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*Full Length Research Paper*

# Atmospheric air pollution and mapping of Faisalabad city using syntax map method

**M. A. K. Shahid[1]* and Khadim Hussain[2]**

[1]Department of Physics, G.C. University, Faisalabad, Punjab, Pakistan.
[2]Department of Physics, High Energy Physics, Punjab University, Lahore, Punjab, Pakistan.

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**The major sources of air pollutants are man's industrial manufacturing and motor vehicle operation activities, both of which are concentrated in urban areas, where also the bulk of the world's population lives. It is depicted from the available data that the air quality in most major cities of the world has deteriorated to levels that make air quality management strategies necessary. This paper briefly accounts the air quality management capabilities of developed and developing countries and indicates that in developing nations, especially those in Asia, such capabilities are either absent or only rudimentary. The situation at Faisalabad is taken as an example. This paper is based on a study carried out to determine the spatial distribution of "solid aerosols in Faisalabad environment". As such, the scaled map of Faisalabad was scanned using syntax map method. A map showing the distribution was produced, probably the first of its kind for the city, which showed that the levels of 'solid aerosols' in most locations are much above the average recommended by the United States Environmental Protection Agency (EPA), European Academy of Quranic Studies (EAQS) and World Health Organization (WHO). In order to find out which model can be properly used for the pollutant concentration on it, the sensitive zone, medium zone and safe zone were developed respectively. However, the map was found misfit for classifying the zones, hence theoretical and remote sensing techniques were recommended for further improvement.**

**Key words:** Air pollution, dispersion, solid aerosols, shortage of management data, Faisalabad mapping, misfit, syntax map method, theoretical modeling, remote sensing techniques.

## INTRODUCTION

### Air pollution

Air pollution is defined as any atmospheric condition in which certain substances are present in such concentrations and durations that they may produce harmful effects for man and its environment. Common air pollutants include carbon monoxide, nitrogen oxide, sulphur dioxide, lead and solid aerosols which include dust, smoke, pollen and other solid particles. Most of these substances occur naturally in low (background) concentrations, when they are largely harmless; they become pollutants only when their concentrations are relatively high compared to the background value and begin to cause adverse effects (Rao, 1991). With increasing urbanization and industrialization, humans started to release more wastes into the atmosphere than nature could cope with. Since then, more pollution has been added to the air by industrial, commercial and domestic sources. As these sources are usually found in major cities, the gases that are produced are usually concentrated in the air around them. These concentrations vary widely depending on the sources of pollution and their distribution, meteorological conditions and topographical features in the vicinity. Air pollution is not just a "city problem", many air pollutants are dispersed over areas hundreds of miles from their source where they affect many different ecosystems. These

*Corresponding author. E-mail: profkhan786@yahoo.com.

pollutants often remain toxic in the environment for a very long time where they continue to affect ponds, streams, fields and forests.

The amount of pollutant in the air is expressed in terms of its mass/volume concentration, usually as micrograms of pollutant per cubic meter of air (µg/m$^3$). Previous studies have shown that in general, where there is air pollution, solid aerosols represent the most serious immediate threat to human health amongst air pollutants. Table 1 illustrates this fact. The United States Environmental Protection Agency (EPA) recommends a maximum daily average solid aerosol of 250 µg/m$^3$ and airborne Lead of 0.05 ppm.

### Effects of air pollution

Air pollution is a major environmental health problem affecting the developing and the developed countries alike. The effects of air pollution on health are very complex as there are many different sources and their individual effects vary from one to the other. On man, air pollution is now associated with respiratory and eye diseases such as asthma, lung cancer and conjunctivitis, especially in the young and elderly (UNEP/WHO, 1992; Patel, 1994). Lead as a pollutant is particularly serious for children, since relatively low concentrations of lead in the blood may have a damaging and permanent effect on their mental development (Needleman et al., 1991).

On the environment, air pollution is a major contributor to effects such as acid rain, which has been responsible for much damage to soil, fish resources and vegetation, often very far away from the source of the pollutant (Karue 1991; Government of Kenya 1999; Acid Rain 2000, 2001).

Air pollution due to total suspended particulates is also very hazardous. Solid aerosols are solid or liquid particles or a complex mixture of both that vary in size and composition, and remain suspended in the air. Solid aerosols in the air comes from many sources, namely, the dust blown off the earth's crust, the gases released into the air by burning fuel and the waste created by man. These particulates therefore cause the pollution which threatens life on the planet including man's own existence. They are formed by the conversion of gases to particles, the disintegration of liquids or solids, or the resuspension of powdered material. As the dust particles of the compounds are poor substrate for promoting nucleation of ice in the atmospheric clouds, they are liable to stay steadily in the atmosphere as pollutants. The smaller the size of the particulate, the longer will its residence time be in the atmosphere. If the particulates are poor nucleants, they will not be utilized and hence not washed out from the atmosphere and if their concentration is above normal limits they will behave as pollutants (Pakistan pedia 2006; Shahid and Hussain, 2007).

Air pollution is also responsible for the effect of smog, which is a reduction in visibility due to scattering of light by airborne particles. It may also cause offensive odours in addition to soiling buildings and monuments. However, by far, the most serious long term environmental effect of air pollution is global warming, which, it is now human life, especially in the coastal and highland regions.

Concern about global warming led to the famous Kyoto Protocol of 1997, through which over 100 countries undertook to reduce their emissions of certain pollutant gases significantly (NRP, 2001; Brasseur and Pszenny, 2001; Habib 2007).

Considering its effects and potential effects on man and his environment, air pollution is clearly one of the greatest threats to sustainable development today. The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution.

## AIR POLLUTION MANAGEMENT

### Urban areas: The main focus

Some air pollutants may be introduced through natural occurrences such as wind soil erosion, dispersion of plant pollen, sand storms, volcanic eruptions, forest fires, etc. However, pollutants are mainly introduced through man-made activities, particularly industrial manufacturing and motor vehicle operation. These activities are mainly concentrated in cities and other urban areas, which today are expected to be holding near half the World's population (Ngugi 1983; UNCHS, 1996). Cities and urban areas therefore contain the bulk of people that are most vulnerable to the immediate effects of air pollution. Since the pollutants are generally concentrated in and around urban areas, the outdoor urban pollution levels are far higher than in the rural areas. This fact received international recognition when in 1992, the United Nations Conference on Environment and Development (UNCTED) made specific recommendations in its Agenda 21 (UN, 1992) with regards to addressing air pollution in cities. One key recommendation was the establishment of appropriate air quality management capabilities in large cities and establishment of adequate environmental monitoring capabilities or surveillance of environmental quality and the health status of populations.

### Air quality management capabilities

Ideally, every major city should have an air quality management capability. This is defined as, "… the capability to generate and utilize appropriate air quality information within a coherent administrative and legislative framework, to enable the rational management of air quality" (UNEP/WHO, 1992). This translates into being able to monitor the air quality, compile a pollutant emissions inventory, model and predict air quality trends, set and enforce air quality standards, and put in place the relevant legislative and administrative frameworks. Such capabilities have been put in place in some developed

**Table 1.** Showing category wise WIRS & PIRS for syntax map method.

| Zone category | Well integrated roads | Poor integrated roads |
|---|---|---|
| $Z_1$ | 4 | 7 |
| $Z_2$ | 4 | 6 |
| $Z_3$ | 2 | 3 |

countries and a few developing countries (such as Brazil, India, Mexico, Egypt, etc.) have such capabilities in their major cities (WSL, 1994; USEPA, 1993; NAPS, 2001; CAIP, 2001). Some of these, such as the one in Mexico recognized, may soon threaten the very existence of City, provide regular on-line, real-time air quality reports, much like the weather reports.

## AIR QUALITY MANAGEMENT IN DEVELOPING COUNTRIES

Most developing countries, including almost all Asian countries, have no air quality management capabilities despite having the fastest growing urban populations. Some reasons for this include lack of expertise to formulate air pollution management policies; low budget priority given to air pollution when compared with other social and environmental problems; inadequate political will and inappropriate legislative and administrative frameworks in which responsibility for air quality is divided between a number of government ministries and local administrations, thus complicating policy making.

One major consequence of the lack of air quality management capabilities in developing countries is the lack of data on air pollution, which often gives the illusion that this is not a serious problem; this is far from the truth and only contributes to the concealment of a very significant global public health problem, considering that most urban dwellers live in developing country cities and towns. The case of Faisalabad city is illustrative of this.

### Faisalabad as a case study

For a long time, there has never been any legislative or administrative framework within which air quality management could be formulated and implemented in Faisalabad. Yet the few relevant studies that have been done show that air pollution continues to adversely affect human health and the environment. For example, occupational asthma, silicosis and asbestosis have been reported from industrial workers in textile, battery manufacturing, cement production and mineral processing units. Total Suspended Particulate matter creates increased risk either directly or indirectly to human health, cultural resources and atmospheric visibility. These particulates alone or in combination with other pollutants can cause increased illness, contamination of surface water, impaired growth of agricultural crops, deterioration of materials and loss of amenity through malodor and reduced visibility (Quershi, 1999).

## FAISALABAD AS A TEST CASE

### Air quality management in Faisalabad

Faisalabad is the third largest city of Pakistan covering an area of 5,856 km$^2$ with an estimated population of 3.54 million. The city was founded by the British in 1892 by Sir Charles James Lyall for whom it was originally named Lyallpur (Lieutenant Governor of Punjab, 1887-1892) in acknowledgement of his contributions in the process of colonization of the area. Prior to the British making of the area into an urban center, it largely consisted of various villages. The city-center of Lyallpur (Faisalabad) is just the copy of British flag union jack designed by an architect Desmond Yong. It covers a total area of 110 square acres which was used to build eight bazaars, and a clock tower was in the centre of these bazaars. In 1977, the name of the city was changed to Faisalabad in honor of the late king of Saudi Arabia, Shah Faisal-bin-Abdul Aziz.

Besides agriculture, the agro-based industry of Faisalabad has made rapid strides, for which it is usually referred to as the “Manchester of Asia”, especially for its extensive development of textile industry. There are dozens of textile mills with other subsidiary units. As a rough estimate, there are over 500 large industrial units out of which 328 are textile units, 92 engineering units and others are chemicals and food processing units. Other industries include hosiery, carpet and rugs, printing and publishing, and pharmaceutical products. Besides, the cottage industry has over the year expanded to some 12,000 units, which include some 60,000 power loom factories.

Faisalabad does not have any regular air quality management system yet, and all measurements of air pollution have been done on an ad-hoc basis. Although in general, the current quality of air in Faisalabad does not present a critical health or environmental problem, available data indicate that air quality has been rapidly deteriorating. The situation can only get worse with the increasing population, growing industrial area, deforestation on the city’s fringes, increased construction works and increased vehicular traffic.

This study is useful in predicating air pollution dispersion within the emission areas. Therefore, it can be used in predicting the air quality profile in the industrial areas like Faisalabad. Besides that, it is also useful to predict the future air quality within the affected area. By knowing the profile of air pollutant distribution, it is hoped that this study contributes in planning purposes in locating sites of industrial plants or develop industrial areas along with zoning of the big cities not only in Pakistan but also in the entire world.

## METHODOLOGY

### Mapping of Faisalabad environment on the basis of syntax map method

Space syntax map method is especially designed for representing the morphology of buildings, open spaces and streets. Space syntax models the spatial configurations of urban spaces by using the connectivity graph representation. According to Jiang et al. (2000), it is believed that space syntax provides a configurational description of an urban structure and attempts to explain human behaviours and social activities from a spatial configurational point of view. Space syntax measures geographic accessibility with the axial lines. Axial lines are lines of unobstructed movement used in computing accessibility (CBS 2000; CPK 2000). The first representation, a so called axial map, is defined as the least number of the longest straight lines. According to how each line intersects every other line, a connectivity graph, taking axial lines as nodes and line intersections as links, can be derived. Different configuration parameters are computed from the axial map. Connectivity is the most apparent parameter for morphological analysis and is defined as the number of nodes directly linked with each individual node in the connectivity graph. The second parameter is the control value and is defined as a parameter which expresses the degree of choice each node represents for nodes directly linked to it. The third parameter is integration of a node which is by definition expressed by a value that indicates the degree to which a node is integrated or segregated from a system as a whole (global integration), or from a partial system consisting of nodes a few steps away (local integration) (Jinag et al., 2000; Stedman, 2004; Findpk 2006). These three parameters were redefined as well integrated roads, poor integrated roads and integration radius for this study and were used in the standard mathematics of the space syntax method required results. The formulism of space syntax method is based on the concept of graph. Graph is a finite set of dots called vertices (or nodes) connected by links called edges (or arcs). The value lies in the capacity it has for showing up the essential structure of a set of relationships. Its study belongs to topology, the branch of mathematics which deals with the properties of spaces as they form connected pieces and have boundaries independent of their size and shape (for example, in the case of axial map). The streets are the vertices of a graph and their interconnections, the edges. The various depth status and integration measures are now well established topological parameters. The theory of this method is based on a corollary of a "paradox of centrality" stated as "maximizing internal integration also maximizes external segregation". When a self centered urban system is put into communication with the outside world, its central part which was until then the most integrated one became rather segregated. The application of this modified Syntax Map Method is shown in Figure 1.

## ZONE CLASSIFICATION USING SYNTAX MAP METHOD ON THE BASIS OF GRIDS

### Zone-1 (Sensitive zone)

**$G_1$:**

***Intercity highways:***
Sarghoda Road 3.375 km
Sheikhupura Road 1.5 km

***City roads:***
Bilal Road 0.30 km
Millat Road 1.75 km
Jail Road 2.875 km
Stadium Road 1 km

**$G_2$:**

***Intercity highways:***
Narwala Road 3 km
Jhang Road 2.25 km

***City roads:***
Allama Iqbal Road 0.875 km
Government College Road 1 km
National Hospital Road 1.75 km

### Zone-2 (Less sensitive zone)

**$G_1$:**

***Intercity highways:***
Summundri Road 3.25 km

***City roads:***
Digkot Road 2.125 km
Samanabad Road 1.50 km

**$G_2$:**

***Intercity highways:***
Summundri Road 1 km
Sityana Road 2.05 km
Jaranwala Road 1.82 km

***City roads:***
Railway Road 0.75 km
Circular Road 2 km

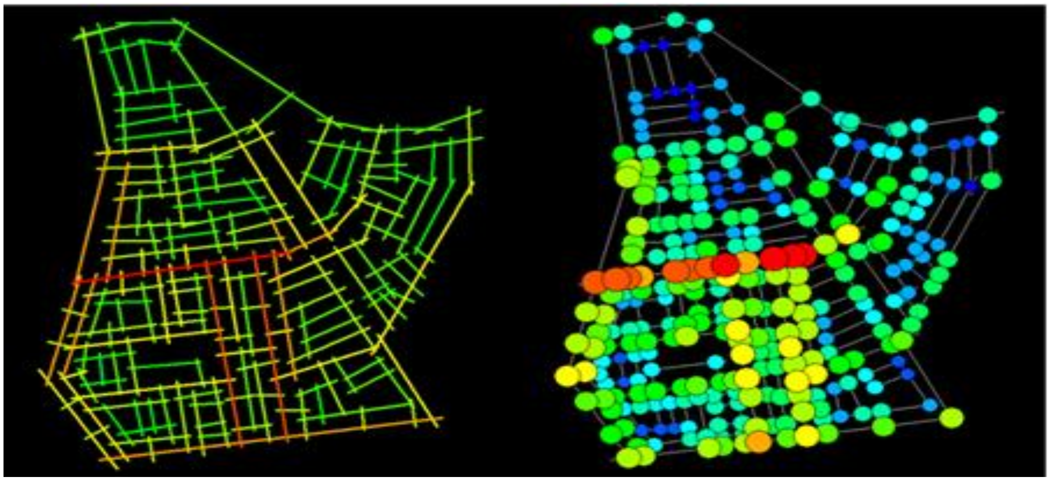

**Figure 1.** Space syntax map.

Kohinoor Road 0.50 km
Madina Town Road 0.50 km

**Zone-3 (Safe zone)**

**$G_1$:**

***Intercity highway:***
Jhumra Road 3 km
***City road:***
Madina Town Road 1.375 km

**$G_2$:**

***Intercity highway:***
Sheikhpura Road 0.75km

***Intercity road:***
Jhumra Road 0.375 km

***City roads:***
Millat Road 3.25 km

**DETAILS OF SITE LOCATION**

**KS - 01:** (C/R): Faisalabad Market start
**KS - 02:** (C): New Graveyard
**KS - 03:** (C/A): Outside UAF
**KS - 04:** (C/R): PMC Sargoda Road side
**KS - 05:** (I/C): Cresent Textile Mills
**KS - 06:** (R): Gulshan Colony
**KS - 07:** (T/R): Police Line outside
**KS - 08:** (R/T): Near Allied Hospital and PMC side
**KS - 09:** (H): Inside Allied Hospital
**KS - 10:** (R/T): Razabad outside
**KS - 11:** (R): Jinnah Colony
**KS - 12:** (C/A/H): Between Sahal Hospital and East Inn
**KS - 13:** (C): Shaheedi Millat Market
**KS - 14:** (R/C/T): Islamia College
**KS - 15:** (T): Jail Road
**KS - 16:** (R/T): Income Tax Office
**KS - 17:** (R): Model Town inside
**KS - 18:** (R/T): GC University
**KS - 19:** (R/T): Between Ayub Research Colony & Niab
**KS - 20:** (R/T): Army Food Industries
**KS - 21:** (8 bazars): Clock Tower
**KS - 22:** (T/R): Habib Bank building
**KS - 23:** (I/C): General Bus Stand
**KS - 24:** (R): Regency Arcade
**KS - 25:** (H): Saint Raphel Hospital
**KS - 26:** (C): Railway Goodams
**KS - 27:** (T/C): F.M.C. (Circular Road)
**KS - 28:** (C/I): Between Barah Market and Lyallpur Cotton Mill
**KS -29:** (C/T): Beneath Overhead Bridge
**KS - 30:** (C/T): Near Railway Station
**KS - 31:** (R): Tariq Abad inside
**KS - 32:** (C/R): Between Nigebanpura and Mansoorabad
**KS - 33:** (C/I): Outside General Bus Stand
**KS - 34:** (C/R): Rafhan Mill
**KS - 35:** (C): Flying Coach Stand
**KS - 36:** (C/R): Between Deego Restaurant and Spinzer Restaurant
**KS - 37:** (I/R/A): Muhammad Abad, Sitana Road
**KS - 38:** (I/R/A): Overhead Bridge cinema side
**KS - 39:** (I/T/C): Overhead Bridge opposite cinema side
**KS - 40:** (T): Quaid-i-Azam Road
**KS - 41:** (I/T): Government College Samanabad
**KS - 42:** (T/C): New Big Graveyard, Jhang Road
**KS - 43:** (I/C): Samundri Road
**KS - 44:** (I): Iron Market
**KS - 45:** (R/A): Outside Peoples colony-2
**KS - 46:** (I/C): In between Peoples Colony-2 and Peoples Colony-1
**KS - 47:** (I/R/C): Jaranwala Road outside Kohinoor Mills
**KS - 48:** (R): Kohinoor Mills inside

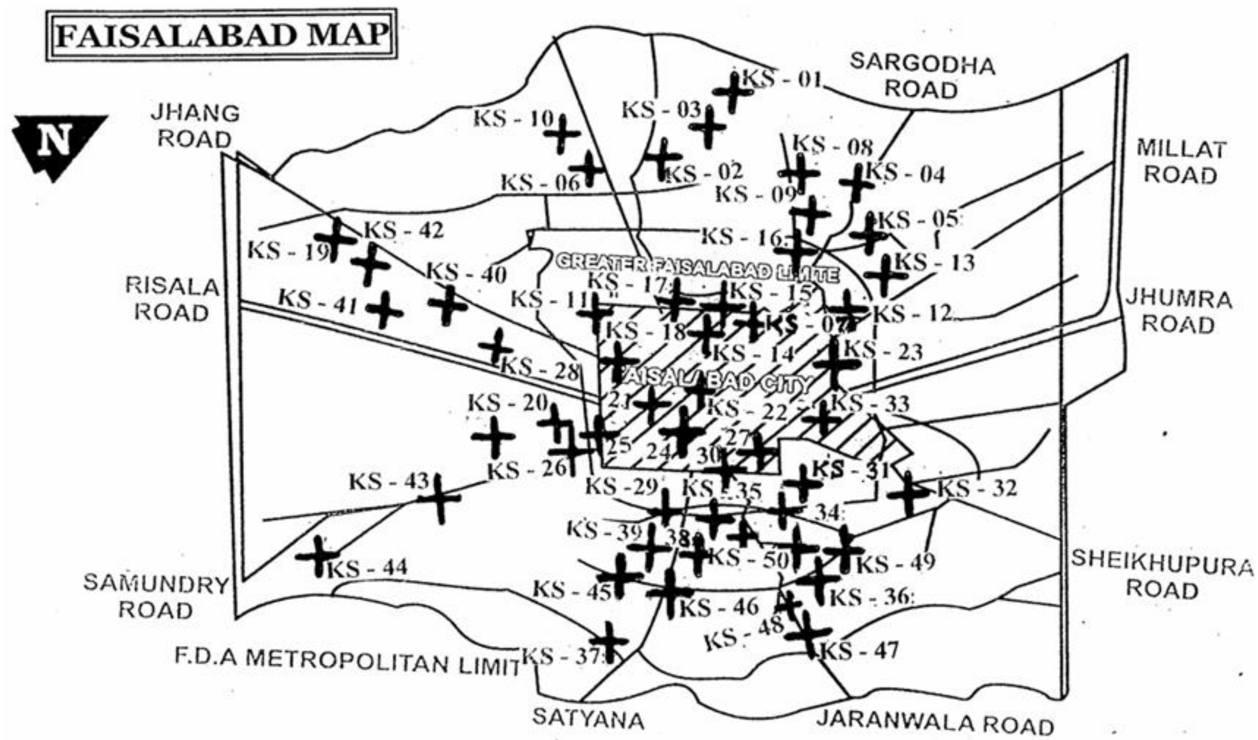


**Figure 2.** Sites selection of Faisalabad city.

**Table 2.** Strength Of The Site Selection Centrality On The Basis Of Syntax Map Method Mathematics

| Integration value | Connectivity | No. of samples collected |
|---|---|---|
| 0.0260 | 38.46 | Max (27) |
| 0.1758 | 5.60 | Min (3) |
| 0.0582 | 17.18 | Medium (20) |

Integration value K= 7, 6, 3 for A1, A2, A3, where K is number of lines in the axial map.
* Integrated radius = 5 km.
** Grid selection: (5 × 5) km.

**Table 3.** Location wise average concentration of solid aerosols and lead.

| Zone classification | Solid aerosols | Airborne lead | Category area |
|---|---|---|---|
| Sensitive zone | 70.7%,High | 16%, High | HIGH - > 250 µg/m$^3$ , > 0.05 ppm |
| Less sensitive zone | No data | 9.3%, Medium | MEDIUM- ≈ 250 µg/m$^3$, ≈0.05 ppm |
| Safe zone | 29.3%, Low | 74.7%, Low | LOW - < 250 µg/m$^3$ , < 0.05 ppm |

Urban air pollution in different locations of Faisalabad (EPA /US, Dust / $H_2O$ Standard).

**KS - 49:** (R): Madina Town inside
**KS - 50:** (I/R/C): Madina Town and Kohinoor Mills (Figure 2).

A total of 100 samples were randomly selected from three zones, of which two samples were mixed into one sample to make them fifty for lead concentration (Table 2). From those 100 samples, 75 were selected for solid aerosols concentration. The sampling stations were positioned on Map 2 of Faisalabad. Positive signs were described around sampling stations to delineate areas around each sampling station within which its measurement could be taken to apply. These areas were then classified as having LOW (< 250 µg/m$^3$ annual mean), MEDIUM (≈ 250 µg/m$^3$) and HIGH (> 250 µg/m$^3$) levels of solid aerosols and class boundaries generated. LOW means that the solid aerosols levels are below the United States Environmental Protection Agency's (EPA)

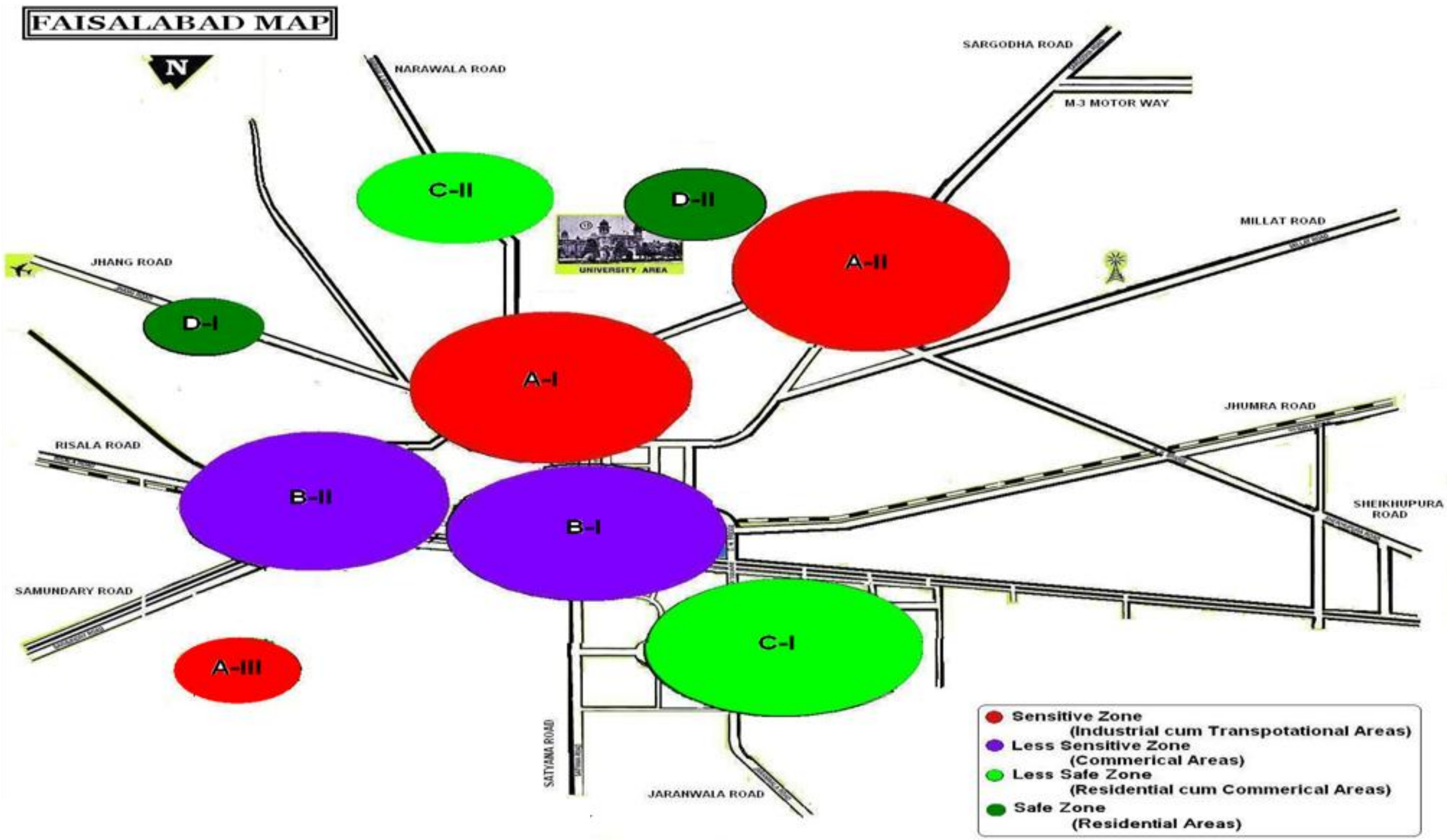


**Figure 3.** Zone distribution of Faisalabad city.

recommended mean value of 250 µg/$m^3$; MEDIUM means that the solid aerosols levels are equivalent to 250 µg/$m^3$, while HIGH means it is greater than 250 µg/$m^3$ (Table 3).

The weight percentage of solid aerosols was calculated using standard methods and Lead concentration was determined using Atomic Absorption Spectrometric Technique (AAS) (Hitechi-8200) with the collaboration of EPD, Faisalabad and NIBG Faisalabad (Shahid, 2008).

For the estimation of $SO_2$, WEST Gackc Method was adopted using sodium tetrachromocurate as

**Table 4.** Weight percentage of green house gases.

| Zone classification | Co | HC | No | Others |
|---|---|---|---|---|
| Sensitive zone | 63.73 | 27.65 | 6.06 | 2.57 |
| Less sensitive zone | 64.66 | 26.83 | 5.10 | 2.60 |
| Safe zone | 64.88 | 27.23 | 5.50 | 2.40 |
| | EAQS, 20ppm, WHO, 110 ppb | | EAQS (40-60)ppb, WHO, 110 ppb | EAQS 200ppb, WHO, 120ppb |

absorbent by Spectrophotometric analysis for nitrogen oxide. In NaoH solution, 0.1% of sodium arsenate was used as absorbing solution, where it was converted to nitrate ion. The nitrate content was estimated spectrophotometrically following the modified method of British standards. For other gases, EPD Mobile lab was operated in selected zones and the measurements were made accordingly.

## RESULTS AND DISCUSSION

The problem of solid aerosols is becoming more acute not only in the advanced countries of the world but also in the developing countries like Pakistan. The geographical location, the topographical configuration and the textile industry make the air pollution problem in the Faisalabad city so critical that it is very essential to investigate about it.

This study aimed at finding out whether or not the air pollution situation in Faisalabad is already serious enough to warrant the setting up of a regular air quality management system through which intervention measures can be planned and implemented. It specifically aimed at producing a basic spatial distribution map in respect of solid aerosols using GIS techniques. Such a spatial distribution map can give city planners a much more effective visual perspective of the spatial variations in city air quality than can tabular data from point samples, and this lead to faster decision making about which areas represent the greatest risks and therefore most in need of intervention measures.

Mapping of Faisalabad city was carried out using Syntax Map Method as shown in Figure 3. This map though based on a very simple dispersion model and relatively few sampling points, clearly shows that solid aerosols levels in most of the city are above the recommended levels of the United States Environmental Protection Agency (EPA), EAQS and WHO. Most of the city's residential and commercial areas are within the sensitive zone with the highest concentrations of solid aerosols, which is consistent with their proximity to the city's industrial areas. Similar is the case with green house gases and zone classification (Table 4). The results of this study do not show any dependence of solid aerosols and lead concentration along with weight percentage of green house gasses on zone classification. However, there would have been dirty and clean patches in all zones whether they are less sensitive, highly sensitive or safe, which implies that zone classification on the basis of syntax map method is not successful for Faisalabad environmental pollution, or in other words, Faisalabad mapping is completely misfit as it is, due to haphazard industrial, transportational and commercial expansion. Some modifications on the basis of these results are urgently required according to the environmental pollution pattern and climatological, metrological and geological set up of the area. The result of these locations showed that the maximum pollution was found to be 2 $K_{21, 26,28,41 \text{ and } 81}$, which did not belong to a specific zone but had a mixed and heterogeneous environment comprising 50% industrial, 25% commercial, 12.5% transportational and 12.5% residential. The identified pollutants belong to proper paints, pottery, plastic, ceramics, tire and bearings, lubricants, air conditioners and refrigerators with full burning batteries and optical glasses wares showing the involvement of transport and industry in the atmosphere of Faisalabad. It indicates that the mapping plan of Faisalabad was not done according to the international standards. These ought to be sufficient indicators to enable basic decision making on intervention measures (Shahid, 2008).

A more accurate distribution pattern could be obtained by using more complex dispersion model that would take into account the actual sources of pollution, distance from the source(s), meteorological conditions, and topography and census data. However, most of these data were not available for this study. So this study was partially successful (Kahenya 1996; Chaudhary and Rasul, 2004; Mehrabi, 2005; Qadir, 2002; Smith et al., 2009; Zinati and Najafpour, 2003).

## Conclusion

Air pollution and its major adverse effects on human health and the environment are concisely explained in this paper. The protection of environment is one of the most important problems facing us today. It convinces about the necessity of air quality management, especially in urban areas where pollution sources and human population are concentrated. It has accounted briefly the air quality management capabilities of developed and developing nations, citing Faisalabad as an example of the latter. Finally, it has reported a short study to determine the spatial distribution of Total Suspended Particulates and lead along with green house gasses in Faisalabad. This study has shown that the levels of these pollutants are above the recommended levels of United States Environmental Protection Agency (EPA), EAQS and WHO in most parts of the city, indicating a need for a regular air quality monitoring and management system. Reliable and robust strategies for keeping pollution caused by harmful chemicals under safe level have to be developed and used routinely.

## FUTURE RECOMMENDATION

This study recommends that theoretical modeling and remote sensing techniques should be used for optimization between classification and pollutant concentration along with air profile mapping in different seasons of the year, keeping in view the climatological and meteorological parameters for short term and long term evaluation.

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