 ppm	22 ppm	400 ppm
CO	334 ppm	600 ppm	800ppm
CO_2	8.99%	9 %	Does not exist
Flow rate of wet flue gas	3182 m^3_N/h	14910 m^3_N/h	Does not exist
Flow rate of dry flue gas	2799 m^3_N/h	13762 m^3_N/h	Does not exist
Temperature of flue gas	60.2 ^oC	67.8 ^oC	Does not exist
Moisture of the flue gas	12.06 %	8%	Does not exist
Velocity of the flue gas	0.21 m/sec	0.53 m/sec	Does not exist

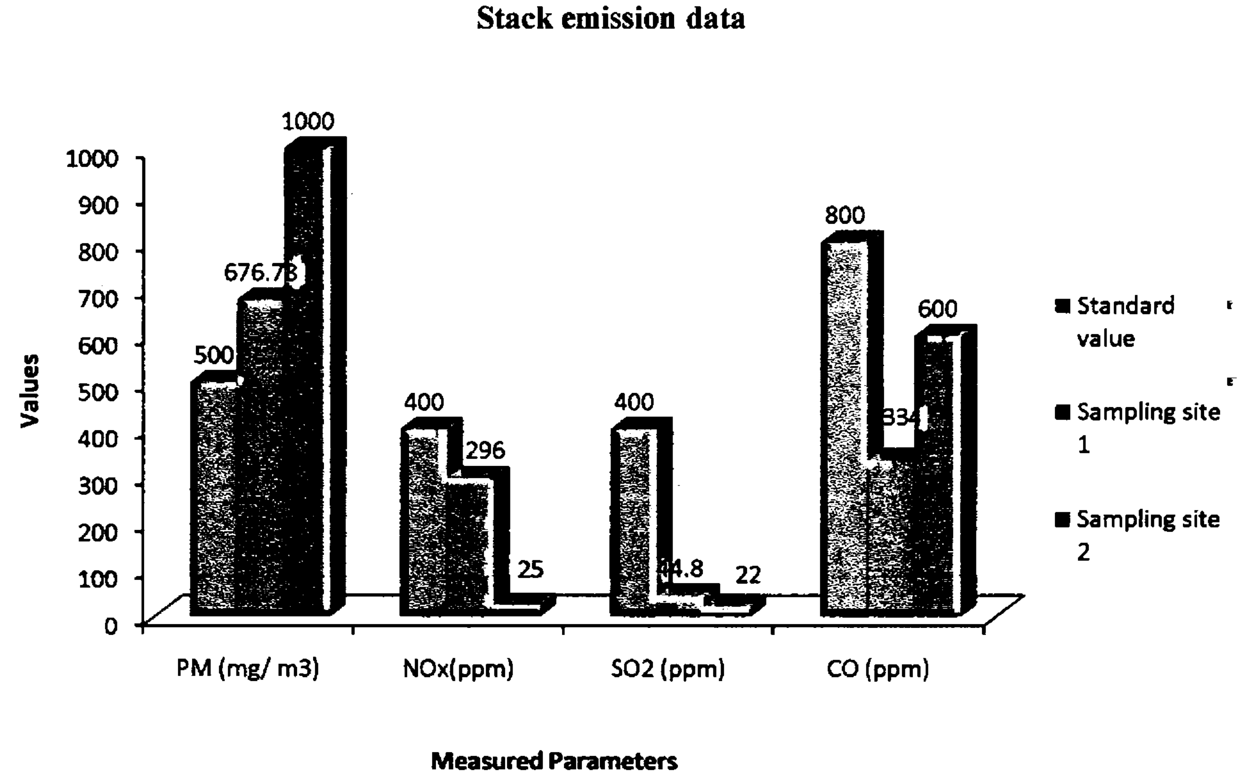

Figure 3.14 Comparison of stack emission monitoring results with standard values

village near motorway) was 1000 mg/m^{3}which exceeded the National industrial emission standards stipulated by the Pakistan Environment protection Agency for such type of sources under S.R.O. 742 (I)/93 in 1993.

The observed values of NOx on hourly basis at two sampling sites are 296 – 25 ppm which are below the permissible limit as mentioned in the Industrial Emissions Standards promulgated for the country. The range of hourly SO_2 and CO measured at two sites in April 2010 in the study area are 44.28-22 ppm and 334 to 600 ppm respectively not exceeding the national emission standards for industries.

3.3 Integrated Dispersion Modelling

The dispersion modeling tool used in the present study is CALPUFF which is coupled with a mesoscale meteorological model MM5 to generate the data of meteorological parameters required for further processing using CALMET. Finally, this meteorological data is used in CALPUFF modeling system to simulate the dispersion of pollutants.

3.3.1 Mesoscale Meteorological Model (MM5)

A) Measured meteorological data:

The three hours (11:00 pm-14:00 pm) data of temperature, wind speed and wind direction for 21 September 2011 was measured at Tarlai area of Islamabad and the half hour average values of temperature and wind speed are mentioned in Table 3.5. The comparison of two measured parameters such as temperature and wind speed can be clearly shown by Figure 3.16. It is obvious that the stable atmospheric conditions prevailed during the monitoring day with slight increase of temperature from 31°C to 33°C. The values of wind speed for the total measured time period varies from 0.9 m/s to 3 m/s and from 3m/s to 1.85 during initial two and last hours respectively in the given area. The wind speed in the early hour of observed period near the brick kiln cluster was 1m/s with the predominant direction towards south. There was an increase in the wind speed up to 3 m/s in the second hour. The declining trend in the value of wind speed up to 1.2 m/s to 1.8 m/s was noticed in the last hour with changing wind direction towards southeast.

Table 3.5 Measured temperature and wind speed average values

Time (hour)	Ambient temperature (□C)	Wind speed (m/s)
0	31 00	0.91
0.5	31.13	1.55
1	32 19	2.29
1.5	32.45	2.14
2	33.08	2.96
2.5	33.2	1.25
3	33.25	2.53
3.5	33.35	1.85

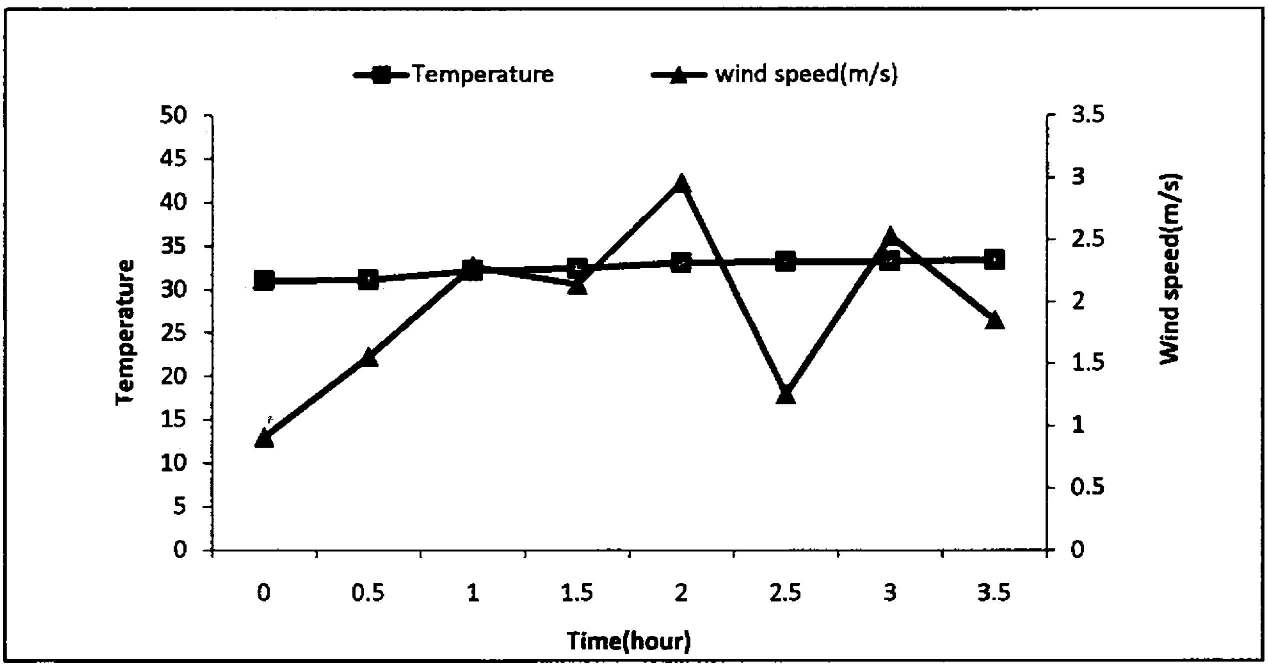

Figure 3.15 Measured temperature and wind speed average values

B) Simulated meteorological data using MM5

In order to check the MM5 model performance, the simulated data of metrological parameters i.e. ambient temperature, win speed and wind direction is compared with the measured data. The variation of metrological variables such as air temperature, wind speed and wind direction with time is shown in figures 3.16, 3.17 and 3.18 respectively. The average measured and simulated ambient air temperature values are given in table 3.6. However, the plotted air temperature data in figure 3.16 clearly indicates that there is a close agreement between modeled and measured results and there is a slight mismatch during the day time.

Table 3.6 Average values of measured and simulated ambient temperature

Time (hour)	Measured values	Simulated values
0.5	31.00	32.75
1	31.13	33.01
1.5	32.19	33.01
2	32.45	33.26
2.5	33.08	33.22
3	33.2	33.11
3.5	33.25	32.68
4	33.35	32.66

A comparison of numerically calculated and observed data of wind speed and wind direction is shown in figure 3.17 and 3.18 respectively.

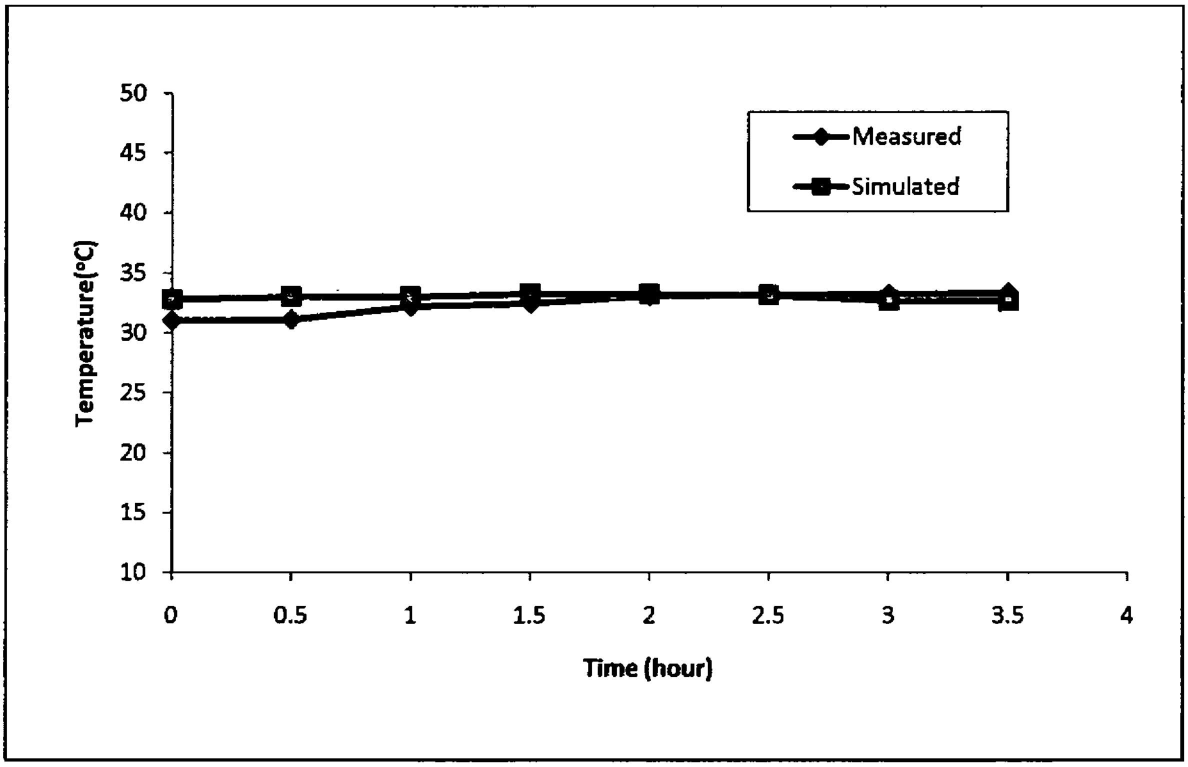

Figure 3.16 Comparison of Observed and MM5 modeled ambient Temperature

Temporal change of measured and modeled values of wind speed (m/s) is presented in table 3.7 whereas table 3.8 contains the measured as well as simulated wind direction values on average basis. It is clearly depicted by figure 3.17 that the measured values of prevailing wind speed show higher range than predicted by model. In contrary to wind speed, the simulated data for wind direction show exceeding values than the observed data as illustrated in figure 3.18. The possible reasons of slight mismatch between measured and simulated data of wind speed and wind direction are the fluctuating behavior of wind parameters and presence of a number of brick kiln stacks (approximately 85 feet) which may act as obstacle in the way of blowing wind. Since temperature does not experience abrupt changes during daily solar cycle therefore it shows more stable behavior as compared to temperature.

Table 3.7 Average values of measured and simulated wind speed (m/s)

Time (hour)	Measured values	Simulated values
0.5	0.913	1.216
1	1.556	1.246
1.5	2.29	1.243
2	2.143	1.22
2.5	2.96	1.17
3	1.253	1.126
3.5	2.533	1.066
4	1.853	1

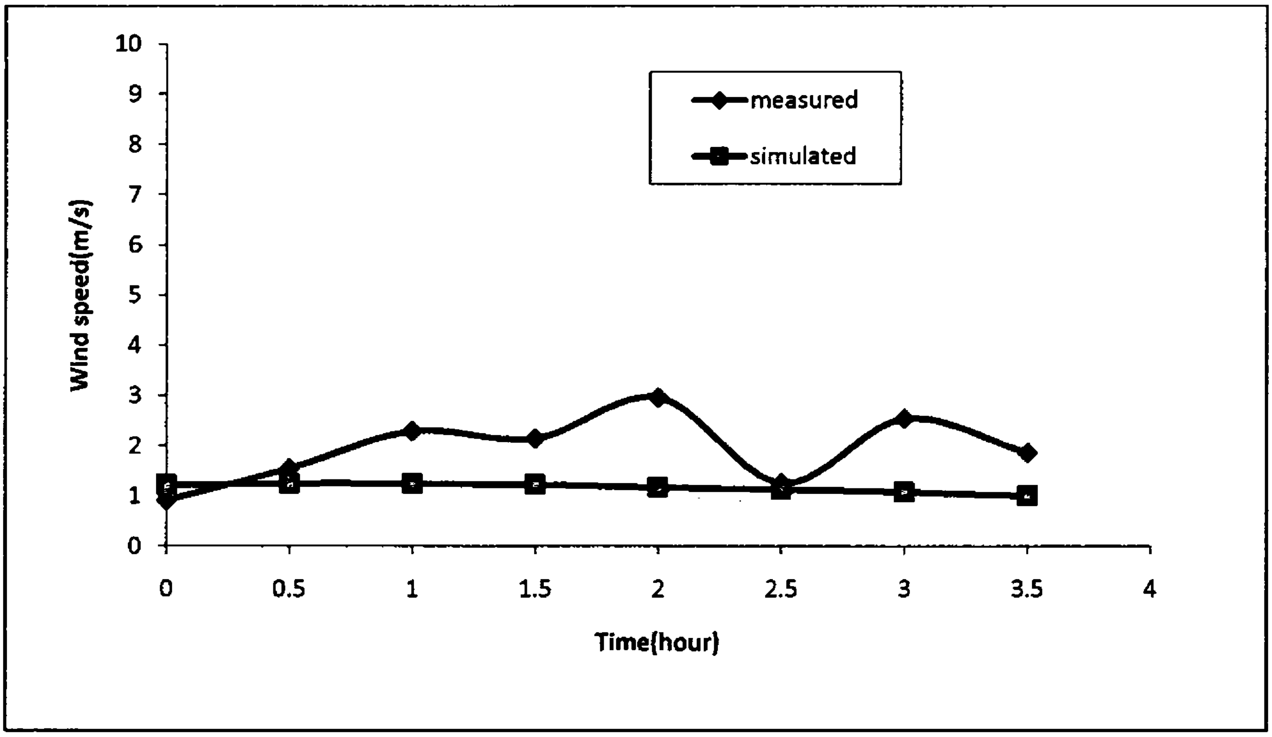

Figure 3.17 Comparison of observed and MM5 modeled wind speed values

Table 3.8 Average values of measured and simulated wind speed

Time (hour)	Measured values	Simulated values
0.5	201.21	190.3
1	171.78	171
1.5	88.31	168.33
2	138.66	167.33
2.5	116.16	163
3	152.89	161.56
3.5	184.11	161.6
4	64.82	161.66

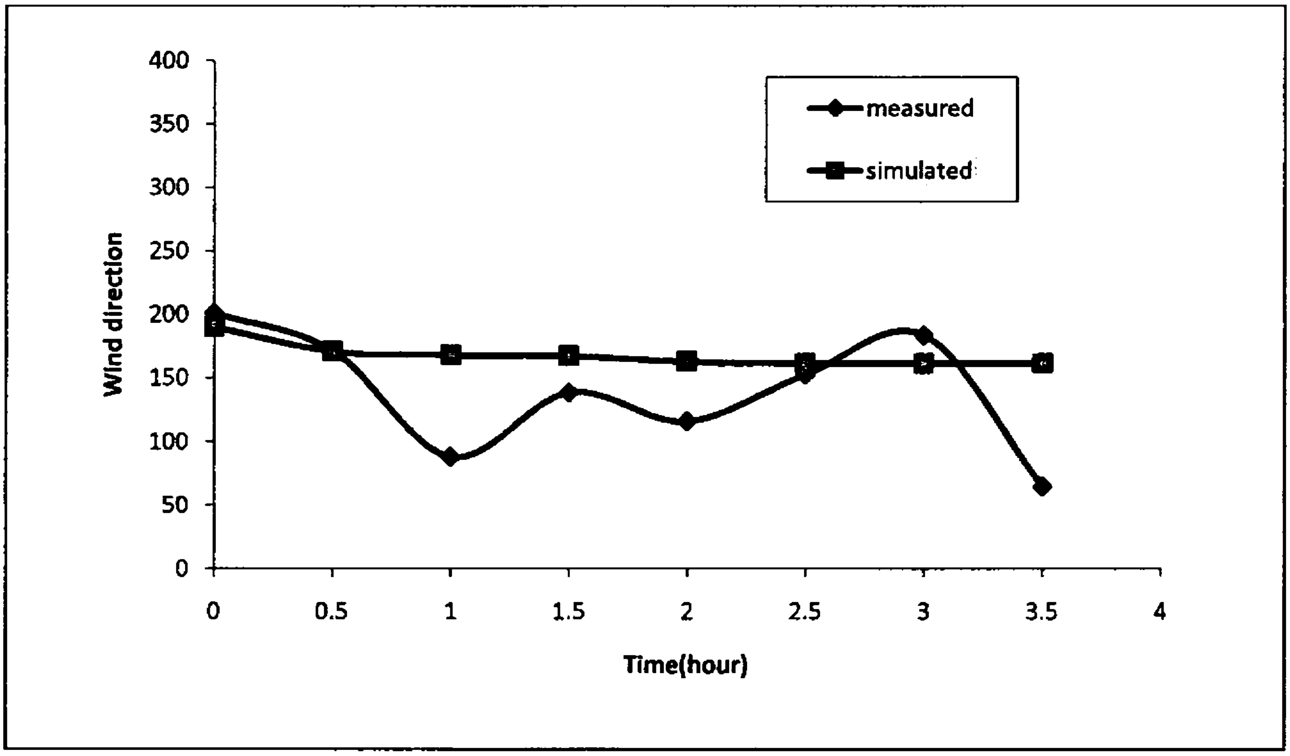

Figure 3.18 Comparison of observed and MM5 modeled wind direction values

3.3.2 CALPUFF Dispersion Model

This section describes the dispersion results of brick kiln emissions particularly SO_2 and NOx produced as a result of 3 hours simulation executed for 21-9-2011 at Tarlai area, Islamabad by using MM5-CALMET-CALPUFF modelling system.

i. SO_2 dispersion:

SO_2 is the significant pollutant released directly into the atmosphere from coal combustion as sulpher is the main component of coal. The 3 hours averaged ground level concentration of brick kiln emissions particularly SO_2 in the surroundings of the cluster of brick enterprises at Tarlai are shown by isopleths plots. These isopleths indicates the spatial and temporal variations in the pollutant concentration in the study domain.

Figure 3.19 shows the modeled predicted hourly averaged SO_2 ground level concentrations varied from 0.1-10 $\mu g/m^3$ at 12:00 pm on September 21, 2011 over Tarlai cluster of brick works in Islamabad. It is illustrated by the figure that the dominant south eastern wind as indicated by the wind vectors was responsible for the transportation of pollutants released from brick kilns cluster away from the sources. The maximum hourly average concentration of SO_2 was estimated higher than 10 $\mu g/m^3$, originating from brick kiln cluster and strong wind magnitude enabled the emitted pollutant to slightly disperse over the area before transported away.

The dispersion pattern of averaged ground level SO_2 concentrations at hours 13:00 for 21 September 2011 in the modeled domain are depicted by figure 3.20. As anticipated, the maximum computed SO_2 dispersion as presented by different concentration ranks (0.1-<10) contributed by brick works at study area over the area of about 8km in the south whereas 3.5 km towards eastward side.

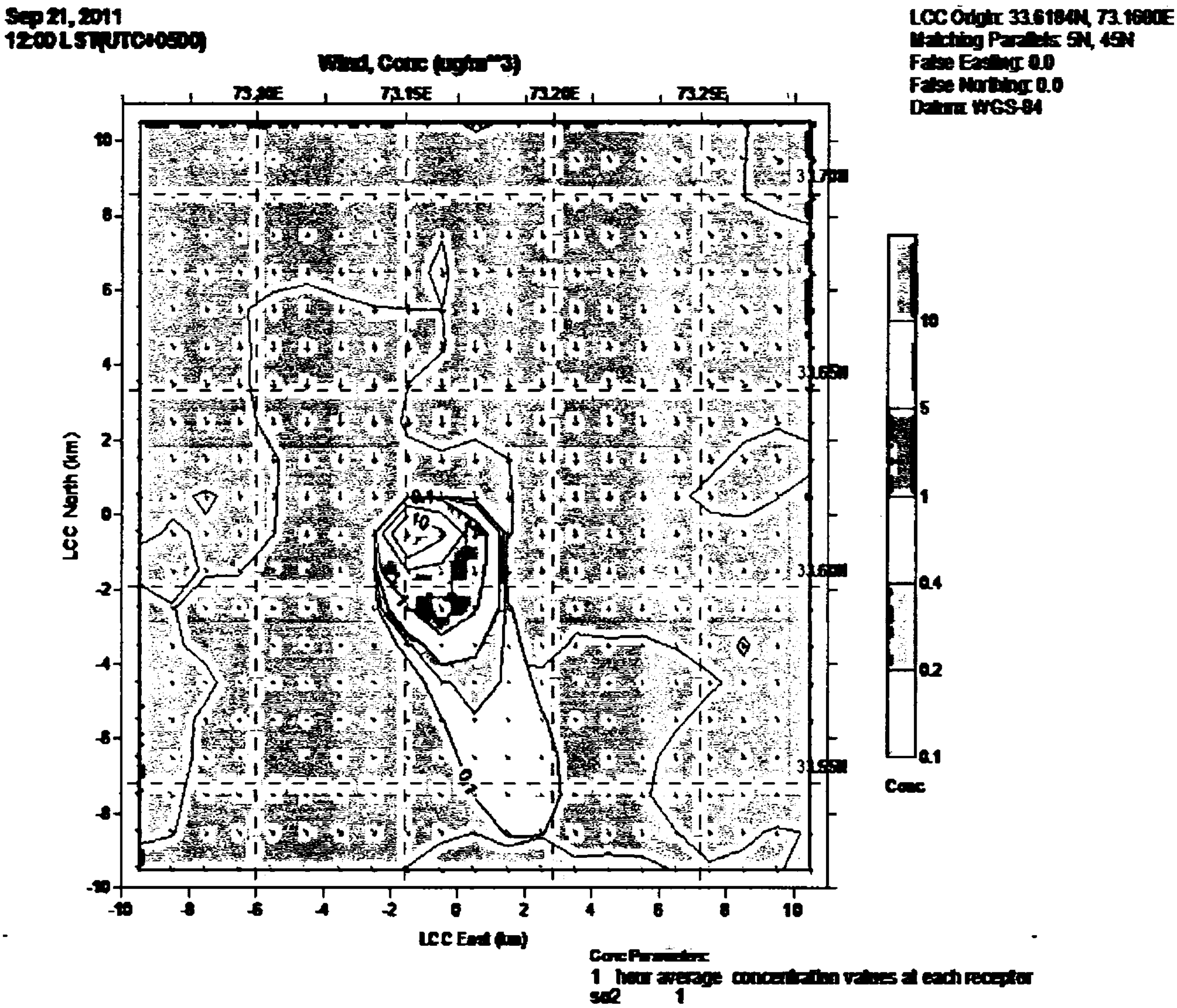

Figure 3.19 Hourly averaged SO_2 ground level concentration contours at 12:00 pm

The SO_2 emission follows the same dispersion pattern (towards the southeast), after released from a cluster of operational brick enterprises as in the earlier hour. The contour lines of the SO_2 plume in the south direction are concentric and homogenous in shape due to presence of flat terrain (containing few obstacles) away from the emission sources in the south direction. The high magnitude contours tends to show less spreading away from the source than the contours lines with higher concentration values.

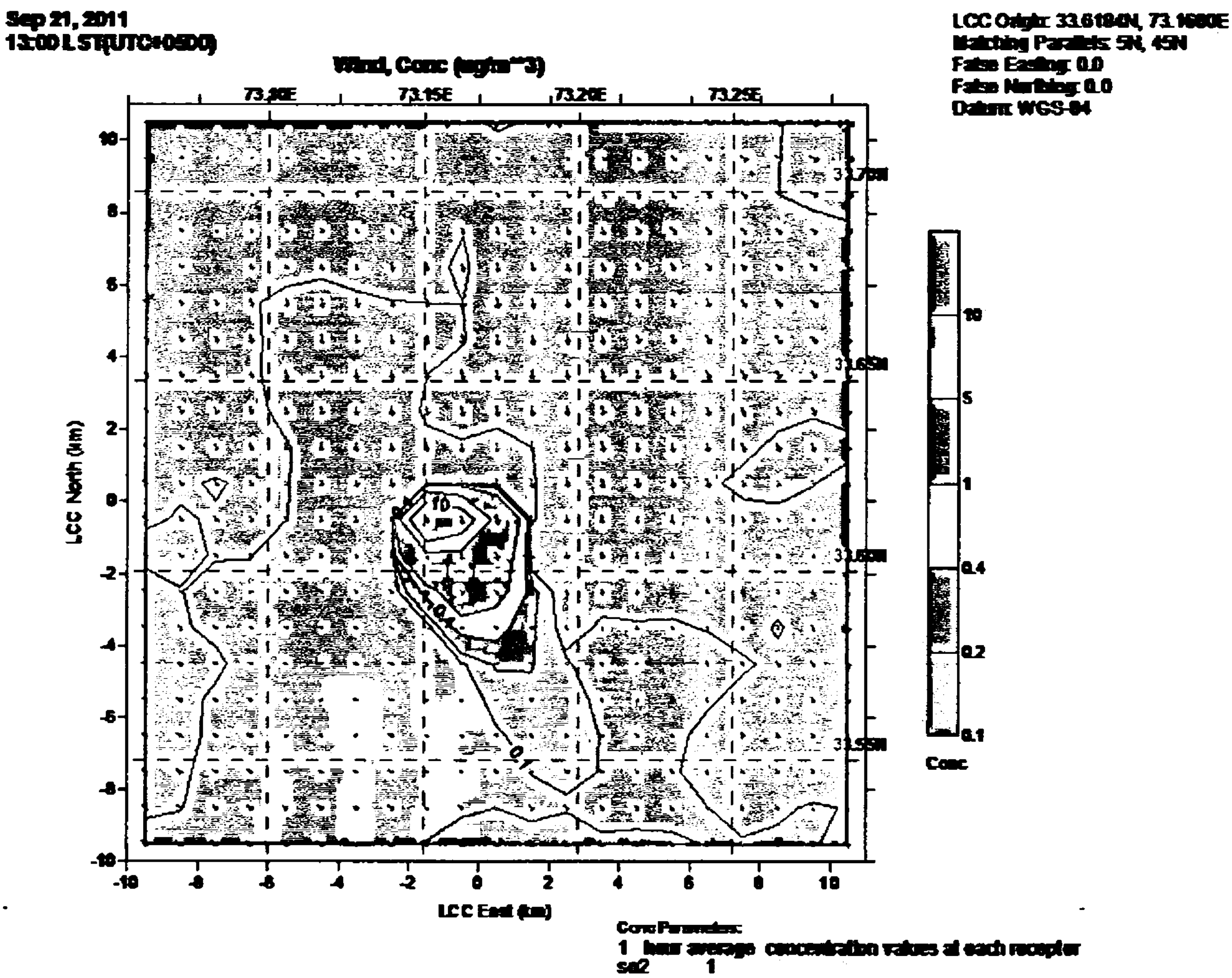

Figure 3.20 Hourly averaged SO_2 ground level concentration contours at 13:00 pm

Figure 3.21 depicts the pattern and magnitude of SO_2 for the 3rd hour (14:00pm) of September 21, 2011. The isopleths of SO_2 dispersion for the last simulated hour depicted the southward dispersion is reduced up to area of 7.5km than the previous hour where it is 8 km. On contrary to the southward dispersion, the pollutants transported more i.e. up to 4 km eastward side mainly contributed by development of the southeasterly wind fields as shown in figure 3.21.

Unlike the previous ones, the spatial and temporal distribution of concentrated plume is slightly heterogeneous due to little variations in terrain of the area along with changing wind direction. The leading direction of concentrated plume dispersion is more toward the southeast as clearly indicated by the wind vector.

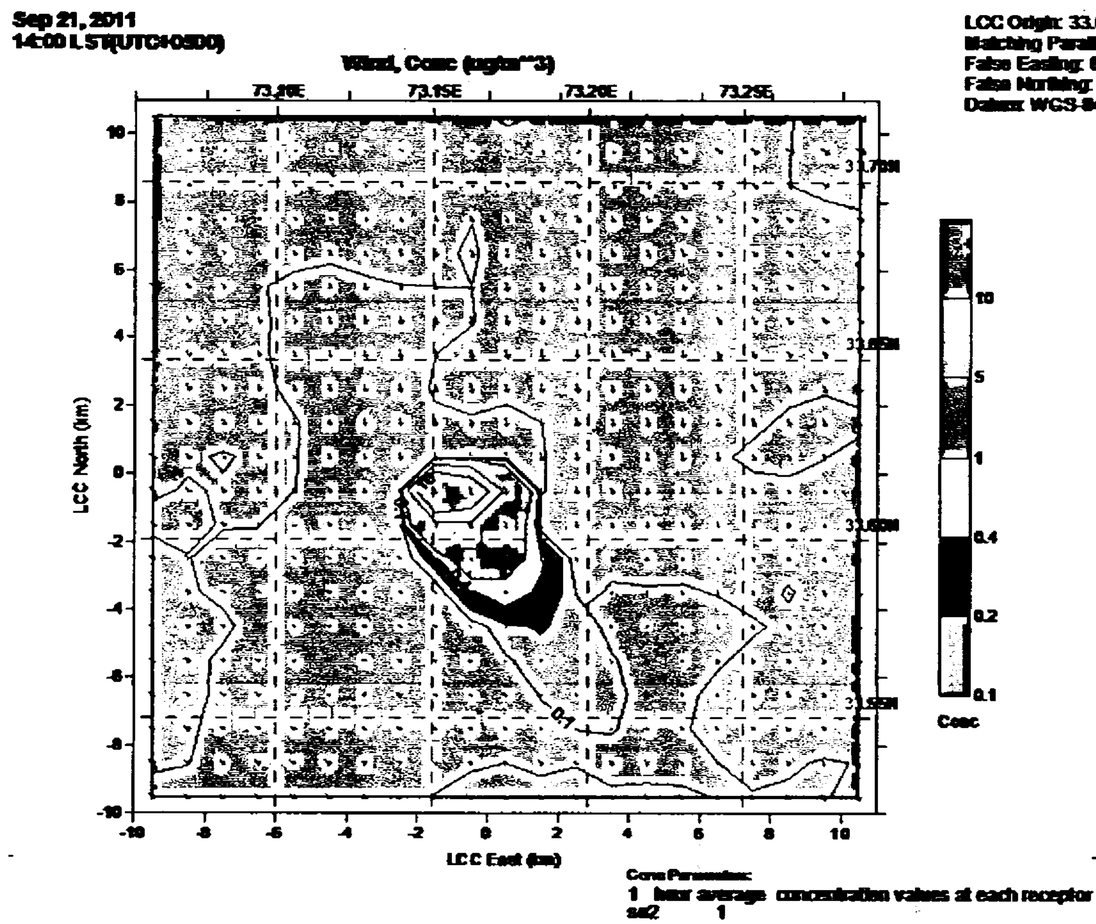

Figure 3.21 Hourly averaged SO_2 ground level concentration contours at 14:00 pm

The flow of wind from the north of pollution sources is responsible for transporting the emissions away from the sources towards the south eastern areas up to 4 km although the magnitude of the emitted pollutants concentration drops rapidly with increasing distance from the source which is clear from contour having concentration of 0.1μg/m^3 but considered important particularly considering the health perspective of the nearby residing communities.

ii. NOx dispersion:

The important pollutant released into the atmosphere from coal fired brick enterprises in the modeled domain is Nitrogen dioxides usually known as NOx. The average behavior of NOx dispersion within the selected domain of Calpuff model for 3 hours simulation on 21-9-2011 can be seen from figures 3.22, 3.23 and 3.24 for the consecutive simulated hours.

In the present case, the high magnitude wind with varying directions dominates the northern side of the modeled brick kilns cluster which tends to become weaker while blowing in the south and south eastern direction as is obvious from given figures of NOx. The length of the wind vector (arrow) describes the strength of the wind dominating the area in chosen domain.

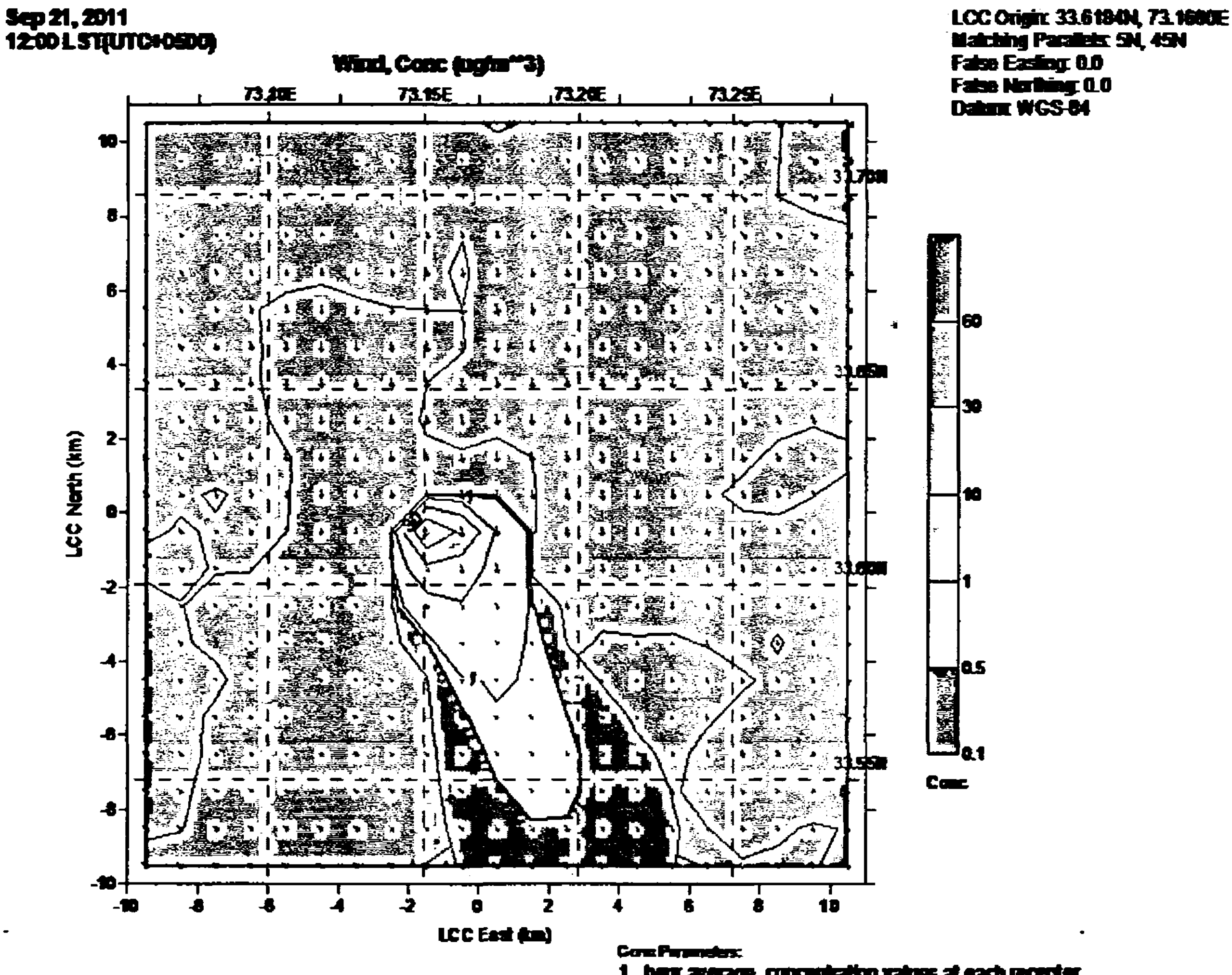

Figure 3.22 Hourly averaged NOx ground level concentration contours at 12:00 pm

The results of hourly averaged concentration profile of dispersed nitrogen oxides released from brick kiln cluster during total time period of simulated day is visualized from figure 3.22, 3.23 and 3.24 clearly illustrating the maximum NOx concentration (above 60 $\mu g/m^3$), released from the sources during three simulated hours, transported away from the sources and scattered over the area of 2 km (N-S) and nearly 1.5 km along eastern and western direction. Similarly, almost the same dispersion pattern is shown/presented by the second rank of averaged NOx concentration values from 30-60 μg/m^3 with a slight increase of over 1.5 km compared with maximum NOx values along the southward direction as clearly depicted from figures.

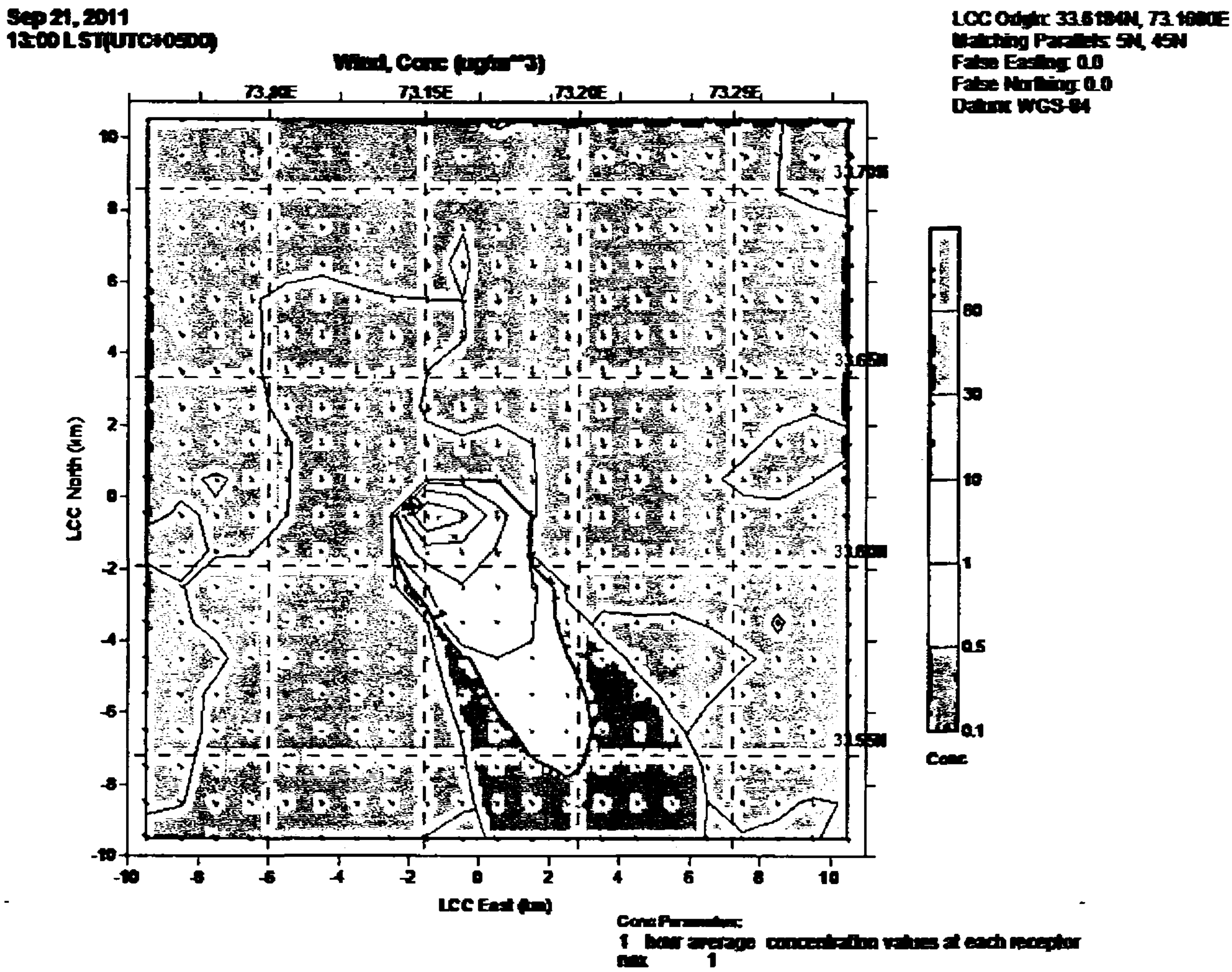

Figure 3.23 Hourly averaged NOx ground level concentration contours at 13:00 pm

Average hourly distribution of NOx pollutant ranking 10-30 μg/m^3 concentration in the modeled domain spread over 2.5 km in the south and 0.8 km towards west of brickworks at Tarlai kalan area of Islamabad territory. It is obvious from the results that 1-10 μg/m^3 concentration of emitted NOx emissions on hourly basis is distributed up to 5 km in the first simulation hour followed by the spread of 4.5 km in southward of the emission source during next two hours. The homogenous and concentric lines shown by the dispersed NOx plume in the southward direction indicates the flat terrain area.

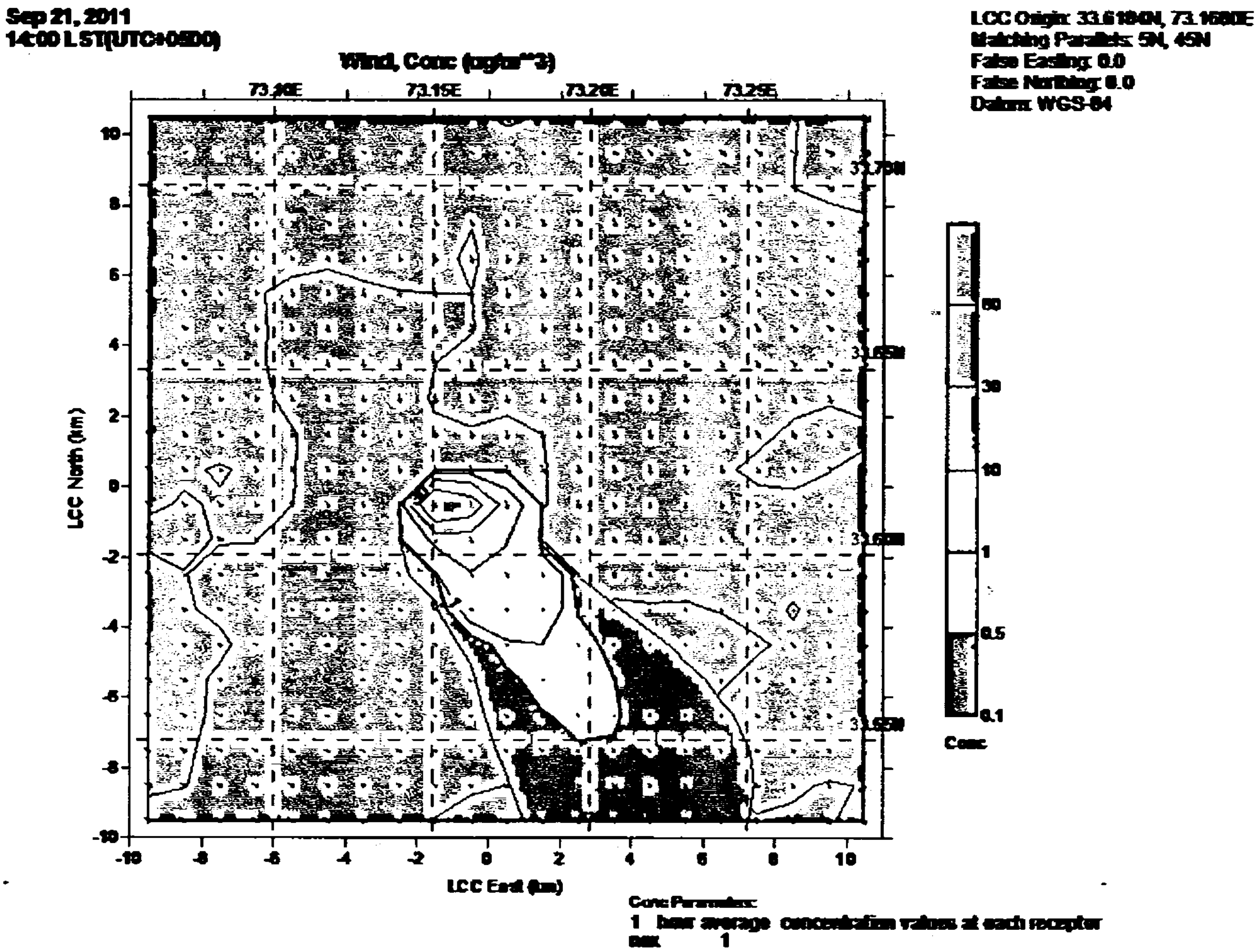

Figure 3.13 Hourly averaged NOx ground level concentration contours at14:00 pm

In addition to previous results, the emission of NOx with 0.1-0.5 μg/m^3 concentration originating from the simulated cluster of brick enterprises(at Tarlai) show highest dispersion of 9.5 km in the southern side. The declined distribution pattern of NOx emission towards southward and increased dispersion values towards east of the emission sources (brick kilns) in the selected domain reflects the variations in the prevailing southeast wind flow responsible for the more dispersion of pollutants away from sources as clearly displayed in computed CALPUFF images for NOx dispersion.

4. CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

Air quality deterioration is the matter of grave concern in urban area all over the world fueled by industries and transportation. Despite other sources, the issue of air quality is compounded ultimately by the unorganized and small scale brick production enterprises confining the suburban areas of capital city.

The present study conducted for baseline and emission data generation of existing brick enterprises in the vicinity of Federal capital Islamabad indicated that out of total 103 brick enterprise, 78 were functional and 25 were non-functional mostly confined to the suburbs of Islamabad. The operational mainly coal fired brick enterprises with 65 feet averaged stack height employed total number of 8200 workers covering 10118 kanal area land 82% of which was taken on lease by the brick kiln operators/entrepreneurs. Combustion of approximately 5-6 tonnes coal daily resulted into the production capacity of 20,000 bricks per day. The combustion of fuel results into the emission of hazardous gasses mainly CO, SO_2, NOx and PM into the ambient air. The monitored stack emission was found within the permissible limits by regulatory authorities except Particulate Matter indicated 676.78 and 1000 mg/m^3 exceeded the stipulated national industrial emission standards.

CALPUFF dispersion model was employed to estimate the ground level concentration of SO_2 and NOx emission emitted from a set of 34 coal fired brick kiln stack clustered in the southeastern suburbs of federal capital Islamabad. The selected brick kiln emissions were simulated by employing CALMET/CALPUFF system for 3 hour (11:00am to 14:00pm).The latest and prognostic meteorological modeling system MM5 was used to generate meteorological data required for the CALPUFF, dispersion model. The model performed reasonable for the study area with satisfactory agreement between simulated and measured metrological as well as emission data. The magnitude and dispersion pattern of NOx and SO_2 as predicted by the CALPUFF dispersion model indicated that maximum hourly averaged concentration of <10 μg/m^3 for SO_2 and <60 μg/m^3 for NOx, estimated in and around the modeled cluster scattered over 1.5 km area while the low magnitude plume ranging from 0.1-0.5 μg/m^3 plume showed maximum dispersion over the area of about 8 km for NOx and 4 km for SO_2 towards southeast, mainly attributed by the prevailing meteorological conditions (wind speed and wind direction). The dominant southeasterly wind vector was responsible for the dispersion of brick kiln emission during the simulated time span.

Further research on the assessment of emissions from brick kiln and the effort/activities such as plantation, anti-pollution devise installation, introduction, promotion and shifting of more environmental sound brick making technology, regular emission monitoring, relocation of brick kiln sites, promulgation of brick kiln emission air quality standard may contribute to cleaner air quality situation in the federal capital.

4.2 RECOMMENDATIONS

Due to the unavailability of sufficient air-quality information especially for brick kiln sector in capital city there is an immediate need to improve the monitoring and evaluation systems for urban air pollution. Some suggestions are recommended in order to ensure the viable and sustainable operation of brick production sector through maintenance of environmental responsibility.

1. A comprehensive, integrated and enforceable air quality management plan incorporating all emission sources to protect the environmental conditions of the area and as earlier the plans are enacted, the lower the air pollution will occur.
2. Strong understanding and effective coordination among the planners, implementation authorizes about air quality management system/ plans to make this fruitful regarding environmental protection.
3. Designation of brick kiln sector under small scale industries in country like India, as brick kilns are the significant air deterioration sources, so that self pollution assessment regulation like SMART for industries would be possible to implement and enforced.
4. A large number of brick enterprises are being in operation across the country to meet the construction demands of the people as no any kind of permission or registration is required to initiate the business. As a result no exact data on their number and location are available yet. Therefore, for availability of exact and sufficient information of this business, a staged proper method / procedure should be developed, approved and enacted by the concerned Government authorities for the registration and establishment of brick kilns in an area.
5. Coal fired clay brick production enterprises are polluting the air quality but the actions like banning, closing and demolishing for the sake of environmental protection are not the feasible solutions to cope with the worsening air quality as high capital investment and employment of huge number of workers are associated with this business.
6. Emission of dangerous pollutant (mainly SO_2, CO and NOx) from brick kilns are directly related to the combustion of fuel quantity and quality. Burning of fuel wood, low quality coal, rubber and plastics are mostly used for clay brick backing. The prime combustion

fuel, coal with low sulpher content (named as high quality) should be encouraged and supplied by government on subsidized rates to the brick kilns owners or operators to minimize atmospheric pollutants.

7. There is need to establish an effective monitoring and evaluation system for hazardous emissions released from the brick kiln stacks regularly for environmental damage estimation.
8. The low stack heights in the city contribute to confine the pollution load within the area where brick kilns are operating. So, there should be some stack height limits to control the air pollution.
9. Installation of air pollution control devices such as wet scrubbers and gravity settling chambers proved to be really helpful in emission reduction.
10. Separate National Air Quality Standards (NAQS) for this category of stack emissions on the basis of physical stack height and other characteristics including fuel consumption are need to be established and enacted.
11. The brick kilns should be relocated to some suitable place/site blessed with availability of abundant resources such as water, clay, needed for brick making.
12. The brick kiln owners can be persuaded to protect the environment by ensuring them incentives in land acquisition during relocation process, shifting to environmental friendly technology, supply of pollution control devices and high quality coal
13. Plantation on the periphery of brick kiln area would prove to be very effective in pollution control.
14. The concerned regulatory authorities must seek for introduction and transfer and promotion of the state-of-the-art brick firing technologies employed worldwide such as Vertical shaft brick kiln (VSBK), Tunnel kilns and Habla kilns which are more effective in terms of energy efficiency and economic viability and environment friendliness.

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		brick kiln	mark	status	owner name	-ment date	(kanal)	no. of workers	workers		purchasing point	consumption (tones)	Production capacity	height (ft)	days/ week	pollution device
1	Lohibhair	Sarhard punjab bricks	A-R	Partially owned & partially leased	Haji amir-ur-rehman	1980	200	200	none	coal	Quetta/ Chakwal	5	2500	80	6	not installed
2	Karal town	Haji munir bricks	R-M	Personally owned	Haji munir	1978	150	60	none	coal	Quetta	2	2200	85	7	not installed
3	Karal town	Haji Bashir bricks	AR	Partially owned & partially leased	Haji Bashir	1981	150	80	25	coal	Quetta	6	22,000	72	6	not installed
4	Karal town	Raja Zulfiqar and Imran bricks	Imran bricks	Personally owned	Raja Zulfiqar	1990	100	40	10	coal	Quetta	5	20,000	60	6	not installed
5	Tarlai kalan	Mohammad Riaz Bricks	A.-R	leased	Moh. Riaz	1980	300	250	50	coal	Quetta &Punjab	7	25,000	65	6	not installed
6	Tarlai kalan	N.B bricks	N.B	Personally owned	Mohammad Ihsan	1997	150	350	30	coal & wood	Quetta &Punjab	5	30,000	65	6	not installed
7	Tarlai kalan	Ittefaq bricks	I.B	Personally owned	Ch.Manzoor/ Ch.Abdul Majid	1990	70	30	none	coal	Quetta &Punjab	4	20,000	80	6	not installed
8	Tarlai kalan	Rizwan bricks	A.R	leased	Rizwan	1994	150	100	none	coal	Quetta &Punjab	5	25,000	80	6	not installed
9	Tarlai kalan	Haji Riaz Azam bricks	M.A	leased	Haji Riaz Azam	1984	150	100	20	coal	Quetta	6	20,000	65	6	not installed
10	Tarlai kalan	Mirza Nasir Mehmood bricks	A-one	leased	Mirza Nasir Mehmood	1990	150	80	none	coal	Chakwal	5	20,000	65	6	not installed
11	Tarlai kalan	Chaudary Nasir bricks	A-R	leased	Chaudary Nasir	1995	100	100	40	coal	Quetta	5	20,000	65	6	not installed
12	Tarlai kalan	National bricks	T	leased	Chaudary Riaz Gondal	1995	150	100	32	coal	Chakwal	5	25,000	65	6	not installed
13	Tarlai kalan	Chaudary Moh Azam & co.	M-A	leased	Chaudary Moh.Azam	2007	250	500	10	coal	Quetta	4	20,000	65	5	not installed
14	Tarlai kalan	Chaudary Farooq bricks	M-B	leased	Chaudary Farooq	1990	150	120	20	coal	Quetta &Punjab	5	20,000	65	6	not installed
15	Tarlai kalan	Zia Cheema Bricks	T-H	leased	Zia Cheema	2004	100	100	35	coal	Chakwal	5	20,000	65	7	not installed
16	Tarlai kalan	Chuadry Munnawar bricks	A-M	leased	Chuadry Munnawar	1990	150	100	80	coal	Chakwal	5	25,000	65	6	not installed
17	Tarlai kalan	Ch. Fazal Rehman bricks	T.M	leased	Chuadry Fazal rehman	1996	150	95	none	coal	Chakwal	4	20,000	65	6	not installed
18	Tarlai kalan	Ch.Rhaheel Bricks	S-T	leased	Chaudry Raheel	1995	150	300	40	coal	Chakwal	5	20,000	65	6	not installed

Annexure - I Baseline datasheet of brick kilns Operating in Islamabad

19	Tarlai kalan	Mirza Baber bricks	M.B	leased	Mirza Baber	1980	120	60	4	coal	Quetta &Punjab	4	22,000	68	6	not installed
20	Tarlai kalan	Ch.Ikram bricks	A-M	leased	Chaudry Ikram	2010	150	80	10	coal	Quetta &Punjab	5	20,000	65	6	not installed
21	Tarlai kalan	Ch.Ikram bricks	A-M	Personally owned	Chaudry Ikram	1980	150	400	30	coal	Quetta	4	25000	65	6	not installed
22	Tarlai kalan	Chaudry Nasir bricks	R.S	leased	Chaudry Nasir	2005	150	40	5	coal	Chakwal	5	20,000	65	6	not installed
23	Tarlai kalan	Chaudry Taseer bricks	H	Personally owned	Chaudry Taseer	2007	150	40	7	coal	Quetta &Punjab	5	20,000	65	6	not installed
24	Tarlai kalan	Mohammad Riaz Bricks	T	leased	Mohammad Riaz	2005	150	40	5	coal	Chakwal	5	20,000	65	6	not installed
25	Tarlai kalan	Sheikh Nasir bricks	S-N	Partially owned & partially leased	Sheikh Nasir	1980	150	20	none	coal	Quetta &Punjab	3	25,000	65	6	not installed
26	Tarlai kalan	Sheikh Nasir bricks and co.	S-N	Personally owned	Sheikh Nasir	2000	200	80	10	coal	Chakwal	5	20,000	65	6	not installed
27	khanna pull	Chaudary Moh.Irfan bricks	A-R	Personally owned	chaudary Moh.Irfan	1985	150	60	none	coal	Quetta/ Chakwal	10	15,000	65	6	not installed
28	Kirpa	Chaudary Irshad Mehmood bricks	AM, MY	leased	chaudary Irshad Mehmood	1990	150	40	none	coal	Quetta/ Chakwal	4	20,000	65	6	not installed
29	Kirpa	Mohammad Khan Bricks	AR	leased	muhanmad khan	2002	110	110	none	coal	Chakwal	6	18,000	60	6	not installed
30	Sher damial	Khan Zaman Khan bricks & co.	AR	leased	Khan Zaman	1981	120	150	40	coal	Quetta &Punjab	5	18,000	68	6	not installed
31	Sher damial	Haji shakeel bricks & co	AR	leased	Haji Shakeel	1981	120	150	35	coal	Quetta &Punjab	4	18,000	68	6	not installed
32	Budhana village	M-A bricks	M-A	leased	Mian Abdul Bashir	2009	110	150	35	coal	Chakwal	3	15,000	62	6	not installed
33	Budhana village	A-H bricks	A-H	leased	mMoh.Riaz	2009	160	150	20	coal	Quetta	6	30,000	68	6	not installed
34	Budhana village	Hakeem Khan bricks	M-D	leased	Abdual Hakeem khan	2001	100	70	none	coal	Chakwal	4	16,000	65	6	not installed
35	Budhana village	C-N bricks	C-N	leased	Malik Gul Bahar	1993	150	180	none	coal	Chakwal	6	20,000	65	6	not installed
36	Budhana village	Gulfam bricks	A-H & A-R	leased	Fazal Karim	1991	150	300	none	coal	Quetta	3	18,000	60	6	not installed
37	Budhana village	Quetta bricks	M-L	leased	Haji Mirza Gul	2007	200	200	none	coal	Quetta	6	22,000	68	6	not installed
38	Budhana village	Hazrat Nabi bricks	C-N	leased	Hazrat Nabil	1985	120	70	none	coal	Chakwal	8	40,000	65	6	not installed
39	Budhana village	A-R bricks	A-R	leased	Muhammad Zahoor	2007	120	25	5	coal	Chakwal	3	10,000	63	6	not installed

40	Budhana village	Gujor-1 bricks	IM-1	leased	abdul Qayyum	2001	120	100	20	coal	Chakwal	4	17,000	66	6	not installed
41	Budhana village	Sikandar bricks company	S-R	leased	Mehtab Ahmad Abassi	2006	100	100	none	coal	Chakwal	6	20,000	62	6	not installed
42	Budhana village	A-R bricks	A-R	leased	Haji Aurangzeb	2004	150	70	none	coal	Chakwal	4	20,000	67	6	not installed
43	Budhana village	Haji Aurangzeb bricks	A-R	leased	Haji Aurangzeb	2004	140	80	none	coal	Chakwal	3	18,000	60	6	not installed
44	Budhana village	Murtaza bricks	B-R	leased	Haji Murtaza	2001	130	80	none	coal	Quetta/ Khushab	5	22,000	62	6	not installed
45	Budhana village	Al Harman bricks	A-S-1	leased	Shah Jahan Khan	2001	136	100	none	coal	Chakwal	4	20,000	67	6	not installed
46	Budhana village	F-7 bricks	F-7	leased	Murad Khan	2009	130	80	none	coal	Quetta/ Chakwal	5	20,000	62	6	not installed
47	Budhana village	P-R-1 bricks	P-R-1	leased	Malik Hafiz	2000	120	80	none	coal	Chakwal	4	20,000	68	6	not installed
48	Budhana village	B-S bricks	B-S	leased	Ch.Mehmood	2005	120	100	25	coal	Quetta	6	12,000	65	6	not installed
49	Budhana village	B-S bricks	B-S	leased	Ch.Mehmood	2005	120	100	25	coal	Quetta	6	12,000	65	6	not installed
50	Budhana village	B-S bricks	B-S	leased	Ch.Mehmood	2005	120	100	25	coal	Quetta	6	12,000	65	6	not installed
51	Budhana village	M-Q bricks(2)	M-Q	leased	Mushtaq	2000	150	70	none	coal	Quetta	4	25,000	67	6	not installed
52	Banazir Chowk Tamol	Shams-ur-Rehman bricks	K-B	leased	Shams-ur-Rehman	2001	150	70	none	coal	Quetta/ Khushab	7	30,000	65	6	not installed
53	Banazir Chowk Tamol	Gujar one bricks	M-1	leased	Ch.Qayyum	1980	40	150	10	coal & wood	Chakwal	5	24,000	65	6	not installed
54	Banazir Chowk Tamol	A-1 bricks	A-1	leased	Jan muhammad	2001	100	80	none	coal	Quetta/ Chakwal	5	30,000	62	6	not installed
55	Banazir Chowk Tamol	Shaheen bricks company	R-C	leased	Haji Azhr Muhammad Khan	2001	100	80	20	coal	Quetta/ Chakwal	5	25,000	60	6	not installed
56	Banazir Chowk Tamol	Manzoor Khan bricks	555	leased	Manzoor	2007	140	25	none	coal	Quetta/ Chakwal	6	25,000	55	6	not installed
57	Banazir Chowk Tamol	Gondal Bricks company	A	leased	Haji Asghar Ali	1997	90	50	15	coal	Quetta/ Chakwal	6	40,000	66	6	not installed
58	Noon village	Ch.Masud bricks	J-C	leased	Ch.Masud	2003	100	120	30	coal	Chakwal	4	20,000	66	6	not installed
60	Noon village	Ch.Asif Jahangir bricks	J-C	leased	Ch.Asif Jahangir/Ch. Masud	2003	100	120	30	coal	Chakwal	4	20,000	66	6	not installed

61	Dhoke Hameedan	Haq Bahu Bricks	H-B	leased	Malik daud	1999	200	100	25	coal,wood ,rubber	Chakwal, local	6	25,000	65	6	not installed
62	Dhke Hameedan	Haq Bahu Bricks	H-B	leased	Malik daud	1999	200	100	25	coal,wood ,rubber	Chakwal, local	6	25,000	65	6	not installed
63	Dhoke Hameedan	Haji Rab nawaz brick kiln	P.R-1	leased	Haji Rab Nawaz	2000	85	70	none	coal & wood	Chakwal, local	5	22,000	64	6	not installed
64	Dhoke Hameedan	Malik Javed Brick kiln	P-1	Personally owned	Malik Javed	1995	80	40	none	coal & wood	Chakwal, Khushab	5	25,000	65	6	not installed
65	Dhoke Hameedan	Naveed and company	N-C	leased	Akhter Ali	2007	80	30	10	coal & wood	Chakwal, local	4	24,000	65	6	not installed
66	Dhoke Hameedan	Golden bricks	B-C	leased	Chaudary Bilal Shokat	1984	125	150	none	coal	Chakwal	6	20,000	65	6	not installed
67	Dhoke Hameedan	Habib said brick kiln	A-1	leased	Habib said	1986	130	80	none	coal & wood	Chakwal, Khushab	6	30,000	65	6	not installed
68	Dhoke Hameedan	M-1 brick kiln	M-1	leased	Haji Shakoor	2005	120	60	none	coal	Chakwal	4	20,000	65	6	not installed
69	Bajnail village	Abdullah brick kiln	B-1	leased	Malik Nazir	2006	115	35	none	coal	Chakwal	3	20,000	65	6	not installed
70	Bajnail village	Haji Amanullah brick kiln	P.R-1	leased	Haji Amanullah	2009	80	40	none	coal	Chakwal	3	15,000	65	6	not installed
71	Bajnail village	Qasim Khan brick kiln	P.R-1	leased	qasim khan	2006	107	40	none	coal & wood	Chakwal, local	3	20,000	65	6	not installed
72	Noughazi village	B-1 Brick kiln	B-1	leased	Haji abdullah	1998	120	70	20	coal & wood	Quetta, Chakwal, local	6	24,000	65	6	not installed
73	Noughazi village	B-1 Brick kiln	B-1	leased	Haji abdullah	1998	120	70	20	coal & wood	Quetta, Chakwal, local	6	24,000	68	6	not installed
74	Noughazi village	Qandari bricks	A	leased	Abdul Hakim	2010	100	120	none	coal & wood	Chakwal, local	5	28,000	65	6	not installed
75	Noughazi village	Haji muhammad - ullah bricks	B-1	leased	Haji muhammad ullah	2000	100	70	none	coal,wood ,rubber	Chakwal, local	7	35,000	65	6	not installed
76	Noughazi village	Al Awan bricks	T	Personally owned	Haji Gul zameer	2009	70	150	none	coal & wood	Chakwal, local	5	25,000	70	6	not installed
77	Noughazi village	Chanab bricks	R	leased	Ch.Ghanfer ali Gondal	1999	120	100	25	coal,tyre	Chakwal	10	40,000	67	6	not installed

Annexure- II

Questionnaire for the collection of base line data/ information of brick kilns in Islamabad

Name of the interviewer......................................

Date ....

1. Name of the Respondent...
2. Gender...(M/F)
3. Age ....
4. Education status

a- Illiterate ☐ b- Primary ☐ c--Middle ☐

d- Inter ☐ e- Graduate ☐ f- Postgraduate ☐

g- Madrassa Education ☐

Brick kiln Profile

5. Name of the brick kiln --
6. Trade mark of the brick kiln---------------------------------------
7. What is the ownership status of the brick kiln?

a- Personally owned ☐ c- leased ☐

b- Privately owned ☐ d- partially owned and partially leased ☐

8. What is the name of the brick kiln owner?

----

9. Contact No.--

10. Address/location of the brick kiln?

----

11. Date of establishment of the brick kiln?

----

12. Area covered by the brick kiln (kanals)?

----

13. Total number of workers?

----

14. Is there any female worker in the brick kiln? ☐

15. If yes than what is the number of female workers working in the brick kilns?

----

16. What type of fuel is used for firing the bricks in the brick kiln?

a- Furnace oil	☐	b- Wood	☐
c- Coal	☐	d- Old tires	☐
e- Rubber	☐	f- Kerosene oil	☐
I- Mixed	☐	j- Others	☐

17. Mostly used fuel in the brick kiln?

----

18. If mixed fuel is used than what is the proportion of fuels to be mixed?

----

19. What are the reasons of using that specific fuel for bricks manufacturing?

----

20. From where do u get/purchase the fuel?

----

21. What in the per day production capacity of the brick kiln?

----

22. What is the per day consumption of fuel in the brick kiln?

----

23. How many chimneys are found in the brick kilns?

a- one ☐ b- Two ☐ c- More than two ☐

24. What is the height of the chimney?

----

25. DO you clean the chimney of the brick kiln? ☐

26. If yes than how do you clean the brick kiln chimney?

----

27. For how many days brick kilns are functional /operated in a week?

----

28. Are there any shifts of workers in the brick kiln per day? [ ]

29. Do you have any pollution control devices in your brick kiln? [ ]

30. If yes than what is the name of pollution control device used in your bricks manufacturing industry?

Annexure III

Coordinates of emission sources (km) at Tarlai cluster:

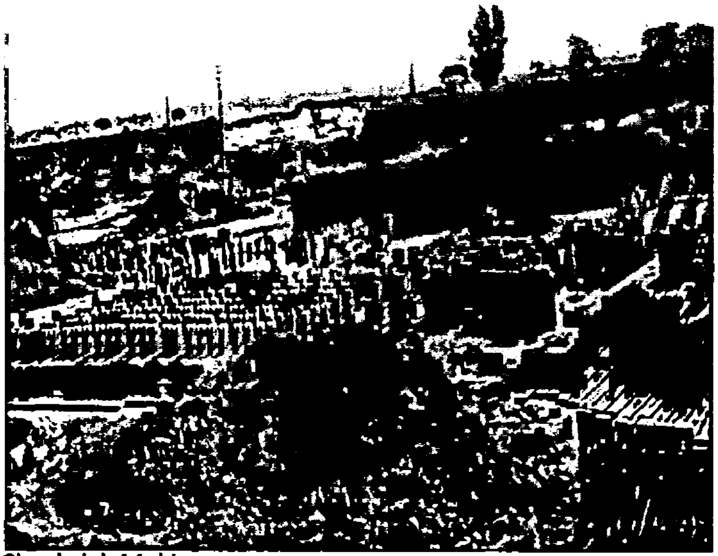
S.No.	Latitude(Y -km)	Longitude(X-km)
1	11.242	-0.0340
2	11.858	-0.0315
3	.012966	-0.002919
4	.01493	0.0237
5	0.008162	-0.003225
6	0.008115	0.02414
7	.007767	-0.02217
8	0.004188	-0.01712
9	0.00133	-0.02193
10	-0.0004004	0.02259
11	0.00222	0.0255
12	0.00081004	0.0238
13	0.00396	-0.0287
14	0.00197	-0.03427
15	-0.001201	-0.0265
16	-0.00206	-0.0245
17	-0.0077	-0.02276
18	-0.00948	-0.0196
19	-0.01241	-0.02061
20	-0.01755	-0.002154
21	-0.0176	-0.01588
22	-0.00964	-0.01591
23	-0.009178	-0.016505
24	-0.00462	-0.01807
25	-0.004127	-0.014694
26	-0.003187	-0.010658
27	0.00214	-0.00045
28	0.000446	-0.01164
29	0.00214	-0.00530
30-	-0.00158	-0.00403
31	-0.00326	-0.00194
32	-0.00520	-0.00181
33	-0.01031	0.00162
34(reference kiln)	00	00

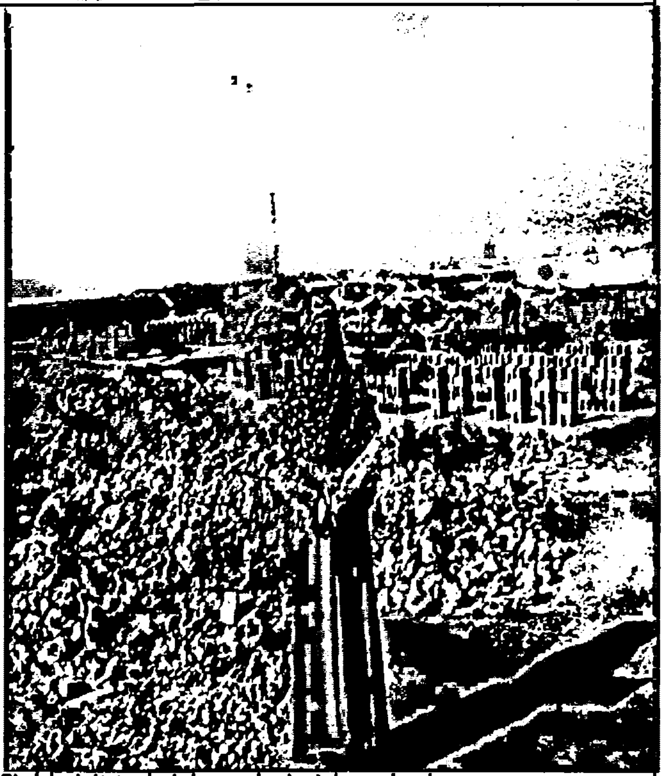
Coordinates of Receptor location:

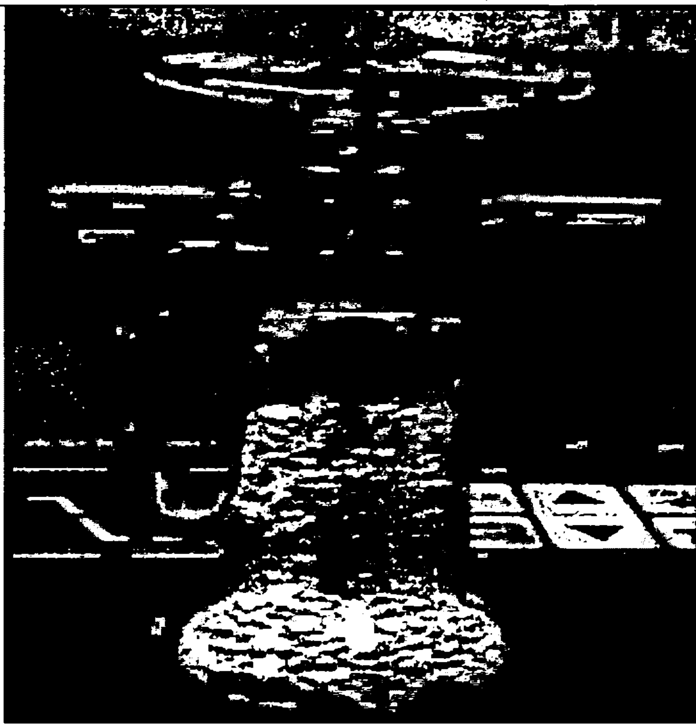
latitude	33∘37′ 07.47″N
longitude	73∘09′ 13.52″E


Brick kiln data collection at Karal Town Islamabad


Questionaire survey at tarlai Kalan in Islamabad


Clay brick Making area

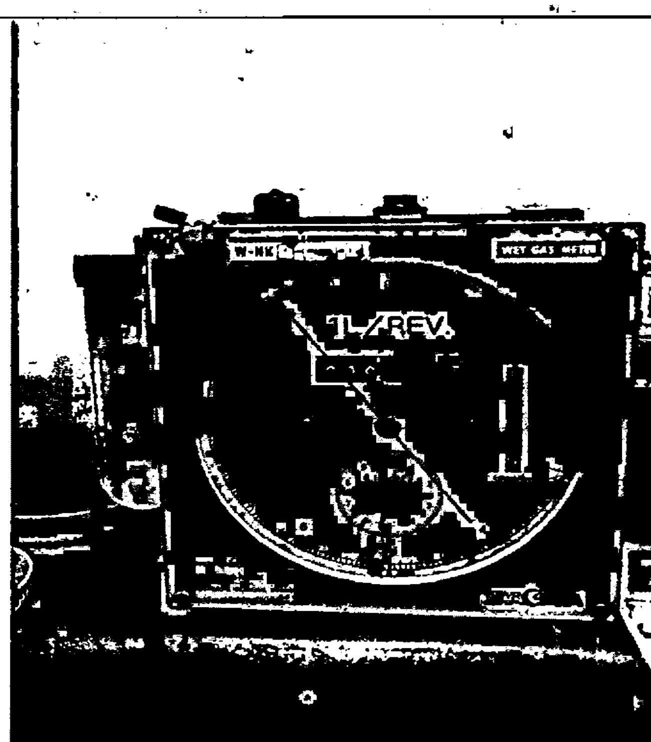

Field visit to brick works in Islamabad



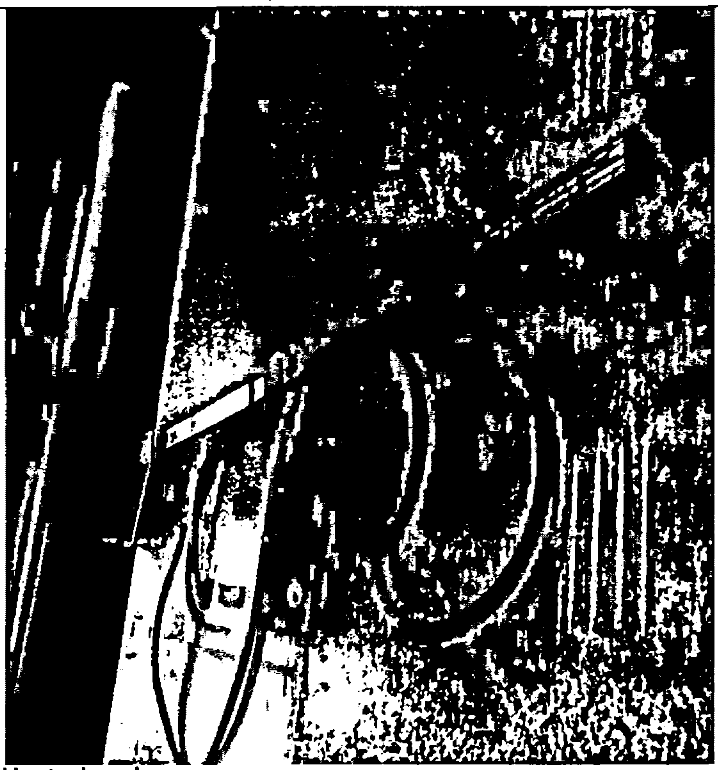
Sheifield tube(with micro fibers and $CaCl_2$) used for water content determination

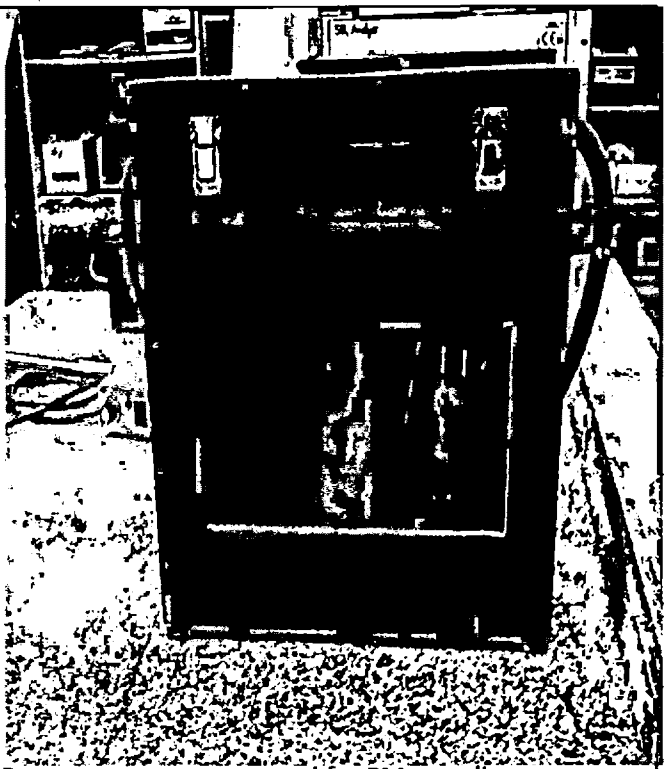
Stack emission monitoring

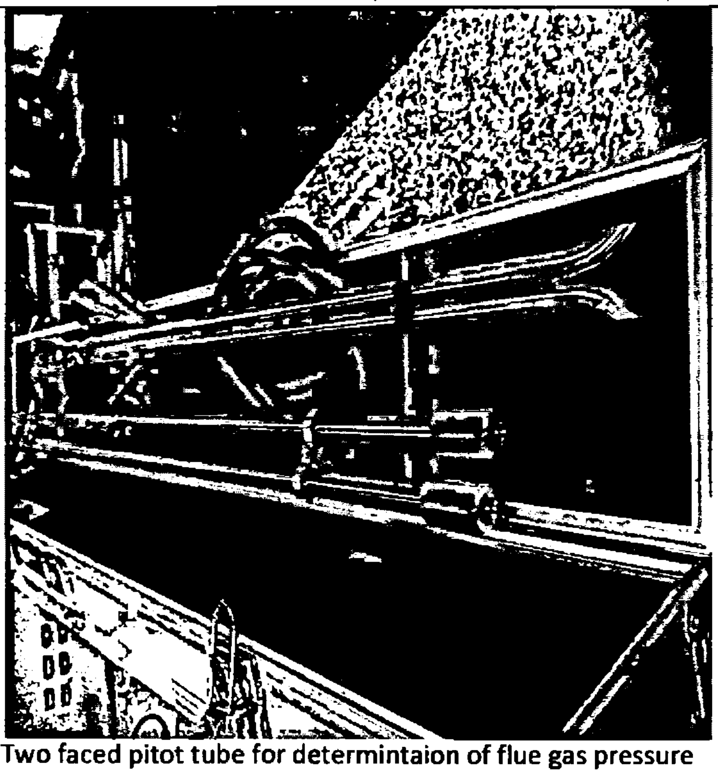
Thermocouple for measurement of Flue gas temperature

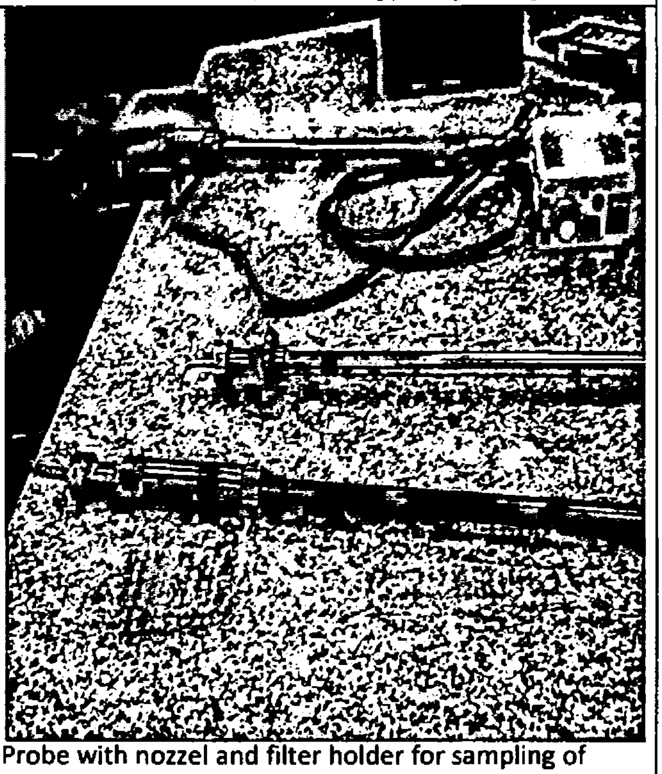


Wet gas meter

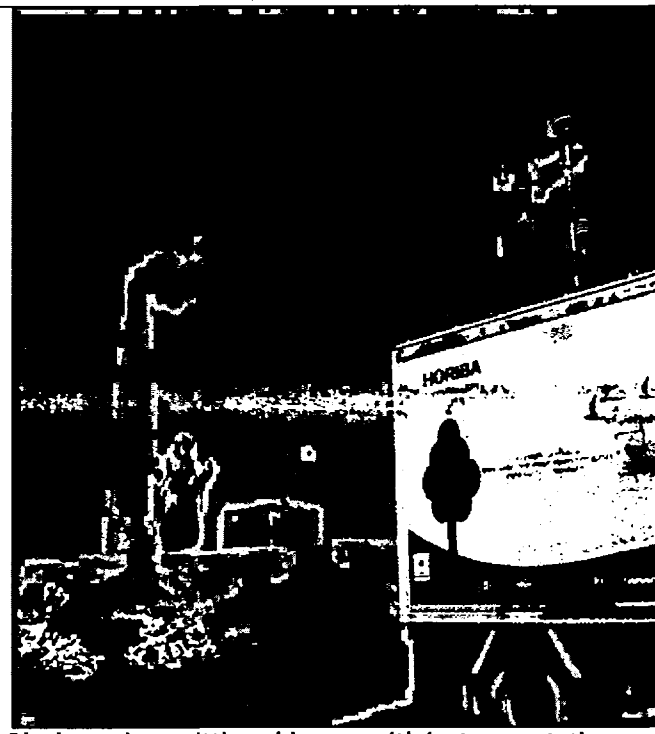

Heated probe


Pre-treatment system used for PM sampling


Two faced pitot tube for determintaion of flue gas pressure

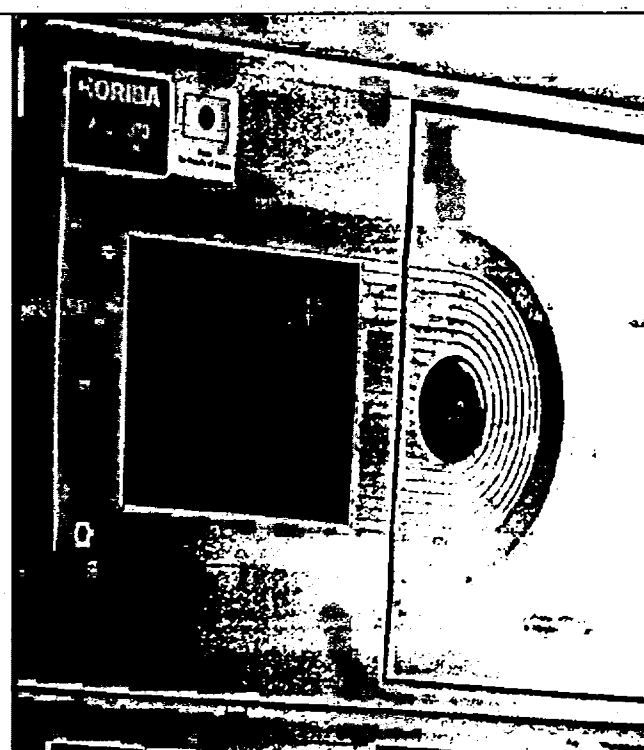

Probe with nozzel and filter holder for sampling of Particulate matter

Team members during ambient air qulaity monitoring exercise at Tarlai

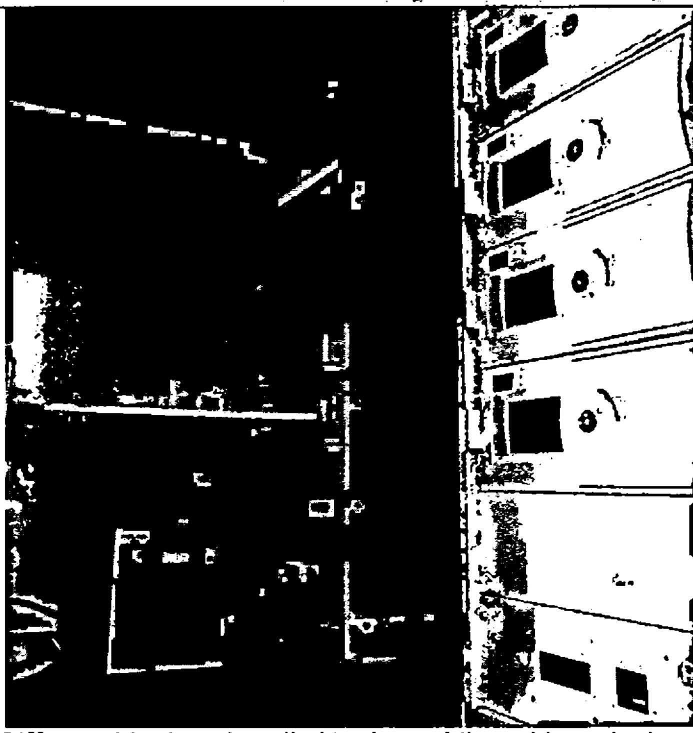


Black smoke emltting chimney with instrumentation mounted on the mobile van

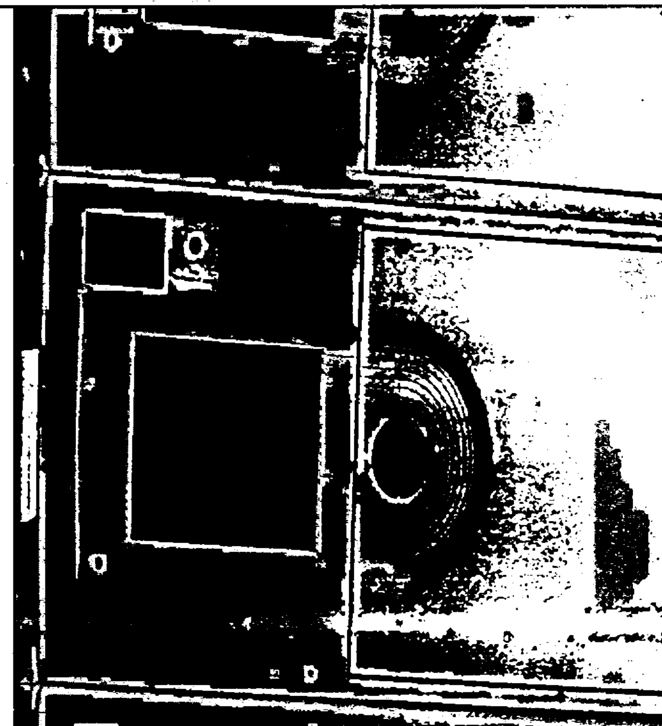
Field visit to Tarlai kalan for ambient air quality monitoring



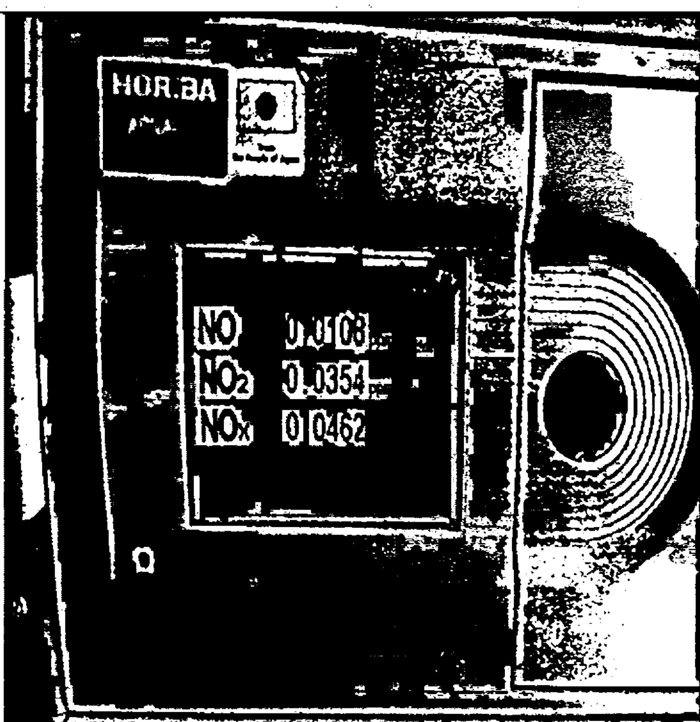
Sulphur dioxide(SO_2) Monitor



Different Monitors installed in the mobile ambient air air quality monitoring station



Carbon monooxide(CO) monitor



Moniror for measurement of ambient nitrogen related pollutants

Particulate Matter monitor