MAPPING AND ANALYSIS OF AIR POLLUTION IN NAIROBI, KENYA

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ABSTRACT

Air pollution is any atmospheric condition in which certain substances are present in such concentrations and duration that they may produce harmful effects on man and his environment. Common air pollutants include carbon monoxide, nitrogen oxide, sulphur dioxide, lead and Total Suspended Particulates (TSP), the latter being the most widespread and the most serious for human health. 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. Available data shows that the air quality in most major cities of the World has deteriorated to levels that make air quality management strategies necessary.

This paper outlines the air quality management capabilities of developed and developing nations and finds that in developing nations, especially those in Africa, such capabilities are either absent or only rudimentary; The situation in Kenya given as an example. The paper then reports on a study to determine the spatial distribution of TSP in Nairobi, Kenya's capital city. A map showing the distribution has been produced, probably the first of its kind for the city, which shows that the levels of TSP in most of Nairobi are much above the average recommended by the World Health Organization.

1. AIR POLLUTION AND ITS EFFECTS

> *"Clean air is a public good; Indeed no other resource exhibits the same degree of 'publicness'; Land can be parceled and fenced; Water can be bottled; Scenery can be hidden; One can even isolate himself from noise; But man has no choice but to breathe the air around him – polluted or not."*
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> Anonymous

1.1 Air Pollution

Air pollution is defined as any atmospheric condition in which certain substances are present in such concentrations and duration that they may produce harmful effects on man and his environment. Common air pollutants include carbon monoxide, nitrogen oxide, sulphur dioxide, lead and Total Suspended Particulates (TSP) 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). These concentrations vary widely depending on the sources of pollution and their distribution, meteorological conditions and the topographical features in the vicinity. The amount of pollutant in the air is expressed in terms of its mass/volume concentration, usually as micrograms of pollutant per cubic metre of air ($\mu g/m^3$). Previous studies have shown that in general, where there is air pollution, TSP represent the most serious immediate threat to human health amongst air pollutants. Table 1, which is an abstract from a study done by UNEP/ WHO in 1992, illustrates this fact. The World Health Organization (WHO) recommends a maximum daily average TSP of 230 $\mu g/m^3$ and a maximum annual mean of 90 $\mu g/m^3$.

CITY	Sulphur dioxide	TSP	Airborne Lead
Bangkok	Low	High	Low
Beijing	High	High	Low
Bombay	Low	High	Low
Calcutta	Low	High	Low
Cairo	No data	High	High
London	Low	Low	Low
Los Angeles	Low	Medium	Low
Mexico City	High	High	Medium
Rio de Janeiro	Medium	Medium	Low
Sao Paulo	Low	Medium	Low

LOW – conforms to WHO guidelines

MEDIUM – WHO guideline exceeded by upto a factor of 2

HIGH - WHO guideline exceeded by more than a factor of 2

Table 1: Urban air pollution in megacities of the World, 1992 (After UNEP/WHO, 1992).

1.2 Effects of air pollution

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 (Acid Rain 2000, 2001).

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 recognized, may soon threaten the very existence of 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).

Considering its effects and potential effects on man and his environment, air pollution is clearly one of the greatest threats to sustainable development today.

2. AIR POLLUTION MANAGEMENT

2.1 Urban areas; the focus

Some air pollutants may be introduced through natural occurrences such as volcanic eruptions, wind soil erosion, forest fires, sand storms, dispersion of plant pollen, 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 nearly half the World's population (UNCHS, 1996). Cities and urban areas therefore contain the bulk of people that are most vulnerable to the immediate effects of air pollution. 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 the establishment of adequate environmental monitoring capabilities or surveillance of environmental quality and the health status of populations*".

2.2 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, 1996). This translates into being able to monitor 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 countries since the 1960s when countries such as the US and Canada put in place legislation to provide for air quality management. Today, practically all developed 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 etc). Some of these, such as the one in Mexico City, provide regular on-line, real-time air quality reports, much like weather reports.

2.3 Air Quality Management in Developing Countries

Most developing countries, including almost all African 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 the 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 Kenya is illustrative of this.

2.4 The Case of Kenya

For a long time, there has never been any legislative or administrative framework within which air quality management could be formulated and implemented in Kenya; 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 battery manufacturing, cement production and mineral processing in Nairobi, Athi River, Thika and Mombasa towns (Kahenya, 1996). A recent church sponsored environmental study around the paper manufacturing plant in Webuye town showed that bronchitis, asthma, conjunctivitis and lung cancer are on the increase in this area; in addition, a decline in agricultural activity has been observed; The study estimated the annual cost of air pollution from this factory to Webuye town and its environs to be 38 million US dollars (3 billion Kenya shillings), which is many times the town's annual budget (CPK, 2000). Kenya's potential to manage air quality has improved somewhat with the passage of the Environmental Conservation and Management Act of 1999 (Government of Kenya, 1999), whose administrative framework is still being put into place.

3. THE NAIROBI STUDY

3.1 Air Quality Management in Nairobi

Nairobi is the largest town in Kenya and also the country's capital city. It covers an area of 700 km^2 and currently has a population of over 2.1 million (CBS, 2000); nationally it has the greatest concentration of industrial and vehicle air pollutant sources. Nairobi is reputed to be the fastest growing city in the World after Guadaloupe, Mexico City (Mexico) and Maputo (Mozambique). Nairobi does not have any regular air quality management system yet, and any measurements of air pollution have been done on an ad hoc basis; indeed out

of 20 mainly developing country cities sampled for a UN study on air quality management capability, Nairobi's capacity was rated as the worst (UNEP/WHO, 1996). Although in general, the current quality of air in Nairobi does not present a critical health or environmental problem, available data indicates that air quality has been rapidly deteriorating (Ngugi, 1983; Karue, 1991). 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.

3.2 The Study

This study aimed at finding out whether the air pollution situation in Nairobi 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 TSP 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 can lead to faster decision making about which areas represent the greatest risks and are therefore most in need of intervention measures.

Data from 11 TSP air pollution sampling stations which were distributed in commercial, industrial and residential areas was used. The sampling stations were positioned using hand held GPS and integrated with digitized base map data for Nairobi. Thiessen polygons were described around each sampling station to delineate areas around each sampling station within which its measurement could be taken to apply. These areas were then classified as having LOW (< 90 $\mu g/m^3$ annual mean), MEDIUM (90 – 180 $\mu g/m^3$) and HIGH (>180$\mu g/m^3$) levels of TSP and class boundaries generated. LOW means that the TSP levels are below the WHO recommended mean value of 90 $\mu g/m^3$; MEDIUM means that the WHO recommendation is exceeded by up to a factor of 2, while HIGH means that the WHO guideline is exceeded by more than a factor of 2. *Cartalinx* GIS software was used to digitize the base map data, while *IdrisiW* and *ArcView* were used for the analysis and presentation. The final result is shown in Figure 1.

The final map, though based on a very simple dispersion model and relatively few sampling points, clearly shows that TSP levels in most of the City are above WHO recommended levels, and that most of the City's eastern residential areas and the City Centre are within the "hot zone" with the highest concentrations of TSP, which is consistent with their proximity to the City's industrial area. These ought to be sufficient indicators to enable basic decision making on intervention measures.

A more accurate distribution pattern could be obtained by using a more complex dispersion model that would take into account the actual sources of pollution, distance from the source(s), meteorological conditions, topography and census data; However, most of these data were not available for this study.

4. CONCLUSION

This paper has defined air pollution and stated its major adverse effects on human health and the environment, thus demonstrating why air quality management is necessary, especially in urban areas where pollution sources and the human population are concentrated. It has outlined the air quality management capabilities of developed and developing nations, citing Kenya as an example of the latter. Finally it has reported on a short study to determine the spatial distribution of Total Suspended Particulates in Nairobi, which study has shown that the levels of this pollutant are above WHO recommended levels in most parts of the City, indicating a need for a regular air quality monitoring and management system.

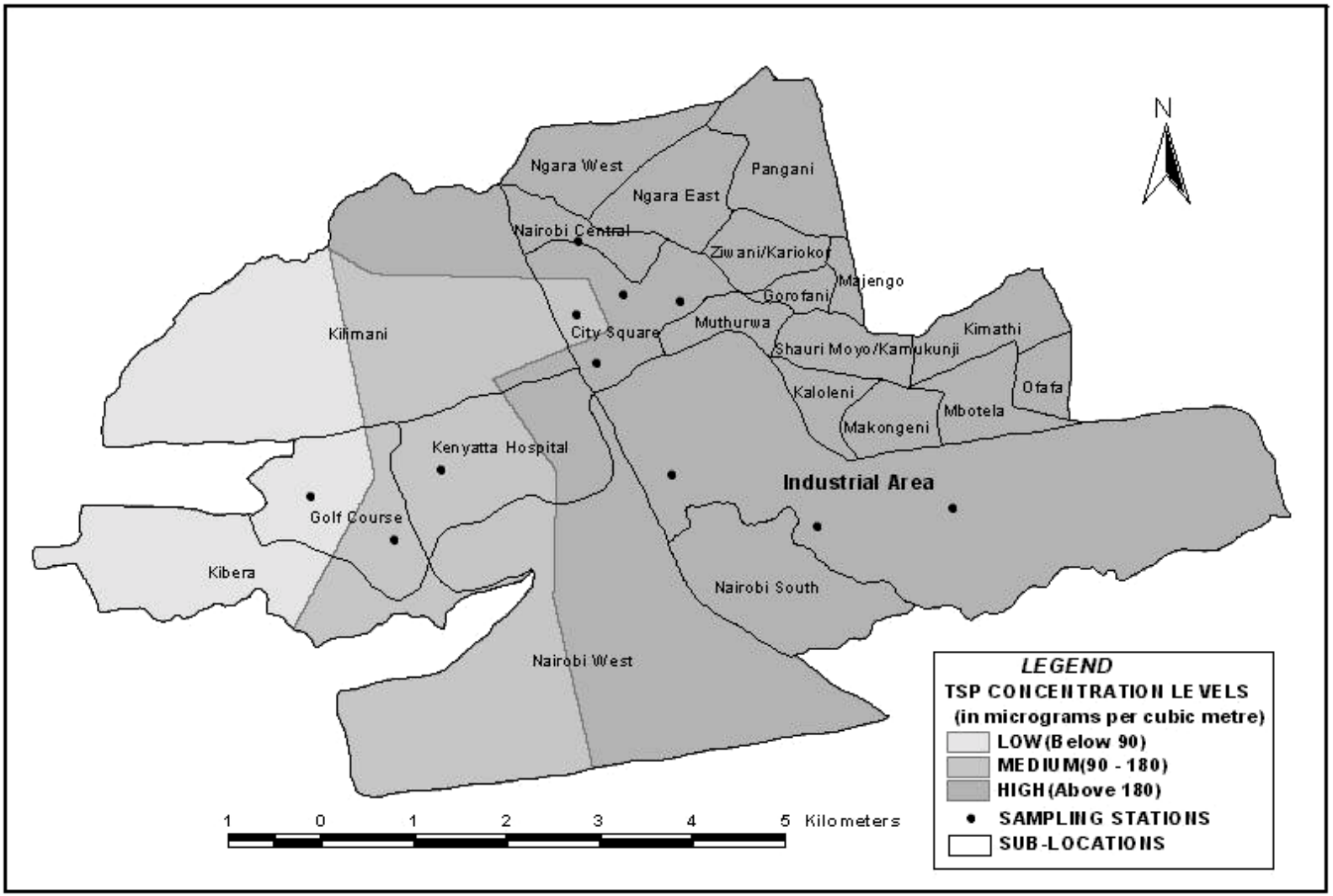

Figure 1: Average TSP distribution in Nairobi

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BIOGRAPHICAL NOTES

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