STUDY OF GASEOUS POLLUTANTS, PARTICULATE MATTER, TRACE METALS AND VOLATILE ORGANIC COMPOUNDS IN AIR OF DHAKA CITY

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SUBMITTED BY

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Declaration

We certify that the research described in the M.Phil thesis entitled "Study of Gaseous pollutants, particulate matter, trace metals and volatile organic compounds in air of Dhaka city" is original and has been carried out by Mr. Mohammad Rakibul Islam, Reg. No. 252, Session 2001-2002, Department of Chemistry, University of Dhaka. The style and contents of this thesis have our approval.

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ABSTRACT

Air pollution from various sources is considered to be a major environmental challenge the burgeoning metropolitan cities of the developing nations confront today. Dhaka is one of the largest mega cities of the world, is also faced with serious air pollution problem due to unplanned urbanization, establishment of heavy industries, and rapid growth of vehicles in recent times. The sudden rise in these sectors has already led to rise in the concentration of particulate matter, troposphere O_3, SO_2, NO_2, CO and trace metals in the air of the city is detrimental to the public health. Considering the gravity of the problem the present study was undertaken to identify the pollutants level in air of Dhaka city. Atmospheric gaseous pollutants and particulate matters were collected with low volume samplers attached impingers for eight hours (except CO for 1-hour) from different locations in Dhaka city. PM_{10} and $PM_{2.5}$ were collected on the micro fiber filters and particles were larger than 10 μm were collected into the dust cup vial. The average concentrations were 311.05μg/m^3, 112.57μg/m^3 and 63.56μg/m^3 for SPM, PM_{10} & $PM_{2.5}$ respectively. Average concentrations of gaseous pollutants were 285.44μg/m^3, 25.33μg/m^3, 39.59μg/m^3 and 27.05μg/m^3 for CO, NO_2, SO_2 and O_3 respectively. Trace metals concentration (Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, and Ag) were determined with Atomic Absorption Spectrophotometer (AAS). The average concentrations were 4.717, 2.467, 2.111, 1.744, 1.256, 0.824, 0.424, 2.080, 0.105 and 1.403μg/m^3 for Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, and Ag respectively in PM_{10} and 2.618, 1.468, 1.279, 1.019, 0.911, 0.432, 0.246, 1.618, 0.050, 0.734μg/m^3 for Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, and Ag respectively in $PM_{2.5}$. The fine particles are dominating into particulate matter (about 77% of PM_{10}), which indicates that fossil fuel and road dust are the main sources of pollution of Dhaka city.

Key word: Dhaka city, air pollution, particulate matter, gaseous pollutants and heavy metals.

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CHAPTER – ONE

INTRODUCTION

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1. Introduction:

1.1 General

Air pollution is one of the greatest environment evils. The air we breathe has not only life-supporting properties but also life-damaging properties. Air is indispensable for the survived of all living organisms on earth, including human beings. It is even more important than water - without water a person can survive for days, but without air no more than a couple of minutes. Urban air pollution has already been identified to be extremely harmful to public health in the capital city of Dhaka and other major cities of Bangladesh (Swapan K. Biswas and Bilkis A. Begum, 2004).

Humans probably first experienced harm from air pollution when they built fires in poorly ventilated caves. Since then we have gone on to pollute more of the earth's surface. Until recently, environmental pollution problems have been local and minor because of the Earth's own ability to absorb and purify minor quantities of pollutants. The industrialization of society, the introduction of motorized vehicles, and the explosion of the population are factors contributing toward the growing air pollution problem.

Air pollution is a major environmental health problem [1,2,3], affecting developed and developing countries around the world. Increasing amount of potentially harmful gases and particles are being emitted into the atmosphere on a global scale, resulting in damage to human health and the environment [4]. It is damaging the resources needed for the long-term sustainable development of the planet.

Air pollution is a term used to describe any unwanted chemicals or other materials that we breathe resulting in the degradation of air quality. Typical urban pollutants from man – made activities include nitrogen oxide, carbon monoxide, sulphur dioxide, hydrocarbons and particulate matter. Common sources of these primary pollutants include road transport (CO, PM and NOx), power station and industrial plants (SO_2).

There are three broad sources of air pollution from human activities: Stationary sources, Mobile sources, and Indoor sources [5]. Air pollutants are usually classified into suspended particulate matter (dusts, fumes, mists, and smokes), gaseous pollutants (gases and vapours) and odours (Hydrocarbon and aromatic compound).

Mobile sources of pollution are those that move. These are classified as on-road (cars, trucks, buses, motorcycles) and non-road (aircraft, aircraft, lawn and ships, agricultural and construction equipment). Mobile sources pollute the air through combustion and fuel evaporation. They produce several pollutants such as apart from CO_2, the main ones are Carbon monoxide (CO), nitrogen oxides (NOx) and hydrocarbones (HC), i.e. volatile or non-volatile organic compounds, soot particles (particulate matter) and ozone (O_3). Others are sulfur dioxide (SO_2), greenhouse gases, including CO_2, NOx, CH_4 and the precursors to ozone, air toxics (e.g. formaldehyde, acetaldehyde, 1,3-butadiene and diesel particulate matter). SO_2 is produced by locomotives, large ships, and some no-road diesel equipment when they burn high sulfur fuel. CO is produced during incomplete combustion of fossil fuels. The lethal and sublethal effects of CO poisoning have been extensively documented (US National Research Council, 1977). The main emissions caused by motor traffic are NOx, HC, and CO, accounting for 58%, 50% and 75% respectively of all such emissions. In the past years, the fuel consumption in the community increased by 1.5% a year. (USEPA, http://www.epa.gov/ebtpages/air.html)

A stationary source (immobile source) is any building, structure, facility, or in installation subject to regulation which emits or may emit any air pollution. These sources include power generating plants, landfills, petroleum facilities, chemical plants, mining operations, cement and glass manufacturing companies, and many other heavy industrial sources, utility, institution and commercial facilities, Examples are phosphate processing plants and municipal waste combustors. Pollutants are emitted into the air from these plants through fossil fuel combustion, chemical processes, and the grinding or pulverizing of metals for cement, fertilizers, etc. These processes emit a number of harmful contaminants into the air

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including sulfur dioxide, nitrogen oxides, carbon dioxide, hydrocarbons (HC), carbon dioxide, synthetic compounds, and particulate matter, chlorofluorocarbons (CFCs).

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building material and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices. Many office buildings have significant air pollution sources.

High concentrations of theses gases and pollutants arising from them through chemical reactions in the atmosphere or in the soil are harmful to human health, corrode various materials and damage vegetation, have a detrimental effects on agricultural and forestry production and cause unpleasant smells. Many of these pollutants, such as CO_2, methane, nitrogen oxides and chlorofluorocarbons (CFCs), are responsible for the greenhouse effects.

Air pollution is one of a variety of manmade environment disasters that are currently taking place all over the world. It is an atmospheric condition in which various natural or manmade chemical elements or compounds, capable of being airborne, are present at concentrations high enough above their normal ambient levels to produce a measurable effect on people, animals, tries, lakes, crops, vegetation, or materials [6] as well as damage the ozone layer and buildings and also can cause haze [7].These may exist in the atmosphere as gases, liquid drops, or solid particles. It includes any noxious or benign substance. The term measurable effects generally restrict attention to those substances cause undesirable effects.

Local concentrations of air pollutants depend upon the strength of their sources and the efficiency of their dispersion. Day to day variations in concentrations are more affected by

meteorological conditions than by changes in sources strengths. Wind is of key importance in dispersing air pollutants and for ground level sources concentrations are inversely related to wind speed. Turbulence is also important: a "rough" terrain, as produced for example by buildings, tends to lead to increased turbulence and better dispersion of pollutants.

The meteorological variable which affect the severity of an air pollution problem are given time and location are (a) wind speed and direction, (b) insolation (amount of sunlight), (c) mixing depth and (d) precipitation.[8]

The atmospheres cleanness itself up to a point by natural processes. Atmospheric dilution occurs because of wind circulation or atmospheric turbulence caused by local sunshine. Pollution is removed from the atmosphere by precipitation, by different physical and chemical reactions and gravitational fallout. Aerosol residence times in the atmosphere are 6-12 days from the lower troposphere; 2-4 weeks for the upper troposphere; 6-12 months for the lower stratosphere; 1-5 years for the upper stratosphere and 5-10 years for the mesosphere. Residence times are functions of latitude and are generally greater near the equator.[9]

Exposure to air pollution is the main environmental threat to human health in many towns and cities. Particulate emission is mainly responsible for increased death rate and respiratory problems for the urban population. This problem is acute in Dhaka, the capital of the country and also the hub of commercial activity. The other urban areas i.e. Chittagong, Khulna, Bogra and Rajshahi have much lesser health problems related to urban air pollution.[8] (http://nation.ittefaq.com/artman/publish/article30258.shtml)

Dhaka is one of the most densely populated cities in the world and facing a high level of air pollution due to the existence of some gaseous pollutants like CO, SO_2, NOx, O_3, CH_4, Non-methane hydrocarbon and particulate matter ($PM_{2.5}$ and PM_{10}), etc [10].

There are several of air pollution in Dhaka, vehicular emissions and industrial emissions. Dhaka, the capital of Bangladesh, is congested with a large number of motor vehicles,

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including both public and private transportation vehicles. Gasoline engines (especially two-stroke engines) contribute to air pollution by emitting high levels of PM, carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs). Diesel engines also emit high levels of PM, NOx, VOCs, and sulfur oxide (sulfur in diesel fuel is high). A major cause behind the release of a large amount of these pollutants is the exhaust fumes released from faulty engines, old engines especially those run on diesel. A large number of pedestrians, drivers, passengers, traffic policemen, street vendors and other groups undoubtedly suffer from significant health damage as a result of exposure to emissions from a large variety of motorized vehicles including trucks, buses, cars and tow-wheelers. They are responsible for 25% of the particulate matter and 60% of the toxic and smog-forming hydrocarbons contributed by all motor vehicles. Every year, motorized vehicles increase by ten percent in Dhaka city alone (The daily Star, Star weekend Magazine, April 18, 2008).

The other sources of PM emissions are brick kiln around Dhaka, which mainly operate during the winter period (in dry seasons), re-suspension from all of the dusty unpaved roads, and refuse burning by slum dwellers. About 6000 brick kilns are around the Dhaka city. From source apportionment studies, it was found that ~50% of PM<2.2 μm (PM2.5) comes from vehicular emissions. Thus, vehicles are believed to constitute the dominant source of air pollution in Dhaka[11,12].

Industrial development is another source of air pollution. Industries in Bangladesh are situated mainly in major urban areas, particularly in Dhaka, the seaport cities like Chittagong, and Khulna, the inland port city Narayanganj, and other divisional towns. So, air pollution is concentrated mainly in these cities. Some monitoring data have already indicated that $PM_{2.5}$ and PM_{10} exceed ambient standards near many industrial stack emissions. In Dhaka and Chittagong, the major sources of TSP in associated heavy metal pollutants are from brick kilns and cement manufacturing. In Dhaka, over 300 tanneries in a residential area (hazaribagh) potentially emit significant TSP that may also contain heavy metals like Chromium (ADB 2005). Apart from unplanned industrial development in these

areas, the severity of the pollution is increased mainly due to exhausts from motor vehicles, diesel-run vehicles and two-stroke engine.

Traffic congestion is part of daily life in Dhaka, vehicle-related air pollution is growing at an alarming rate, and traffic delays have tripled in the last three years. Standing and slow driving vehicles at the strafing point aggravate the air pollution.

In the rural areas of Bangladesh, The air pollution problems have not yet become a point of concern. This is due to fewer motorized vehicles and industries in rural areas. The primary air pollutants found in the rural areas are carbon monoxides, sulfur oxides, hydrocarbons, and particulate matter (both solid and liquid). These pollutants are dispersed throughout the world's atmosphere in concentrations high enough to gradually cause serious health problems.

Particulate matters are generally known as atmospheric aerosols that have several environmental impacts, some of which are global but mostly are regional. These include polluting the ambient nature by causing acid rain, reducing visibility, affecting radiation balance, modifying cloud property and causing health related problems[1,2,3].

Particulate matter is the main pollutant of concern for Dhaka and has been identified to be extremely harmful to public health. Two-stroke engine driven three-wheelers, commonly known as baby taxis, were the main culprit for this particulate air pollution. Prior to September 2002 a large number of two stroke three-wheelers were used to ply in Dhaka and the number of this class of vehicles was estimated to be between 30 and 65 thousand. Emission inventory calculations showed that these vehicles contribute to about 40% of the vehicular air pollution for the particulate matter [10]. (khaliquzzaman. 2003)

Volatile organic compounds (VOCs) are of concern since many are toxic and they may also be persistent in the environment. VOCs are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects [13].

Exposure to VOCs can potentially lead to a variety of adverse health outcomes such as irritation of the eyes and respiratory tract, and lungs. Several VOCs (Benzene, 1,1-dichloroethylene, 1,4-dichlorobenzene, chloroform, ethylene dibromide, methylene chloride and carbon tetrachloride) commonly found in indoor air have been associate with an increased risk of cancer [14,15].

Volatile organic compounds (VOCs) are a group of major pollutants present in the urban atmosphere. The sources of VOCs are both anthropogenic and nature. The main source of VOCs in the outside environment is from petrol and so vehicle traffic and indoors, cigarette smoke. They are also present in small quantities in drinking water and food, in paints and adhesives. All of these sources contribute to the pollutant of indoor environments [16-28]. Vehicle movement has been confirmed as the dominant influence on benzene and associated VOCs in the atmosphere [20-24,29-33,35]. Benzene, toluene, ethyl benzene and xylene (BTEX) and VOCs can be found in water [26,28,34], soil [36], cigarette smoke [37-40], adhesives [41,42], in paint and varnish shops [43-44], breath [18] (and remember petrol is a substance of abuse [45,46], or blood [19,47].

It has been found that Dhaka city has volatile organic compounds (VOCs) exceeding to tolerable limits. Emissions from 2-stroke auto-rickshaws were found to contain four to seven times the maximum permissible levels of VOC (DoE 2001). (Country Synthesis Report on Urban Air of Quality Management, Bangladesh, December 2006, ADB)

Automobile exhausts fill the air in Dhaka city with volatile organic compounds (VOCs) beyond tolerable limits. Prof. Abul Hussam of George Mason University, Virginia, USA detected 200 organic compounds and identified 35 of those by analysing four air samples collected from the Shewrapara area of the city recently[48].

The tests show that exhausts of auto-rickshaws contain VOCs four to more than seven times beyond the allowable limit. The ambient air in Shewrapara contain these compounds close to the threshold limit, the tests reveal.

Prof. Hussam said the analyses of exhausts of auto-rickshaws showed the presence of toluene, up to 200,000 micrograms per cubic metre as against the threshold limit of 2000 micrograms per cubic metre and Prof. Hussam added that apart from automobile exhausts, natural gas (if cookers are on), chemical processing plants and biogenic sources contributed to the extremely bad VOC pollution of Dhaka's air.

The 35 volatile organic compounds identified included benzene, toluene, octane, ethylbenzene, 1-isocyanato-3-methoxybenzene, o,p-xylene, propylbenzene, imethylbenzene and butylbenzene.

Except from a few studies on the measurement of airborne particulate matters,[49] there is no record on other air pollutants in Bangladesh

Extractable Particulate Organic Fractions - Also called extractable organic matter (EOM), these have the potential to cause adverse health effects. These fractions, and many compounds within them, have been shown to be mutagenic and carcinogenic. Investigators have found that the extractable organic material (EOM) from airborne particles is carcinogenic in animal bioassays (US EPA, 1984). The presence of polycyclic aromatic hydrocarbons (PAHs) in the EOM attributed to be carcinogenic and mutagenic.

A significant quantity of VOCs (dioxane, vinyl chloride, methylene chloride, trichloroethylene, perchloroethylene, benzene, toluene, m,p-xylene etc.) are emitted into the atmosphere through the use of liquid fuels and through the transport, storage, transfer of organic solvents..

Conventional methods for VOCs sampling include active air sampling [50]. GC-MS and GC with other modes of detection following desorption from a solid adsorbent are the most used quantitative methods for detection of VOCs levels in air[16-18,22,24,32,33,51,52]. The aim of the present work was to develop a GC-MS method to evaluate the common aromatic ambient pollutants. Passive sampling with solid phase micro-extraction (SPME) is a

relatively new technique for the analysis of VOCs in air and in other matrics[53]. In this study, the absorption of VOCs on sorbents technique has been used for air sampling.

Air pollution in the big cities in Asia like Dhaka was recognized as a public health issue in early nineties. As health effects are mostly associated with the particles in the size range of about 10μm and 2.5 μm (called PM_{10} and $PM_{2.5}$ particles); it is these particles that are attracting the greatest attention [54,55,56,57,58].These particles also have influence on cloud formation and solar radiation budget and therefore, can affect the weather as well as the climate. High levels of Pb, PM_{10} and $PM_{2.5}$ in ambient air was a major concern [59], both for the public and Government because of its high-ambient concentrations and its documented impact on morbidity and premature mortality. PM_{10} concentrations in a number of cities in South Asia [28] generally exceed internationally accepted standards by several times. PM_{10} have been shown to have significant associations with decline in lung function, respiratory and cardio-vascular diseases and also can cause deaths [60]. Other than these some epidemiological studies across the world found association between suspended particulate matter (SPM) and acute and chronic respiratory disorders, lung cancer, morbidity and mortality[61-64]. The World Health Organization assessed that about 460,000 people die each year because of SPM, among which 135,000 are victims of chronic asthma and the rest die of cardiovascular or heart diseases (WHO 2002). Several studies have shown that the particulate matter of different size have significant negative impact on human health as well as global environment [65,66].

Children suffer more from air pollution in the cities. Most of the children in the cities of Bangladesh are suffering from respiratory problem. Because children breathe more air relative to their body weight and lung surface area than do adults. So, they also receive proportionately higher doses of air pollutants. They spend more time outdoors, often during midday and afternoons when pollutant levels are generally highest.

They are three times more active than adults while outdoor, significantly increasing their oxygen demand and consequently raising their breathing rates. Children often fail to recognize the significance of respiratory symptoms such as coughing, wheezing, and

shortness of breath, and they frequently fail to move indoors of curtail exercise during air pollution episodes. Children tend to breathe more through the mouth than through the nose due to their increased physical exertion, thus reducing the effectiveness of one level of filtration. In addition, young children's small noses are easily blocked by congestion, constriction, or other illnesses.

Children at greatest risk from the effects of air pollution of sensitized respiratory systems, such as allergic or asthmatic, children who live near industrial sources, of heavy traffic, or in homes with cigarette smokers, and children who lack adequate medical attention, or sanitary living conditions.

1.2. Health effects

Air pollution can affect our health in many ways with both *short-term* and *long-term* effects. Different groups of individuals are affected by air pollution in different ways. Some individuals are much more sensitive to pollutants than are others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted. The extent to which an individual is harmed by air pollution usually depends on the **total exposure** to the damaging chemicals, i.e., the *duration of exposure* and the *concentration of the chemicals* must be taken into account.

Examples of **short-term effects** include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Other symptoms can include headaches, nausea, and allergic reactions. Short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema. In the great "Smog Disaster" in London in 1952, four thousand people died in a few days due to the high concentrations of pollution.

Long-term health effects can include chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys. Continual exposure to air pollution affects the lungs of growing children and may aggravate or complicate medical conditions

in the elderly. It is estimated that half a million people die prematurely every year in the United States as a result of smoking cigarettes.

Research into the health effects of air pollution is ongoing. Medical conditions arising from air pollution can be very expensive. Healthcare costs, lost productivity in the workplace, and human welfare impacts cost billions of dollars each year.

(air pollution\Air Pollution_files\pollution-health-effects-f.htm)

1.3. Air pollution in Bangladesh

Bangladesh is a developing country. Most of the development with respect to the growth of industrial and commercial establishment has happened unplanned. None of the industry is equipped with any kind of emission control system.

Developing countries like Bangladesh is characterized by a rapid increase of energy consumption accompanied by a rapid growth of population and economic activities. Thus the increasing contribution of atmospheric loads of SO_2 and NOx to global climate change is anticipated and it is really necessary to quantify these emissions in a hurried manner.

The increasing air pollution is impeding Bangladesh's development and it is indeed a matter that should be addressed seriously. It is not only the health cost that is going to be enormous and burdensome on the national exchequer, but the loss of potential working ability of the people due to poor health conditions.

In Bangladesh, pollution severity occurs due to the large number of high polluting vehicles, impure fuel, inefficient land use, and overall poor traffic management. The pollutants of concern for Bangladesh are fuel, particulate matter, dust, oxides of nitrogen, sulfur dioxide and volatile organic compounds.

In developing countries, indoor air pollution from using open fires for cooking and healing may be a serious problem. It has been estimated that about 1.9 million people die annually due to exposure to high concentrations of suspended particulate matter in the indoor air environment, while the excess mortality due to suspended particulate matter and sulphur dioxide in the ambient air amounts to about 500000 people annually. Although the indoor

air database is weal due to the scarcity of monitoring results, these estimates indicate that a serious air problem may exist in developing countries.

1.4. Air pollution in Dhaka

Dhaka, the capital of Bangladesh, located on the banks of the Buriganga river along with its metropolitan area (1,600 km^2), has a population of around 11 million, making it the largest city in Bangladesh and the 11^{th} most populous in the world. (http://en.wikipedia.org/wiki/Dhaka). The population of Dhaka Megacity is expected to reach 1,56,79,000 by the year 2015 (Source: DMDP July 1994, P.2-9 and present study for DCC). Environmental problem in Bangladesh is a new issue. In an economic evaluation of air pollution in Bangladesh, The World Bank estimated that nearly 15,000 deaths would be avoided annually (10,800 in Dhaka, 2,060 in Chittagong, 1,020 in Khulna and 975 in Bogra), if the level of air pollution in Bangladesh four largest cities reduced to the WHO annual average standard [81(a)]. In addition, there would be an estimated 6.5 million fewer cases of sickness requiring medical treatment; and 850 million fewer restricted activity days, respiratory symptom days, cases of lower respiratory illness in children, and other minor sickness (Mr. Martin). The economic cost of this sickness and death is estimated to be US$200-800 million per year in Bangladesh (Jitendra Shah, a senior World Bank environmental expert), or 0.7%-3.0% of GDP per year (Brandon, 1997) [81(a), 81(b), 81(c), 81(d)]. The major disease in Bangladesh is acute respiratory infections caused mainly by polluted air (Paul Martin, an environmental specialist at the bank's Dhaka office). Due to a rapid growth of automobile traffic in Bangladesh cities in recent year, the World Bank has identified the reduction of urban air pollution and related health impacts as a development objective for Bangladesh. Air pollution levels in Dhaka are considerably higher than World Health Organization guidelines for residential areas, according to World Bank environmental experts.

Dhaka is the worst affected and air pollution is threatening environment and city-dwellers. The state of air pollution of Dhaka does not easily match with the statistics of country's socio-economic situation, agriculture based economy and slow pace of urbanization. The

total industrial units are about 30000 of which 24000 are cottage. Until 1995, the total registered automobiles were approximately 343371.

About 200,000 motor vehicles ply in Dhaka. In industrial countries lead added gasoline driven cars are almost disappearing and at the same time these harmful automobiles are exported to the developing countries in the name of "Reconditioned Cars". In recent years due to reduce tax these cars have conquered Bangladesh market.

In south Asia, the number of motor vehicles will increase from 3.0 per 1000 in 1980 to 7.2 per 1000 persons in 2000 (Faiz et al, 1990). This raising tendency is also prevalent in Bangladesh Where the number of motor vehicle per 1000 people rose from 1.4 in 1982 to 2.28 in 1991, and 2.72 in 1995 (BBS, 1995). In Bangladesh, motor vehicle are classified in the following major categories: heavy truck, tractor, bus/minibus, car, jeep, trawler, auto-tempo, auto-rickshaw (Baby-taxi, mishum), and motor cycle. Nearly one third of motor vehicles are operated by diesel (truck , bus), which contribute a greater portion of urban suspended particulate matter (SPM), sulfur oxides (SOx), and nitrogen Oxides (NOx), sometimes private cars are energized using a proportion of (3:2) Petrol (regular gasoline) and Octane (extra leaded) (Karim, 1999).

Dhaka is a very congested city with little space for locating industry, handling materials and providing for transportation. As a consequence and because potentially discharges can arise in manufacturing processes and because of the known problems of polluting emissions from motor vehicles, emphasis has to be laid on realistic planning, provision of air pollution abatement equipment and the exercise of air quality management techniques[81(f)].

Air pollution levels in Dhaka are considerably higher than Bangladeshi standards or World Health Organization (WHO) guidelines for residential areas. Greater exposure to particulates has been linked to premature deaths from respiratory and cardio-vascular illnesses, and higher rates of sickness, especially bronchitis and other chronic obstructive pulmonary diseases, as well as respiratory tract infections. Other physical impacts of air

pollution include damages to crops and ecosystems, degraded visibility, soiling of buildings, and damage to water quality through deposition of lead and other pollutants. These effects on the ecosystem impair people's livelihood as well as health.

1.5. Transport in Dhaka city

Air pollution in Dhaka is serious due to increasing population and associated motorization. If added with traffic jams, global warming, sailing of materials, and asthetic degradation, the total air pollution would be substantially larger.

The visible signs of ambient air quality of Dhaka is indicating an upward trend in gross emissions in recent years. Motor vehicles, especially the two strokes engine vehicles (TSEV) are responsible for the increase in emissions of both local pollutants and green house gases due to the rapid growth in the number and use of motor vehicles. TSEVs have outgrown all other types of vehicles. The following table shows the vehicle population by type, utilization, and fuel economy.

Table 01: Vehicle population, utilization, and fuel economy in Dhaka, 1996 (Source: European Economic Commission; Dhaka Urban Transport Project Working Papers)

	Vehicle population	Annual utilization (km/yr)	Total annual vehicle kms (millions)	Fuel economy (km/l)
Cars & taxis	42,000	19,200	806.4	8.0
Jeep, station wagon, microbus	12,000	19,200	230.4	8.0
Diesel bus	4,000	57,600	230.4	4.8
Diesel truck	5,000	64,000	320.0	2.4
3-wheeler vehicle	14,500	38,400	556.8	2.4
2-wheeler vehicle	73,500	10,000	735.0	35.0

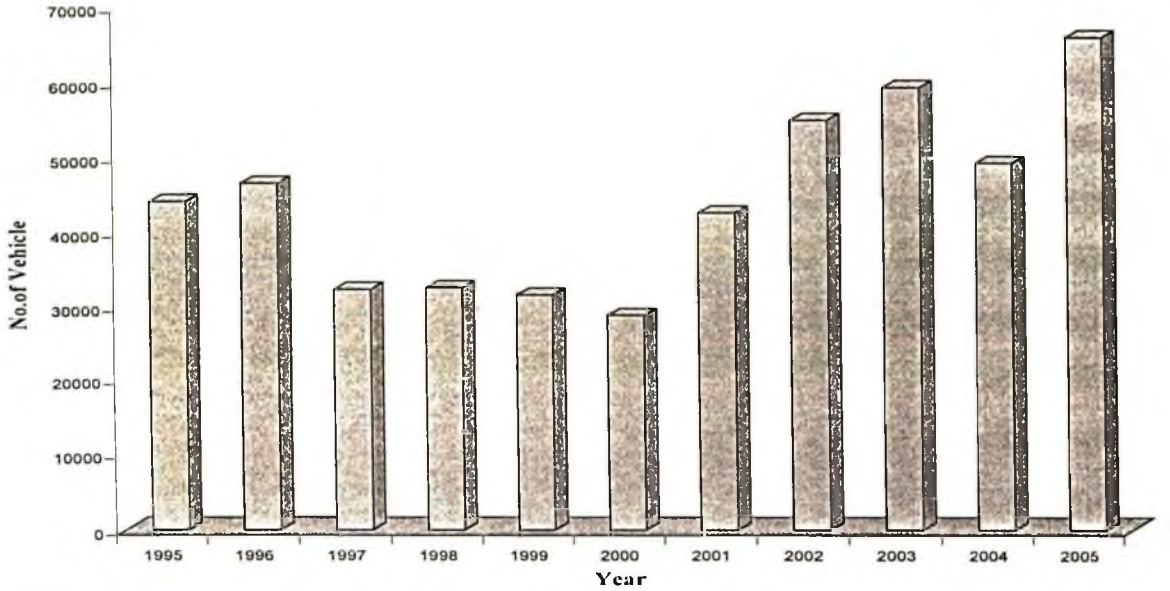
Initial estimates reveal that motor vehicles annually emit 3,700 tons of particulate matters (PM_{10}), 8,550 tons of nitrogen oxides, 50,700 tons of carbon dioxide, etc.TSEVs (mainly 3-wheeler baby taxis) are the significant contributors.
Bangladesh emitted 20 million tons of carbon dioxide in 1995 (International Energy Agency, 1995).

The ratio of vehicles to people in Bangladesh is lower when compared with other developing countries in Asia. As of end of 2005, there were only about 850,000 vehicles in Bangladesh, about 45% of which are registered in Dhaka. However, it is also important to note that the registered vehicles are only about 25-50% of the actual vehicles plying the roadways due to a limited enforcement of registration regulations (Intercontinental Consultants and Technocrats Pvt. 2001).
Motorcycles (45%), then motor cars (15%) and auto-rickshaws and auto-tempos (13%) dominate the registered vehicles mix (Fig 01). Almost the same vehicle mix is experienced by Dhaka.

Although Dhaka's vehicle fleet is large, high traffic volumes, congestion, and poor vehicle maintenance has resulted in the transport sector being a major contributor to air pollution. In addition, inefficient land use and overall poor traffic management further adds to traffic congestion and air pollution. Motor vehicles are often old, overloaded, and poorly maintained. Old trucks and dilapidated mini-buses are also common.

Auto-rickshaws and auto-tempos also make up a significant proportion of the total vehicles fleet. Most vehicles are powered by 2-storke engines. Two-stroke engine three-wheelers were banned from Dhaka 1st January 2003 and the Government is planning to introduce similar vans in other cities, including Chittagong.

Table 02: No. of year wise registered motor vehicles in Bangladesh (1995-2005)



Register motor vehicle in Bangladesh, 2005

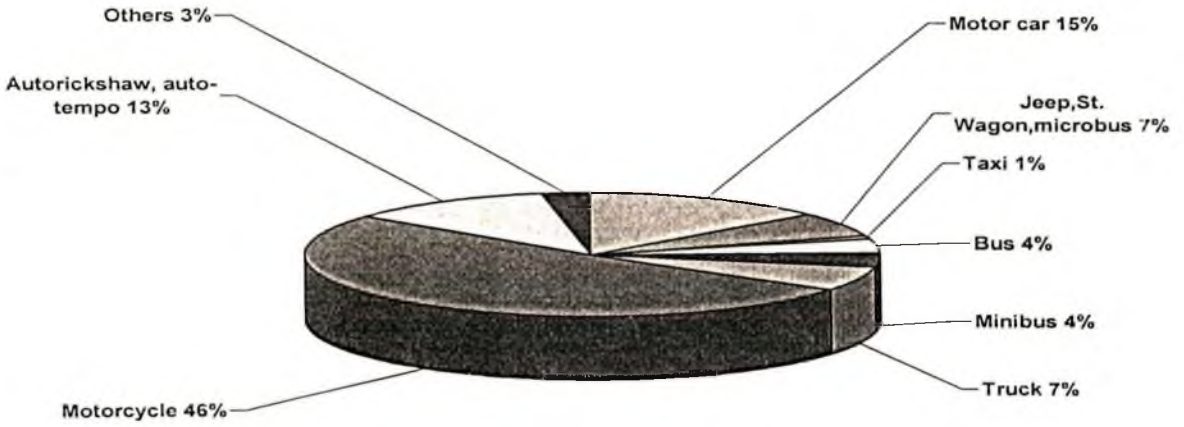


Figure 01: Register motor vehicle mix in Bangladesh, 2005.

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1.6. Heavy metals

1.6.1. Heavy metals in air

Some metal ions play an important rule to the human health as a micronutrients. When metal ion in particulate matter (PM_{10} & $PM_{2.5}$) inhaled through the lungs, it might be the adversed effect to the respiratory system.

Metal ions come to the ambient air due to mechanical, erosion and chemical corrosion effect on any metal surface. The metals are associated with dust, silica, shoot particulate to form particulate to form particulate matter both PM_{10} & $PM_{2.5}$.

There are several metals regularly found in air that can present real or potential risks to human health. The most important of these are arsenic, cadmium, chromium, lead, manganese, mercury and nickel.

Lead compounds are widely distributed in the atmosphere, mostly due to the combustion of fuels containing alkyl lead additives. As many countries are reducing the lead content of petroleum fuels, or have practically eliminated lead from fuels, this route of exposure is declining. However, high levels of lead in fuels and increasing vehicle numbers are increasing exposure to lead in some countries. Other important sources of lead in air are the mining and processing of ores and other materials containing lead. Inhalation of lead is a significant source of lead in adults, but ingestion of lead in dust and products such as paint containing lead is a more important route of exposure in children.

Arsenic and its compounds are widespread in the environment. They are released into air by industrial sources, including metal smelting and fuel combustion, by the use of some pesticides and, during volcanic eruptions, by wind-blown dusts. Arsenic can reach high concentrations in air and dust near some metal smelters and power stations, mostly as inorganic arsenic in particulate form.

Cadmium is emitted to air from steel plants, waste incineration, zinc production and volcanic emissions. Tobacco also contains cadmium; smoking, therefore, can increase uptake of cadmium.

Chromium is widely present in nature, but it can be introduced into the atmosphere by mining of chromites, production of chromium compounds and wind-blown dusts, It is a component of tobacco smoke.

Manganese is a widely distributed element that occurs entirely as compounds that may enter the atmosphere due to suspension of road dusts, soils and mineral deposits. The smelting of ores, combustion of fossil fuels and emissions from other industrial processes also provide local contributions to the manganese content of the atmosphere.

Mercury enters the atmosphere as a alkylated form through natural processes and industrial activities such as the mining and smelting of ores, burning of fossil fuels, smelting of metals cement manufacture and waste disposal.
Nickel is an element with low natural background concentrations. It enters the atmosphere due to the burning of oils, nickel mining and processing, and municipal waste incineration.

Contamination of the environment by heavy metals is a phenomenon of global importance today. When present in high concentration in the environment, heavy metals may enter the food chain from soils and result in health hazards. Accumulation in air is one major way through which heavy metals may find their way into soils and subsequently tissues of plants, animals and human beings. [67]

Heavy metals are present in the environment, occurring in varying concentrations in with various oxidation states. Lead, Cadmium, Vanadium and Arsenic, which occur sometimes either naturally in crude oil or as additives during processing could eventually be released into the atmosphere during the combustion of petroleum products. Moreover Iron, Nickel, Chromium, Antimony and Zinc, which are important additives in the manufacture of components of motor vehicle parts, are also emitted as a result of wear and tear.[68]

In big cities, air is generally composed of car exhaust gas originated particles and wind-transported particles.[69] The metals (e.g. Ni, Cr, Fe, Co, Mn, As, Pb. Zn, Cu, Mo, Cd) come mainly from vehicular activities such as wearing of tire (Zn, Pb, Cr and Ni) and wear of break linings (Ni, Cr and Pb), wear of studded tires Fe, Ni, Mo, Cr, Cu, and Cd), corrosion of bushings, brake wires, radiators and the various types of de-icing chemicals and friction materials used on road surfaces for slipperiness control especially in temperate countries.[70,71] Lead is emitted to the atmosphere by various burning leaded fuel and from certain industrial processes, primarily battery manufactures and lead smelters. As a result of the reduction of lead in gasoline, metal processing is the major sources of lead emission.

These elements eventually settle down on soil surfaces. In fact has been shown that considerable amounts of toxic metals arising from human activities are accumulated in air.[72] With rains, they are percolated in the soil and are eventually transferred into plants and eventually human through the consumption of this plants.[73] They thus enter the food chain as a result of their uptake by edible plants.[74] Toxic heavy metals can also be taken directly by man and other animals through inhalation of dusty soil.[68]

1.6.2. Effects of heavy metals on human health

1.6.2.1 Toxic effects of lead (Pb)

Heavy metals have great effect on human health. Lead is absorbed in the body following inhalation or ingestion. Children absorb lead much more efficiently than adults do after exposure and ingested lead is more readily absorbed in a fasting individual.[68] Growing nervous system of young children is particularly vulnerable. Over 90% of inhaled lead is absorbed directly into the blood. After lead is absorbed in the body it circulates in the blood stream and distributes primarily in the soft tissues e.g. kidneys, brain, muscle and bone. Adults distribute about 95% of their total body lead to their bones while children distribute about 73% of their total body lead to their bones. High concentrations of lead can cause irreversible brain damage (encephalopathy) seizure coma and death if not treated immediately.[75] The Central nervous System (CNS) becomes severely damaged at blood concentrations starting at 40μg/dL causing a reduction in nerve conduction velocities and

neuritis. The kidneys are targets of lead toxicity and prone to impairment at moderate to high levels of lead concentrations Kidney disease both acute and chronic nephropathy is a characteristic of lead toxicity. Other signs/symptoms of lead toxicity include gastrointestinal disturbances-abdominal pain cramps constipation anorexia and weight loss-immunosuppressant and slight liver impairment.[75]

Children are susceptible to the most damaging effects of lead toxicity. 1µg Pb damage 1 IQ. Literature exists that shows just how damaging lead is to children brain. Prenatal and postnatal developments are compromised significantly by the presence of lead in the body. At blood lead concentrations of 80-100µg/dL severe encephalopathy occurs. Those children who survive lead-induced encephalopathy typically suffer permanent brain damage marked by mental retardation and numerous behavioral impairments.

1.6.2.2. Toxic effects of zinc (Zn)

Zinc is a trace element that is essential for human. When people absorb too little zinc they can experience a loss of appetite, decreased sense of taste and smell, slow wound healing and skin sores. Zinc-shortages can even cause birth defects. Although humans can handle proportionally large concentrations of zinc, too much zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause atrtetiosclerosis.[76]Extensive exposure to zinc chloride can cause respiratory disorders. In the work place environment zinc contagion can lead to a flu-like condition know as metal fever. This condition will pass after two day and is caused by over sensitivity. Zinc can be a danger to unborn and newborn children. When their mothers have absorbed large concentrations of zinc the children may be exposed to it through blood or beast feeding of their mothers.

1.6.2.3. Toxic effects of iron (Fe)

Chronic inhalation of excessive concentrations of iron fumes or dusts may result in development of a benign pneumoconiosis called siderosis, which is observable as an x-ray change. No physical impairment of lung function has been associated with siderosis.

Inhalation of excessive concentrations of iron oxide may enhance the risk of lung cancer development in workers exposed to pulmonary carcinogens. LD_{50} (oral, rat) =30 gm/kg. (LD_{50}; Lethal Dose 50. Single dose of a substance that causes the death 50% of animal population from exposure to substance by any route other than inhalation. Usually expressed as milligrams or grams of material per kilogram of animal weight (mg/kg or g/kg)). Amore common problem for humans is iron deficiency, which leads to anemia. A man needs an average daily intake of 7 mg of iron and a women 11 mg; normal diet will generally provided all that is needed.[77]

1.6.2.4. Toxic effects of copper (Cu)

Absorption of copper occurs through the lungs gastrointestinal tract and skin. The degree to which copper is absorbed in the gastrointestinal tract largely depends upon its chemical state and the presence of other compounds like zinc. One absorbed copper is distributed primarily to the liver kidneys spleen heart lungs stomach intestines nails and hair. Individuals with copper toxicity show an abnormally high level of copper in the liver, kidneys, brain, eyes and bones.[40] Signs and symptomps: Acute toxicity of ingested copper is characterized by abdominal pain diarrhea vomiting tachycardia and a metallic taste in the mouth. Continued ingestion of copper compounds can cause cirrhosis and other debilitating liver conditions.[78] Copper deficiency cause anaemia, loss of hair pigment, growth inhibition and loss of arterial elasticity. High levels of vitamin C inhibit good copper absorption. Copper is highly toxic and very dangerous to infants and to people with certain metabolic disorders. Uptake of copper is also influenced by zinc, silver, cadmium and sulphate in the diet.

1.6.2.5. Toxic effects of cadmium (Cd)

It has been well established that excess cadmium exposure produces adverse health effects on human beings. For virtually all chemicals, adverse health effects are noted at sufficiently high total exposures. For certain elements such as copper and zinc, which are essential to human life, a deficiency as well as excess, can cause adverse health effects. Cadmium is not regarded as essential to human life. The relevant questions with regard to cadmium exposure are the total exposure levels and the principal factors which determine

the levels of cadmium exposure and the adsorption rate of the ingested/inhaled cadmium by the individual, in other words, the pathways by which cadmium enters the food chain, the principal pathway of cadmium exposure for most beings.

The kidney is the critical target organ for the general population as well as for occupationally exposed populations. Cadmium is known to accumulate in the human kidney for a relatively long time, from 20 to 30 years and has been associated with bone disease. Most of the available epidemiological information on cadmium had been obtained from occupationally exposed workers or on Japanese populations in highly contaminated areas.

1.6.2.6. Toxic effects of arsenic (As)

Arsenic is one of the most toxic elements that can be found. Despite their toxic effects, inorganic arsenic bonds occur on earth naturally in small amounts. Human may be exposed to arsenic through food, water and air. Exposure may also occur through skin contact with soil or water that contains arsenic. Levels of arsenic in food are fairly low, as it is not added due to its toxicity.[79] But levels of arsenic in fish and seafood may be high because fish absorb arsenic from the water they live in. Luckily this is mainly the fairly harmless organic form of arsenic but fish that contain significant amounts of inorganic arsenic may be a danger to human health.[80]

Exposure to inorganic arsenic can cause various health effects, such as irritation of the stomach and intestines, decreased production of red and white blood cells, skin changes and lung irritation. It is suggested that the uptake of significant amounts of inorganic arsenic can intensify the chances of cancer development, especially the chances of development of skin cancer, lung cancer, liver cancer and lymphatic cancer,

A very high exposure to inorganic arsenic can cause infertility and miscarriages with women, and it can cause skin disturbances, declined resistance to infections, heart disruptions and brain damage with both men and women. Finally, inorganic arsenic can damage DNA. A lethal dose of arsenic oxide is generally regarded as 100mg.

Organic arsenic can cause neither cancer nor DNA damage. But exposure to high doses may cause certain effects to human health, such as nerve injury and stomachaches.

1.6.2.7. Toxic effects of chromium (Cr)

The known harmful effects of chromium in man are attributed primarily to the hexavalent from; trivalent chromium is considered non-toxic. A single oral dose of 10 mg/kg body weight of hexavalent chromium will result in liver necrosis, nephritis, and death in man. A lesser dose will cause irritation and corrosion of the gastrointestinal mucosa and occasionally encephalitis and enlarged liver. No local or systemic effects have been attributed to the ingestion trivalent chromium.

1.6.3. Environmental effects of heavy metals

Lead in the air can be carried long distances and will attach to dust. This lead-containing dust is removed from the air by rain and heavy rain can wash it into rivers, drains, canals. The immediate effects of exposure to lead can mean death of animals, births or fish and death or low growth rate in plants. Especially in soft water, lead is highly poisonous to plants, births or land animals. Long-term effects on animal life are shortened lifespan, reproductive problems, lower fertility and changes in appearance or behaviour. Because lead does not break down and is highly persistent in water, it is expected that fish tissues will contain lead from polluted waters.[81]

On zinc-rich soils only a limited number of plants have a chance of survival. That is why there is not much plant diversity near zinc-disposing factories. Due to the effects upon plants zinc is a serious threat to the productions of farmlands. Despite of this zinc-containing manures are still applied. The world's zinc production is still rising. This basically means that more and more zinc ends up in the environment. Water is polluted with zinc due to the presence of large quantities of zinc in the wastewater of industrial plants. This wastewater is not purified satisfactority. One of the consequences is that rivers are depositing zinc-polluted sludge on their banks. Zinc may also increase the acidity of waters. Some fish can accumulate zinc in their bodies, when they live in zinc-contaminated

waterways. When zinc enters the bodies of these fish it is able to bio magnify up the food chain. Large quantities of zinc can be found in soils. When the soils of farmland are polluted with zinc, animals will absorb concentrations that are damaging to their health. Water-soluble zinc that is located in soils can contaminate groundwater. Zinc cannot only be a treat to cattle but also to plant species. Plants often have a zinc uptake that their systems cannot handle, due to the accumulation of zinc in soils influences the activity of microorganisms and earthworms.

Most copper released to air, water, sediment and soil strongly attaches to other particles, thus reducing the toxicity of copper. Copper can be transported as particles released into the atmosphere or as dissolved compounds in natural waters. Copper is essential to animals and plants. Copper is toxic to many bacteria and viruses. Copper is commonly found as copper (II) in natural waters and the free copper (II) ion potentially very toxic to aquatic life, both acutely and chronically. Its toxicity increase with decreasing water hardness and dissolved oxygen concentration and decreases with high concentrations of dissolved organic compounds and suspended solids. Alkalinity and pH are other factors that influence copper toxicity. Copper is expected to bio accumulate in fish tissues. Copper is normally complex-bound in soil, greatly dimming its toxicity. No data are available on the short-term and the long-term effects of copper to plants, birds or land animals.

Iron (III)-oxo-arsenite and pentahydrate may be hazardous to the environment; special attention should be given to plants, air and water. It is strongly advised not to let the chemical enter into the environment because it persists in the environment.[82]

Large amounts of arsenic end up in the environment and in living organisms. Arsenic is mainly emitted by the copper producing industries but also during lead and zinc production and in agriculture. It cannot be destroyed once it has entered the environment, so that the amounts that we add can spread and cause health effects to humans and animals on many locations on earth.

Plants absorb arsenic fairly easily so that high-ranking concentrations may be present in food. The concentrations of the dangerous inorganic arsenics that are currently present in

surface waters enhances of alteration of genetic material of fish. This is mainly caused by accumulation of arsenic in the bodies of plant-eating freshwater organisms. Birds eat the fish that contain eminent amounts of arsenic and will die as a result of arsenic poisoning as the fish is decomposed in their bodies.[83]

1.7. Ambient air quality standards

The first set of ambient AQ standards for Bangladesh was defined in the Environment conservation Rules of 1997. These 1997 standards were recently replaced a new set in June 2005 based on the proposal of the World Bank-funded AQM project which reviewed the old standards. The new standards for PM (PM_{10}, $PM_{2.5}$), NO_2, SO_2, CO, and ozone (O_3) are the same as the ambient Air Quality (AQ) standards set by US EPA and the standard for Pb is equivalent to the guideline value set by WHO. Bangladesh is the only country in South Asia which set $PM_{2.5}$ in its National Ambient Air Quality Standards (NAAQS). The standards for CO, NO_2, SO_2, and O_3 are seen to be more lenient than the guidelines set by WHO. Table 03 shows the updated ambient AQ standards for Bangladesh.

Table 03: Updated (2005) Bangladesh National Ambient Air Quality Standards vs. WHO Guideline Values and Standards

Pollutant	Averaging Period	Bangladesh Standards[a]	WHO[b] Guideline Values ($\mu g/m^3$)	US EPA Standards ($\mu g/m^3$)[d]
CO	8-hour (a)	10,000$\mu g/m^3$ (9 ppm)	10,000	10,000
	1-hour (a)	40,000$\mu g/m^3$ (35 ppm)	30,000	40,000
Pb	Annual	0.5$\mu g/m^3$	0.5	-
NO_2	Annual	100$\mu g/m^3$(0.053ppm)	-	100$\mu g/m^3$
TSP	8-hour	200$\mu g/m^3$	-	-
PM_{10}	Annual (b)	50$\mu g/m^3$	20	revoked
	24-hour (c)	150$\mu g/m^3$	50	150
$PM_{2.5}$	Annual	15$\mu g/m^3$	10	15
	24-hour	65$\mu g/m^3$	25	35
O_3	1-hour (d)	235$\mu g/m^3$ (0.12ppm)	-	235
	8-hour	157$\mu g/m^3$ (0.08ppm)	100	157
SO_2	Annual	80$\mu g/m^3$ (0.03ppm)	-	78
	24-hour (a)	365$\mu g/m^3$ (0.14ppm)	20	365

Source: a S.R.O. No:220-Law, 2005; b WHO, 2000; and d US EPA, 2006

CO= Carbon monoxide; NOx = Nitrogen oxide; O_3 = ozone; Pb = lead; PM_{10} = particulate matter with a diameter of not more than 10 microns; $PM_{2.5}$ = particulate matter with a diameter of not more than 2.5 microns; SO_2 = Sulfur dioxide; US EPA = United states Environmental Protection Agency; TSP = total suspended particulates; WHO = World Health Organization; $\mu g/m^3$ = micrograms per cubic meter; ppm = parts per million; - = no value

Notes:

(a) Not to be more than once per year

(b) The objective is attained when the annual arithmetic mean is less than or equal to $50\mu g/m^3$

(c) The objective is attained when the expected number of days per calendar year with a 24-hour average of $150\mu g/m^3$ is equal to or less than 1.

(d) The objective is attained when the expected number of days per calendar year with the maximum hourly average of 0.12 ppm is equal to or less than 1.

1.8. AQ information

An Air Quality Index (AQI) is a scale that indicates the quality of air, based on air pollutant monitoring data. It is an index for reporting air quality for a particular day. This is a simple way of describing the pollution level of a particular area or region that can easily be understood by the public. AQI tells you how clean or polluted the air you are breathing in relations to health based objectives.

The AQI focuses on short term health effects that can happen within a few hours or days after breathing polluted air. This index is based on measurements of the concentrations of five pollutants: particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and Ozone (O_3). Air quality standards have been developed for each of these. For each pollutant, a value of 100 is assigned to the maximum permitted concentration of that pollutant. After determining a value for each of the five pollutants, the highest of the five numbers is reported as the pollutant standards index for the day. A scale

devised by the U.S. Environmental Protection Agency (EPA) to provide a way for broadcasts and newspapers to report air quality on daily basis.

Bangladesh adopted an AQ index system to be used for raising the awareness of the public on the quality of air that they breathe. The AQ index for Bangladesh is primarily based on US EPA's system. Ideally, AQI should be made public on a daily manner, however, due to lack of infrastructure and equipment, DoE will initially present the three times a week (Islam 2003).

AQMP reviewed US EPA's AQI system and has recommended this for adoption in Dhaka with some modifications. The number of categories has been reduced from six to four to make the AQI simpler and easily understood. In addition, appropriate Bengali terms were used to describe the AQI categories (AQMP 2003). AQI categories are presented in Table 04.

Table 04: Proposed AQI for Bangladesh

AQI Range	Category	Colour
0-100	Good	Green
101 to 200	Unhealthy	Orange
201 to 300	Very Unhealthy	Purple
>301	Extremely Unhealthy	Red

Source: Air Quality Management Project (AQMP), 2003

An index for any given pollutant is its concentration expressed as a percentage of the relevant standard:

$$\text{Index} = \frac{\text{Pollutant Concentration}}{\text{Pollutant Standard or Goal}} \times 100$$

An index value greater than 100 means the pollutant has exceeded the relevant air quality standard. [Atmosphere – Adelaide's Current Air Quality, http://www.environment.sa.gov.au/reporting/atmosphere/airindex.html]

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1.8. Objectives:

- The objective of the study is to determine the concentrations of gaseous pollutants (NO_2, SO_2, CO, O_3) and particulate matters (SPM, PM_{10} & $PM_{2.5}$) to find out the variation of air pollutants in different locations of Dhaka city.

- The heavy metals Fe, As, Cd, Cu, Ag, Mn, Zn, Cr, Pb, Ni in PM_{10} & $PM_{2.5}$ is determined at different locations of Dhaka city.

- Volatile organic compounds (Benzene, Toluene, Chlorobenzene, Para-xylene, Ortho-xylene, Meta-xylene, Methoxy benzene, 1,2,4-trichlorobenzene) are detected in air of Dhaka city.

- A case study was undertaken at New Colony of Agargaon to observe morning to afternoon (6AM-2PM), afternoon to night (2PM-10PM) and night to morning (10PM – 6PM) variation of particulate matter and gaseous pollutants in a day and seasonal variation.

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CHAPTER – TWO

THEORETICAL ASPECTS

2. THEORETICAL ASPECTS

2.1. Method for detection of sulphur dioxide in air (Modified west and Gacke method, As recommended by CPCP, Govt. of India

2.1.1. Principle:

Sulphur dioxide from air is absorbed in a solution of potassium tetrachloro-mercurate (TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, is formed [84,85]. Once formed, this complex is stable to strong oxidants such as ozone and oxides of nitrogen and therefore, the absorber solution may be stored for some time prior to analysis. The complex is made to react with pararosaniline and formaldehyde to form the intensely colored pararosaniline methylsulphonic acid (86). The absorbance of the solution is measured by means of a suitable spectrophotometer (87-95).

Concentration of sulphur dioxide in the range of 25-1050 $\mu g/m^3$ can be measured under the conditions given are measure concentration below 25 µg/m3 by sampling larger volumes of air, but only if, the absorber efficiency of the particular system is first determined and found to be satisfactory. Higher concentration can be analyzed by using smaller gas samples of a suitable aliquot of the collected sampler. Beer's law is followed through the working range from .03 to 1.0 absorbance unit. This corresponds to 0.8-27µg of sulfite ion in 25 ml of final solution calculated as sulphur dioxide. The lower limit of detection of sulfhur dioxide in 10 ml absorbing reagent is 0.75 $\mu g/m^3$ based on twice the standard deviation, which represent a concentration of 25 $\mu g/m^3$ in a air sample of 30 litres.

2.1.2. Interferences

The Effects of the principal known interferences have been minimized or eliminated interferences by oxides of nitrogen are eliminated by sulphamic acid (86-88). Ozone is made to decompose by allowing the solution to stand for some time prior to analysis (89). The interference of trace materials may be eliminated by the addition ethylenediamine tetra acetic acid (EDTA) to the absorbing solution prior to sampling (87-89). At least 60 µg iron (III), 10 µg manganese (II), and 10 µg chromium (III) in 10 ml absorbing reagent can be

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tolerated in the procedure. NO significant interference was found from 10 μg copper (II) and 22 μg vanadium (V). Ammonium, sulphide, and aldehydes do not interfere.

2.2. Determination of nitrogen dioxide in the atmosphere (Jacob and Hochheiser method/sodium arsenic method, as recommended by CPCB, Govt. of India)

2.2.1. Principle:

2.2.1.1. Ambient nitrogen dioxide (NO_2) is collected by bubbling air through a solution of sodium hydrogen and sodium arsenite. The concentration of nitrite ion (NO_2) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acis, sulfanilamide and N-(1– naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the highly colored azo-dye at 540 nm.

2.2.1.2. The nominal range of the method is 9 to 750 μg NO2/m3 (0.005 to 0.4 ppm)[96]. The range of the analysis is 0.04 to 2.0 μg NO_2/ml, following Beer's Law throughout this range (0 to 1.0 absorbance units). Under the specified conditions of 50ml of absorbing reagent, a sampling rate of 200 cm^3/min for 24 hours, and a sampling efficiency of 0.82, the range of the method is, therefore, 9 to 420 μg NO_2/m^3 (0.005 to 0.22 ppm). Nitrogen dioxide concentrations in the range of 420 to 750 μg /m3 (0.22 to 0.4 ppm) are accurately measured by 1:1 dilution of the collected sample.

2.2.1.3. Based on results from a collaborative study, the within Laboratory standard deviation is 8 μg /m^3 (0.004 ppm) and the between laboratory standard deviation is 11 μg /m^3 (0.006 ppm) over the range of 50 to 300 μg NO_2/m^3 (0.027 to 1.16 ppm).

2.2.1.4. Based on results from a collaborative study, the method has as average bias of –3% over the range of 50 to 300 μg NO_2/m^3 (0.027 to 1.16 ppm).

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2.2.2. Interferences:

2.2.2.1. Nitric oxide (NO) is a positive interferant and carbon dioxide (CO_2) is a negative interferant. The average error resulting from normal ambient concentrations on NO and CO_2 is small for most monitoring situations and does not necessitate applying a correction to measurements obtained with the method.

2.2.2.2. Potential interference from sulfur dioxide (SO_2) is eliminated by converting any SO_2 to sulfate with hydrogen peroxide during analysis[84].

2.3. Methods for measurement of carbon monoxide (CO) by indicator tube method.

2.3.1 Principle (chart method): CO Detector Tubes the compound packed in the tube (yellow colour) is Potassium Palladium Sulphite ($K_2Pd\ SO_3$) which get oxidized to green colour. Oxidized compound by passing the air if CO is present in the air. Which one can match the colour intensity with colour matching chart and calculate the concentration. Which is depending upon the quantity of air passed.

2.3.2. Interferences: Hydrogen sulphide, unsaturated hydrocarbons, moisture etc, interfere but they may be removed by passing the sample through various absorbents provided with the indicator tubes.

2.3.3. Procedure: Follow the manufacturer's instruments carefully. Draw 250 ml of the sample at sample at the prescribed rate (40 to 50 ml/min) through the tube by the aspirator provided and calculate the concentrations [97].

2.4. Methods for measurement of Ozone (O_3):

2.4.1. Principle:

Micro amounts of ozone and other oxidants are collected by absorption in a solution of potassium iodide buffered to a pH of 6.8. The released iodine equivalent of the

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concentration of oxidant present in the air is determined spectrophotometrically by measuring the absorption of tri-iodide ion at 352nm.

2.4.2. Interferences:

The method is not specific for ozone science other oxidizing and reducing substances may interfere. Many oxidizing substances besides ozone will liberate iodine in this method. Nitrogen dioxide, chlorine, peroxy acids, hydroperoxides and peroxyacyl nitrates may also act as oxidants. Reducing gases such as sulphur dioxide and hydrogen sulphide act as negative interferences. Nitrogen dioxide is known to give 10 percent of the response of an equivalent molar concentration of ozone. Nitrogen dioxide occurs as a result of nitric ion formation in solution. The contribution of nitrogen dioxide to total oxidant may be estimated by concurrent analysis for nitrogen dioxide.

The interference from sulfur dioxide is serious. Up to a hundred fold ratio of sulfur dioxide to oxidant maybe eliminated by incorporating a chromic acid paper absorbent in the sampling train upstream from the bubbler (absorber).

2.5. Measurement of respirable suspended particulate matter (PM_{10}) in ambient air (Cyclonic flow technique)

2.5.1. Principle

Air is drawn through a size-selective inlet and through a 20.3 X 25.4 cm 98 X 10 inch) filter at a flow rate which is typically 1132 L/min. Particles with aerodynamic diameter less than the cut-point of the inlet are collected by the filter. The mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of PM_{10} in the designated size range is calculated by diving the weight gain of the filter by the volume of air sampled [98].

2.6. UV-visible spectrophotometer

2.6.1. Theory

When a molecule absorbs ultraviolet/visible light of a particular energy, it is assumed that a first approximation of only one electron is promoted to a higher energy level and that all other electrons are unaffected. The excited state thus produced is formed in a very short time (of the order of 10^{-15} s) and a consequence is that during electronic excitation the atoms of the molecule do not move.

The most probable ΔE transition would appear to involve the promotion of one electron from the highest occupied molecular orbital to the lowest available unfilled orbital, but in many cases several transitions can be observed, giving several absorption bands in the spectrum. Not all transitions from filled to unfilled orbitals are allowed, the symmetry relationship between the two orbitals being important, and where a transition is 'forbidden', the probability of that transition occurring is low, and correspondingly the intensity of the association absorption band is also low.

UV-visible spectrophotometer is consisting of a light source, double beams (reference and sample beams), a monochromator, a detector, and amplification and recording devices. The sources usually incorporates a tungsten filament lamp for wavelengths greater than 375 nm, a deuterium discharge lamp for values below that and a solenoid-operated mirror, which automatically defects light from either one as the machine scans through the wavelengths.

All UV-visible spectrophotometers are ratio recording; the ratio between reference beam and sample beam intensities (I_0/I) is fed to a pen recorder. The recorder trace is invariably absorbance (A) against wavelength (λ), and most instruments record linearly over the range 0-3 absorbance units.

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2.7. Atomic absorption spectrophotometer

2.7.1. Theory

Atomic absorption spectroscopy is based on the excitement of atoms. This is the term used to describe the situation when an atom is raised its ground state to a higher energy each electron occupying a different energy around the nucleus. There is a ground state, which represents the minimum energy level for an electron. If the atom absorbs energy, this cause excitement and electrons are raised temporarily to higher energy levels. The source of energy may be heat or light (photons). Several energy levels are possible, but unless the temperature is very high. The electrons further from the nucleus require the least of energy for the transition from E_o to E_1.

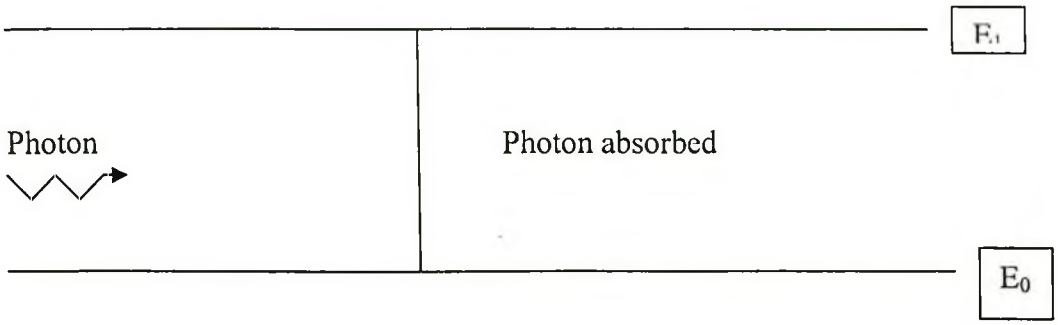
In particular, metallic and semi-metallic elements have outer electrons, which are loosely bound to the nucleus and require low energy to excite whereas other elements require very high energy for transition from E_o to E_1.

Therefore the range of elements, which can be studied by conventional atomic absorption spectrophotometer technique, is limited.

If too much energy is supplied, the electron may be raised to higher energy levels E_2, E_3 and a stage is reached at which the electrons break up completely and ionization occurs. Therefore enough energy must be supplied but not too much. For each of an element the energy gap (E_o - E_1), for a particular element is the some and unique to that element.
As mentioned above the energy sources can be heat of light. The light of an exact wavelength must be used to excite the atom of a specific element. This is the reason why the atomic absorption technique is so selective.

For atomic absorption, a flame forms a cloud of free atoms. Phone of a specific wavelength (dependent on the element being studied) are passed through the cloud and the cloud absorbs a proportion. The proportion absorbed is function of the concentration of the element in the cloud. It should be noted that as well the source photons passing through the

cloud; there will also be emission of photons on the same atoms in the flame work that these should be distinguished from the sources photons. The sources photons are produced as an alternation signal, whereas the emitted radiation is continuous signal.



Atomic absorption spectrometry is a generally accepted method for the analysis of many metals.[99] In a typical AAS method; sample is aspirated into a flame, where ions within the liquid are reduced to the atomic state. The metals in the atomic state can quantitatively absorb light at the wavelengths characteristic of their resonance frequency e.g. 217 & 283.3 nm for lead.[100] Alternatively, the ions may either be chemically reduced by a cold vapor technique or by thermally reduced in a graphite furnace before analysis. AAS method usually gives better sensitivities (as low as 50 μg/kg) than any other methods.

By this method several hundred samples can be analyzed within a working day by using as auto sampler if the samples are already prepared.

Atomic absorption spectrophotometer analysis has been used in the present study for the determination of heavy metals (Pb, Zn, Cu, Fe, Cd, As) in PM_{10} and $PM_{2.5}$.
Production of an aerosol from solution (nebulization)

- Removal of solvent MA (aq) ----------> MA (solid)
- Vaporization of samples MA (solid) ----------> MA (vapor)
- Atomization MA ----------> $M^{\bullet} + A^{\bullet}$
- Excitation $M^{\bullet}$ ----------> M^{*}
- Emission M^{*} ----------> $M^{\bullet}$

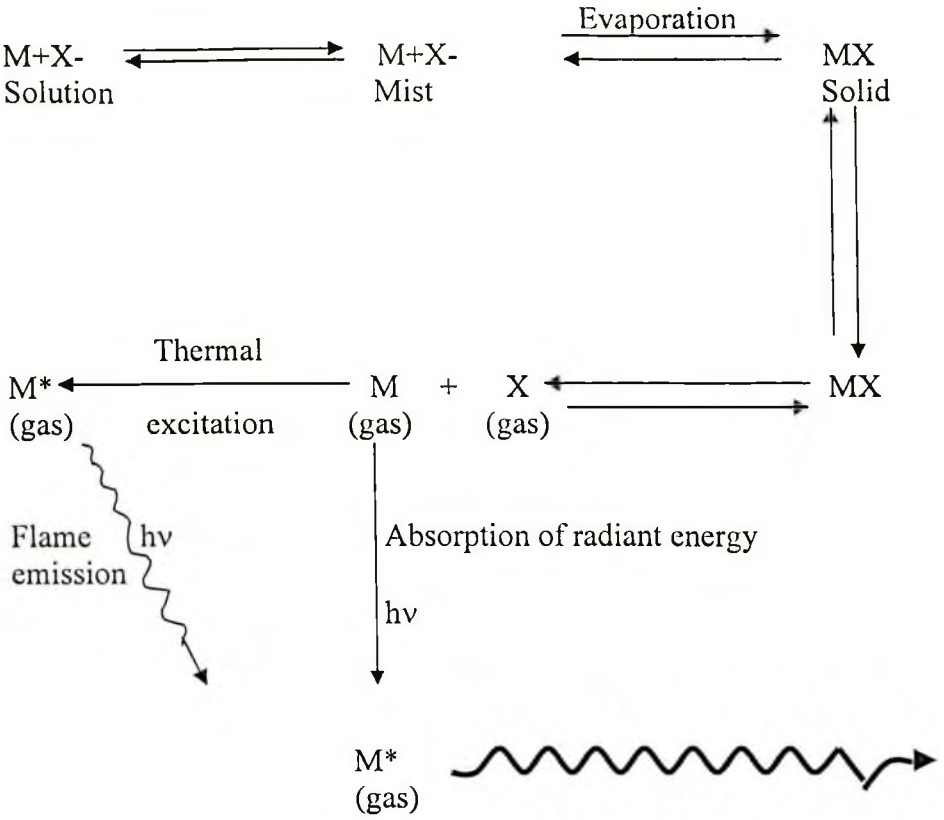


Figure 02: Schematic Diagram of AAS Principle.

2.7.2. Measurement of concentration

The proportion of source protons absorbed is proportional to the concentration is the flame of the element corresponding to that wavelength. This derived from lambert and Beer's law.

This may be written as follows

$$KL = \log I_0/I_t \text{ or } A = \log I_0/I_t$$

Where, k = absorption co-efficient

L = length of the absorbing cell

I_0 = incident light

I_t = transmitted light.

Beer's law is a development of this. If log I_0/I_t is an expression of absorbance and kL is proportional to the number of atoms in the cell, then absorbance is proportional to concentration. However, this is not always true. It is usually holds only for dilute solutions. So at low concentration, there is a linear relationship between absorbance and concentration but at higher concentration it is non-linear and large errors can be introduced. Therefore, for atomic absorption work, the best results are obtained from the range, often samples must be dilute. So that Beer's law is observed.

2.7.3. Interferences

Atomic absorption spectroscopy is a technique, which highly specific, with few problems of interference. Those, which do not occur, can be classified as either spectral or non-spectral.

2.7.3.1. Spectral interference

These occur when some of the light absorption is due to a species other than the element being studied. Since the instrument is highly sensitive, spectral inferences are rarely caused by the overlap of resonance lines. More common is background absorption due to undissociated molecules in the matrix material. This can be overcome by using a continuous source which is usually deuterium lamp positioned at right angle to the element lamp ray path. A mirror deflects this light from the deuterium lamp. So that it passes through the flame and can be detected by the photo multiplier. This light will not be absorbed by atomic absorption, but will be partly absorbed by background adsorption.

2.7.3.2. Non-spectral interference

There are two main types of interferences in this category chemical interference and ionization interference. Chemical interference occurs when the sample contains a component, which forms a thermally stable compound with the analyte element. This prevents complete atomization. An example of this in the measuring of calcium in the

presence of phosphate will not dissociate completely in air acetylene flame. As a result the concentration of phosphate increase and the absorption by calcium decreases. This can be overcome by either (1) Using a hotter flame (Nitrous oxides-acetylene) or by (2) Adding an excess of a releasing agent.

Ionization interference is associated with hotter flames of with more easily ionized elements, particularly the alkali metals and alkaline metals such as sodium, potassium, magnesium, magnesium and calcium. This effect can be overcome by an excess of an element, which is easily ionized; this suppresses the ionization of the analyte element. For example, if calcium is the analyte, potassium could be added to a concentration of 2000 mg/L to act as an ionization suppressant.

2.7.4. Instrumentation

There are five basic components of atomic absorption instrument are given below-

- The light sources, which emits the spectrum of interest
- An absorption cell which atoms of the sample are produced (Flame, Graphite furnace)
- A monochromator for light dispersion
- A detector, which measures the light intensity, amplifies the signal
- A display that shows the reading after it has been processed by the instrument electronics.

A schematic diagram showing the essential components for the absorption spectroscopy is given

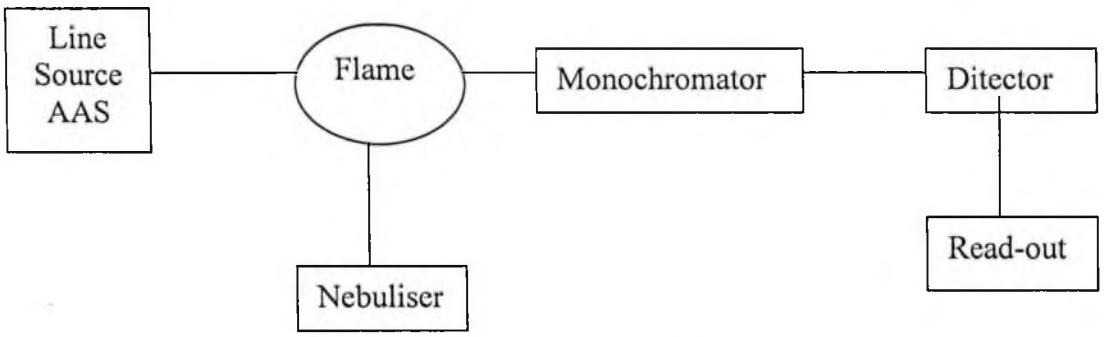


Fig 03: Schematic Diagram of Essential Components of AAS

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2.8. Application of beer's law in UV-visible absorption spectroscopy

Beer's law is the basic of all quantitative application of UV – Visible spectroscopy. Generally a method of calibration or standardization is used for determining the concentration of the analyte. Beer's law will generally hold over a wide range of concentration if the structure of the colored ion or the colored non-electrolyte in the dissolved state does not change with concentration. Small amounts of the electrolytes, which are chemically unreactive with the colored compound, do into usually affect the light absorption and may also change the value of the absorptivity.

Discrepancies are usually found when the colored solute ionize, dissociates or associate in solution. Since the nature of the species in solution will vary with the concentration. The law does not hold when the colored solute forms complexes the composition of which depends upon the concentration. Beer's law holds strictly for monochromatic radiation. But no instrument can attain such resolution of wavelength. A straight line passing through the origin indicates conformation to the law. The slope of the spectrum as the concentration is increased, with the result that the fractions of each wavelength observed may change, particularly if the instrument setting should drift over the period of the measurement. A negative deviation in the absorbance versus concentration plot will in these cases is observed. The greater is the slope of the spectrum the greater is the deviation.

This instrument is designed to measure each sources alternately. The element plus background absorb the analyte element ray, whereas the background only absorbs the deuterium ray. The instrument measures both and subtracts the deuterium reading from the analyte reading to give a corrected value.

(Element plus background) – (background) = Element absorbance

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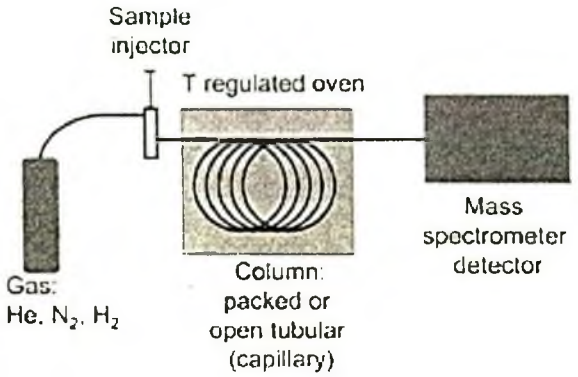
2.9. Gas chromatography- mass spectrometry (GC-MS)

2.9.1. Principle:

GC uses the same principle as the liquid chromatography used for ion analysis. The liquid extract is heated to about 250 °C so that it vaporizes. It is then injected into a mobile phase inert gas, usually helium, which is then fed into a capillary column. The column contains a stationary phase material which is selected depending upon the compounds in the sample to be analyzed. The stationary phase material attracts the compounds in the mobile phase gas at different rates. The capillary column is contained within an oven which can be set at various temperature stages to assist in compound separation. As temperatures increase, compounds with lower boiling points will exit the column faster. A detector at the end of the column measures the presence and amount of each compound. The time taken for a compound to travel through the column is known as the retention time. Retention times for various compounds are known and can be therefore used to identify compounds in the sample.

Following the GC process, the individual compounds can be analyzed using MS. MS uses mass to charge ratios to identify compounds. After leaving the GC, the compounds enter an electron ionized detector where they are bombarded with a stream of electrons causing them to break up. Positively charge ions are accelerated into an analyzing tube. The path of the ions is bent by an electrically generated magnetic field. Ions with high mass will hit the sides if the tube and will be vacuumed out of the tube. Similarly, ions with low mass will hit the other side of the tube and will be vacuumed out. Ions having the proper mass to charge ration will follow the path of the analyzer and will collide with a detector. By varying the magnetic field strength, the mass to charge ration that is measured will change. A spectrum plot of relative intensity against mass to charge ration is then constructed. These spectrums are specific to each compound. The data analyzer will normally contain a database of mass spectrums to allow for compound identification and quantification.

Gas Chromatograph



Mass Spectrometer

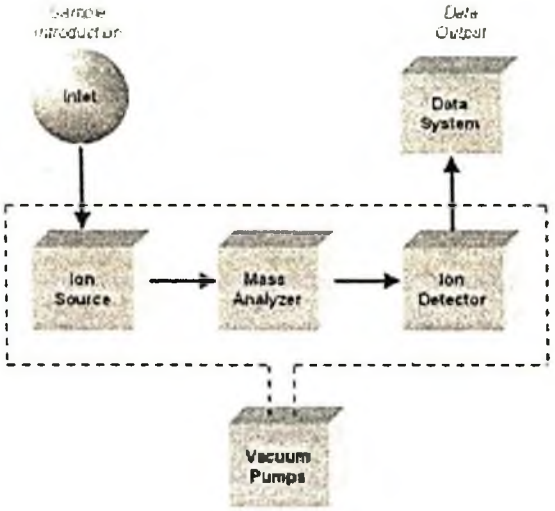


Figure 04: GC-MS schematic diagram.

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CHAPTER – THREE

EXPERIMENTAL

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3. EXPERIMENTAL

3.1. Reagents

3.1.1. Detection of trace elements

Concentrated nitric acid (HNO_3) 20% (100mL), v/v, Solid potassium chlorate ($KClO_3$) (0.5 g), concentrated hydrochloric acid (HCl) (20mL), 4% EDTA solution were used for the digestion of glass fiber filter paper. Dried lead nitrate (for Pb), ferric ammonium sulfate (for Fe), copper sulfate (for Cu), zinc sulfate (for Zn), cadmium chloride (for Cd), arsenic (III) oxide (for As), Ag, Ni, Cr, Mn, were used for the preparation of standard solution for metal detection.

3.2. Instruments

3.2.1. Air sampler

3.2.1.1. Respirable dust sampler

A respirable dust sampler of model Envirotech APM 460 NL was used for the measurement of coarse particle PM_{10}. It was also used for the measurement of non-respirable total particulate matter concentration (SPM) in ambient air (figure 05).

3.2.1.2. Fine particulate sampler

A fine Particulate Sampler of model Envirotech APM 550 was used for the measurement of fine particle PM2.5 concentration in ambient air (figure 06).

3.2.1.3. CO Sampler

An organic vapor sampler of model Envirotech APM 850 was used for the measurement of CO in ambient air (figure 07).

3.2.2. Filter paper

Whatman Glass Micro fiber filters (20.3cm x 25.4cm) (figure 09) and Millipore filters (figure 11) were used for PM_{10} and $PM_{2.5}$ respectively.

3.2.3. Electric balance

A four decimal OHAUS analytical balance, model AR 1140 was used.

3.2.4. UV-Visible recording double beam spectrophotometer

A Shimadzu UV visible model UV-160A was used for the measurement of SO_2, NO_2 and O_3 in air.

3.2.5. Atomic absorption spectrophotometer

A shimadzu flame emission spectrophotometer of model AA-680 was used for heavy metal analysis.

3.2.6. Oven

A BINDER heating oven was used for heating purpose on the digestion of filter paper.

3.2.7. Gas chromatography- mass spectrophotometer (GC-MS)

GC-MS of model Perkin Almer 6890N GC System and 5975 inert XL EI/CI MSD was used for identification of VOCs in ambient air of Dhaka city.

Figure 05: Respirable Dust sampler

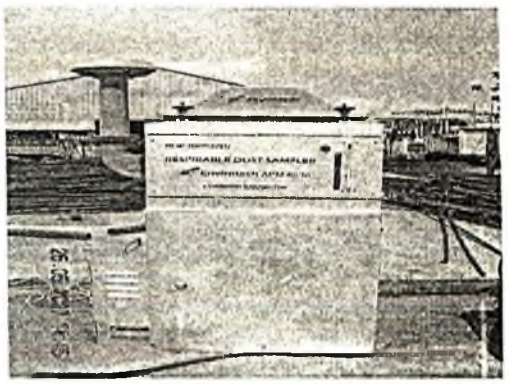

Figure 06: Fine particulate Sampler

Figure 07: Figure 10: CO sampler

Figure 08: Impingers

Figure 09: Blank filters for PM_{10}

Figure 10: Exposed filters for PM_{10}

Figure 11: Blank filters for $PM_{2.5}$

Figure 12: Exposed filters for $PM_{2.5}$

3.3.1. Sampling

Bangladesh is situated in the eastern part of south Asia. It is surrounded by India on the west, the north and the northeast, Myanmar on the southeast and the Bay of Bengal on the south (figure 13). Dhaka ($23'75^0$N, $90'38^0$E, 8m a.s.l.) is the capital of Bangladesh. It is also the center of commerce and industry of Bangladesh. Dhaka city is growing rapidly with all the problems of mega-city. Dhaka is situated in flat land surrounded by rivers (Figure). The sampling Locations were selected to reflect different influences from industrial and mobile sources in the highly populated center part of Dhaka. Sampling

instruments were set up on a light duty vehicle as pick-up (mini truck) for 8 hours at the every sampling location. The height of the sampling instrument is about 3 ft from the surface. People use both motorized and non-motorized vehicles for transportation. Sampling were done on the month of March, April , May 2005 at Jahangirnagar University, Tower Bhaban, Novarties Pharmaceuticals, Hazaribagh, Medinova Hospital, and on September, 2007 & January, 2008 at Uttara Model Model Towan and Hazaribagh respectively.

Figure 13: Map of Bangladesh

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3.3.2. Selection of sampling stations

In order to cover metropolitan area of the Dhaka city sampling stations were selected from among the industrial, commercial, residential, standard and heavy traffic areas of Dhaka to have an idea about the extent of air pollution. Heavy metals were determined at Sangsad Bhaban campus, Lalbagh, Tongi, Tejgaon. These locations are the total view of Dhaka city.

Table 05: Area and status of the sampling locations in Dhaka city

Name of the Sampling Stations	Area of the station	Status of the Station
Jahangirnagar University (JU) Campus,	Savar	Controlled Standard Area
Tower Bhaban,	Dhaka University (DU) Campus	Residential and Restricted Traffic Area
Novarties Pharmaceuticals	Tejgaon	Commercial, Industrial and Traffic area
BCLT, Hazaribagh	Hazaribagh	Tanneries, Residential area, Old city in Dhaka
Medinova Hospital	Dhanmondi	Residential/ Commercial
BCIC Bhaban	Motijheel	Commercial and Heavy Traffic area
Uttara Model Town	Uttara	Residential and traffic area

The eight hours air sampling was done in front of Mukarram Hossain Biggan Bhaban for the determination of volatile organic compounds (VOCs).

A case study was carried out in Agaorgoan New colony, Sher-e-Bangla Nagar, Dhaka. It is a residential government colony, about 1400 people is living in this colony. Heavy traffic road (Mirpur road) is about 100m of away from the colony. Agargaon New Colony is 5km away form the zero point of Dhaka city. There are high rise bulding in and around the New Conlony, but there is no industrial establishment within 1 (one) km radius. Sampling was carried out in January 2006, July 2006, November 2006 and August 2007 to find out the monthly variation of air pollutants between two years. The total sampling time was divided into three categories such as 6 AM to 2 PM, 2 PM to 10 PM and 10 PM to 6 AM in a day to observe the eight hour variation of air pollutants.

The locations of the sampling station are shown in the figure 17

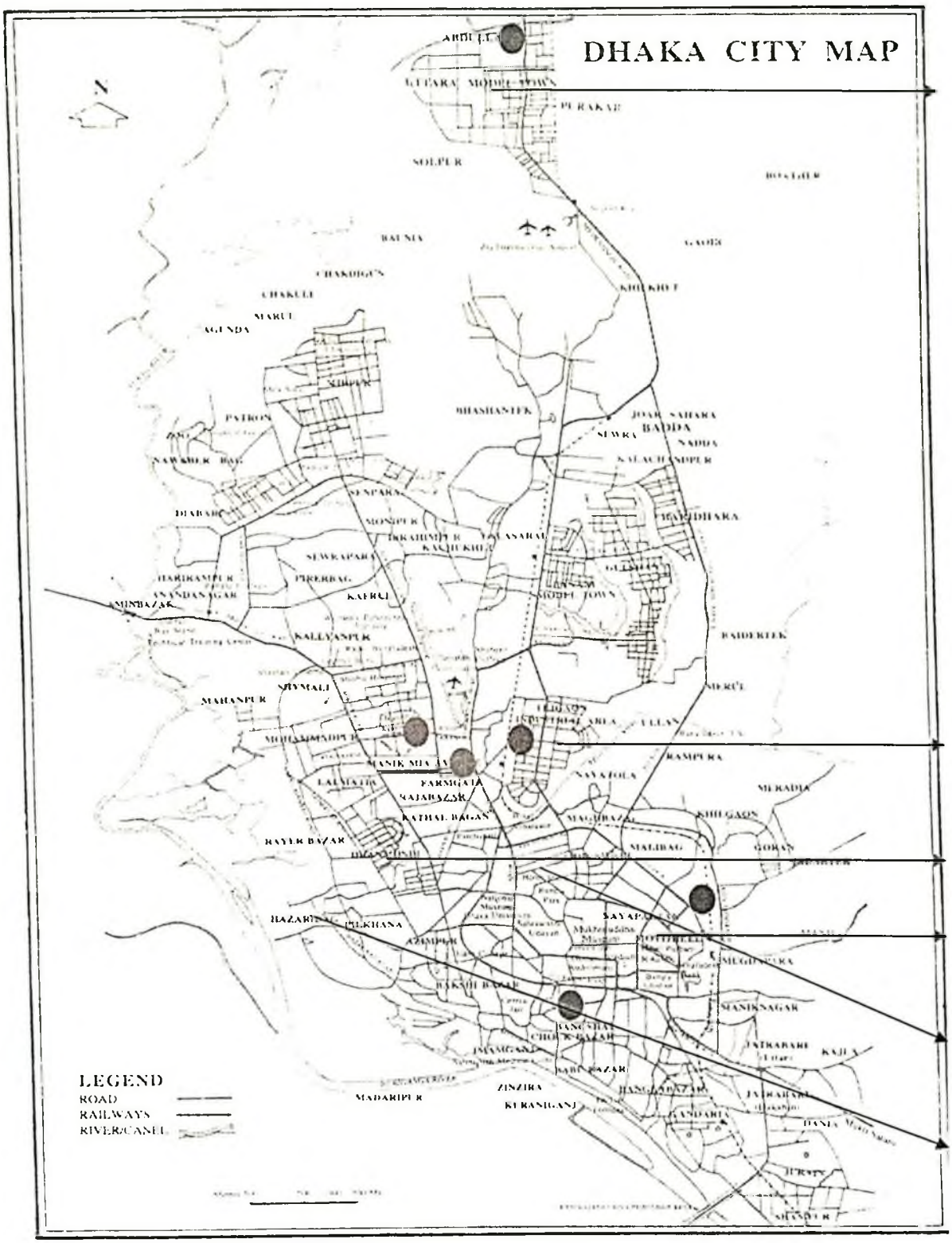

Figure 14: Sampling Locations in Dhaka Metropolitan Area

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3.3.4. Method of analysis

The aerosol masses of both coarse particle (PM_{10}) and fine particles ($PM_{2.5}$) were determined by the weighing (Gravimetric measurement) (after moisture equilibration at 22 degree temperature and 50% moisture) the filter papers before and after the exposure. For weighing, a four decimal OHAUS analytical balance, model AR 1140 was used.

The gaseous air pollutants (NO_2, SO_2, and O_3) were collected by passing the air through particular absorbent solutions in individual impinger at a constant flow rate (100 to 200 ml/min). The absorbent solutions finally analyzed and determined in UV-Visible Recording Double Beam Spectrophotometer (A Shimadzu UV visible model UV-160A). Individual wavelength was used as a UV source for NO_2, SO_2 and O_3. 560 nm wavelength passed through absorbent reagent for SO_2, 540 nm wavelength for NO_2 and 352 nm wavelength for O_3. The parameters SPM, SO_2 and NO_2 are expressed in microgram/m^3.
For the determination of CO, Envorotech Organic Vapour Sampler APM 850 is used and value is expressed in ppm. CO detector/indicator tube was connected to Teflon nozzle by silicon tube. A measured volume of air is passed at the flow rate of 100 to 200ml/min for 1 to 8 hrs and colour change (yellow to green) in indicating gel of detector tube is matched with the colour chart provided with detector tubes for finding out carbon monoxide (CO) concentration.

A known volume of air is passed through Activated Charcoal tube connected to Teflon nozzle by silicon tube with Envorotech Organic Vapour Sampler APM 850 at a constant flow rate (100 to 200 ml/min) with minimum pressure drop (10-15 mmHg). Volatile Organic Compounds (VOCs) was adsorbed on Activated Charcoal which was later desorbed/extracted using a suitable organic solvent. Extracted/desorbed solvent was used for quantifying the organic compounds with the help of GC-MS.
The heavy metals were also determined through Atomic Absorption Spectrophotometer (Shimadzu, Model: AA-680).

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3.4. Sample preparation for the analysis in $PM_{2.5}/PM_{10}$

3.4.1. Digestion procedure for glass micro fiber & millipore filter paper

The glass fiber filter (for $PM_{2.5}$)/millipore filter paper (for PM_{10}) was cut into small pieces and placed in a 150 mL squat beaker. Added 0.5 g solid potassium chlorate followed by 100 mL of 20% v/v HNO_3. Covered the beaker the beaker with a watch glass and simmer the contents for 15 min on a hot plate. Then moved the beaker to the edge of the hot plate after it has cooled somewhat and evaporated the liquid to dryness overnight. Cooled the beaker and contents and added 20.00 mL concentrated HCl. Warmed the beaker to about 80°C and added 80.0 mL of the 0.4% EDTA solution. Allowed the mixture to stand for 30 min and then stirred well with a glass rod. Elemental determination was made as described above. Acid, reagent, and filter paper blanks must be carried through the complete procedure.

3.4.2. Sample dissolution procedure

The beaker was removed from the hot plate and allows cooling. The mixture was filtered to a 10 mL volumetric flask and dilute to the mark with di-ionized water.

3.4.3. Blank solution preparation

One unexposed glass fiber filter paper was digested and prepared the blank solution by following the same procedure as an exposed filter.

3.5. Calibration curve for metal detection

3.5.1. Preparation of calibration curve for Lead (Pb) determination

1.598g of dried lead nitrate were taken in a 100 mL volumetric flask and dissolved with de-ionized water where nitric acid concentration was maintained at 0.10 M. 5, 10, 15, 20, 30 mL of lead nitrate solution was taken in each 100 mL volumetric flask and diluted up to the mark with di-ionized water. The prepared solutions were indicated 5, 10, 15, 20, and 30 ppm standard solutions respectively. Lead standard solutions of concentrations 5, 10, 15,

20 and 30 ppm were used as standard at the flame AAS. The wavelength was maintained at 283.3 nm.

3.5.2. Preparation of calibration curve for zinc (Zn) determination

0.0439g zinc sulphate was taken in 100 mL volumetric flask and dissolved with de-ionized water where nitric acid concentration was maintained at 0.10M. 0.1, 0.2, 0.3, 0.4 and 0.5 mL of zinc sulphate solution was taken in each 100mL volumetric flask and diluted up to the mark with de-ionized water. The prepared solutions were i8ndicated 0.1, 0.2, 0.3, 0.4 and 0.5 ppm standard solutions respectively. Zinc standard solutions of concentrations of 0.1, 0.2, 0.3, 0.4 and 0.5 ppm were used as standard at the flame AAS. The wavelength was maintained at 213.9 nm.

3.5.3. Preparation of calibration curve for copper (Cu) determination

Standard solution of 1000 ppm was supplied. 1 ml of this solution was taken in a 100 ml volumetric flask to prepare 10 ppm solution by adding deionized water up to the mark. Again 10ml of this solution was taken in a 100ml volumetric flask to prepare 1000 ppb Cu solution. Then 0.3 ml, 0.6 ml, 0.9 ml and 1.2 ml had been taken from1000 ppb solution in five 100 ml volumetric flask to prepare 3 ppb, 6 ppb, 9ppb and 12 ppb solution. Copper standard solutions of concentrations of 3 ppb, 6ppb, 9 ppb and 12 ppb were used as standard at the flame AAS. The wavelength was maintained at 285 nm.

3.5.4. Preparation of calibration curve for iron (Fe) determination

5 mL of standard iron solution (1000ppm) was poured in a 50 mL volumetric flask and diluted it up to the mark. Concentration of the resulting solution was 100 ppm. Then 0.5, 1, 2, 4, and 6 mL of the solutions were poured to number of 100 mL volumetric flask and diluted with de-ionized water up to the mark. Concentrations of the resulting solutions were 0.5, 1, 2, 3, 4 and 6 ppm. Iron standard solutions of concentrations of 0.5, 1, 2, 4 and 6 ppm were used as standard at the flame AAS. The wavelength was maintained at 248.3 nm.

3.5.5. Preparation of calibration curve for arsenic (As) determination

Arsenic standard solution of 1000 ppm was supplied. 1.0 mL from 1000 ppm standard arsenic solution was taken in 100 mL volumetric flask to prepare 10 ppm solution with de-ionized water. Again 10 mL from 10 ppm was pipetted in 100 100 mL volumetric flask to prepare 1000 ppb solution. Then 0.1 mL, 0.2 mL, 0.3mL, 0.4 mL and 0.5 mL had been taken from 1000 ppb solution in five 100 mL volumetric flasks to prepare 1 ppb, 2ppb, 3ppb, 4ppb, and 5ppb solution. Then 2.0 mL conc. HCl (35-37%) and 2.0g KI were added in each solution and then made up to the mark with de-ionized water. The solutions were left for two hours. Arsenic standard solutions of concentrations of 1, 2, 3, 4 and 5 ppb were used as standard at the flame AAS. The wavelength was maintained at 193.7 nm.

3.5.6. Preparation of calibration curve for cadmium determination

0.1791g Cadmium Chloride was taken in 100 mL volumetric flask and dissolved with de-ionized water. 0.2, 0.4, 0.6, 0.8 and 1.0 mL of Cadmium Chloride solution was taken in each 100 mL volumetric flask and diluted up to the mark with de-ionized water. The prepared solutions were indicated 0.2, 0.4, 0.6, 0.8 and 1.0 ppm standard solutions, respectively. Cadmium standard solutions of concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 ppm were used as standard at the flame AAS. The wavelength was maintained at 288.8 nm.

3.5.7. Preparation of calibration curve for nickel determination

5 ml of standard nickel solution (1000 ppm) was poured in 50 ml volumetric flask and diluted it up to the mark. Concentration of the resulting solution was 100 ppm. Then 0.5, 1.5, 3 and 6ml of the solutions were pored in a number of 100 ml volumetric flask and diluted with de-ionized water up to the mark. Concentrations of the resulting solutions were 0.5, 1.5, 3 and 6 ppm. This nickel standard solution of concentrations 0.5, 1.5, 3.0 and 6.0 ppm were used as standard at the flame AAS. The wavelength was maintained at 232.0 nm.

3.5.8. Preparation of calibration curve for manganese determination

0.5036g $MnSO_4.7H_2O$ was taken in100 ml volumetric flask and dissolved with de-ionized water where nitric acid concentration was maintained at 0.10 M. The strength of the resulting solution is 1000 ppm. 1.0 mL of this solution was taken in a 100 mL volumetric

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flask and made up to the mark. The strength of the resulting solution is 10 ppm. From this solution 0.5, 1.0, 2.5, 5.0, 1.0 and 20 mL of Manganese sulphate solution was taken in each 100 mL volumetric flask and diluted up to the mark with de-ionized water. The prepared solutions were indicated 0.05, 0.1, 0.25, 0.5, 1.0 and 2.0 ppm standard solutions respectively.

3.6. Analysis of gaseous pollutants

3.6.1. Analysis of SO_2:

Step – 1 : Preparation of reagents

A) For sampling

1) Absorbing reagent (TCM, 0.04) – Dissolved 10.86 gm mercuric chloride + 0.066 gm EDTD = 6.0 gm potassium chloride in 1000 ml distilled / deionized water
Caution: - Highly poisonous if spilled on skin, flush off water immediately

B) For analysis

1) Sulphamic Acid (0.6%) :- Dissolved 0.6 gm Sulphamic Acid in 100 ml distilled water.
2) Formaldehyde Solution (0.2%) :- Taken 1.25 ml Formaldehyde solution (36-38%) and diluted to 250ml with distilled / deionized water.
3) Pararosaniline Solution (PRA)

i) Stock PRA Solution : Dissolved 0.5 gm of Specially purified pararosaniline in 100 ml of distilled deionized water and kept to dissolve for 48 hrs.
Note :- Prepare PRA solution 2 days before analysis

ii) Working PRA Solution : Mixed 10 ml of Stock PRA Solution from 3(i) + 15 ml Concentration HCl $\longrightarrow$ made up to 250 ml with deionized water.

C) For preparation of calibration curve

1) Stock iodine solution (0.1N)

Mixed 1.27 gm Iodine + 4.0 gm potassium Iodide + 25 ml deionized water + stirred until all is dissolved make up to 100 ml with deionized water.

2) Working iodine solution (0.01N)

50 ml of stock Iodine Solution from C (i) and made up to 500 ml distilled water

Note: Stare in ambered glass bottle

Note :- Prepare Stock Sodium Thiosulpahte Solution 1 (one) before standardization.

3) Starch indicator

Mixed 040 gm solution starch + 0.002 gm Mercuric Iodide in a little water make a paste + 200 ml distilled water continue boiling untill the clear solution.

4) Primary standard potassium iodate solution :

Dissolved 1.5 gm Potassium Iodate (Oven dried at 180oC) & makeup to 500 ml deionized water.

Note: Prepare freshly

5) Stock sodium thiosulphate solution (01N)

Dissolved 6.25 gm sodium metabisulphite in 250 boiled & cooled deionized water.

1 ml = 320 – 400 µg SO2

Find actual Concentration after Standardization

Step – II : - Standardization

Standardization of Sodium Thiosulphate Solution

- Taken 50 ml of Potassium Iodate Sodium in 250 ml Iodine Flask
- Added 2.0 gm Potassium Iodide & 10 ml of (1:10) HCl
- Put Stopper on the flask and allowed to react for 5.0 min
- Titrated with stock sodium thiosulphate solution to a pale yellow colour
- Added 2 -5 ml starch indicator, it shall give blue colour
- Continued titration up to disappearance of blue colour
- Calculated the normality as follows :-

$$N = \frac{W \times 10^3 \times 0.1}{V \times 35.67} \qquad \text{or } N = \frac{2.8 \times W}{V}$$

Where,

W = Weight of Potassium Iodate, gm (Primary Standard)

V = Vol. of Sodium Thiosulpahte solution consumed (ml)

35.67 = Equivalent Wt. of Potassium Iodate

N = Normality of Sodiaum Thiosulphate

$$N = \frac{1.6 \times 103 \times 0.1}{41.2 \times 35.67} \quad \text{or} \quad N = \frac{2.8 \times \text{----------}}{\text{.....}}$$

N = 0.102 N

2. Working sodium thiosulpahte solution (0.01 N)

Calculated the required volume time of stock sodium Thiosulpahte solution to prepare a required volume of working sodium thisulpahte solution by using the following formula.

Formula

$N_1V_1 = N_2V_2$

Where

N_1 = Normality of Stock Sod. Thiosulpahte Solution Normality (N) (0.102N)

V_1 = ?

N_2 = Normality of working Sod. thiosulpahte solution (0.01 N)

V_2 = Required volume of working Sod. Thiosulpahte solution (250 ml)

$$V_1 = \frac{0.01 \times 250}{0.102} = 24.5\text{ml}$$

Taken 24.5 ml of stock sodium thiosulphate solution ⟶ make up to 250 ml with freshly boiled & cooled Distilled Water.

(3) Determination of sulphite solution strength

(1)	(2)
Iodine Flask – A (Blank)	Iodine Flask – B (Sample)
↓	↓
Pipette 50 ml of 0.01 N Iodine Solution	Pipette 50 ml of 0.01 N Iodine Solution
↓	↓
Add 25.0 ml D. Water	Add 25.0 ml stock Sulpite solution (C – 6)

↓

Stopper the flask and allow to react for 5.0 mins

Titrate each flask in turn to a pale yellow with standard sodium thiosulpahte solution (0.0N)

Add 5.0 ml starch solution to each flask (it shall blue colour)

Note the blank and sample solution consumed in 0.01N note the volume sodium thiosulpahte solution consumed for blank sampled.

Blank Iodine Flask 36.9 (V_1)

Sample Iodine Flask 7.5 (V_2)

Strength Calculation of Stack Sulphite Solution

$$C = \frac{(V_1 - V_2) \text{ X N X K}}{V}$$

Where,

C = Concentration of SO_2 (µg/ml)

V_1 = Volume of sodium thiosulpahte solution (0.01N) consumed for Blank (ml)

V_2 = Volume of sodium thiosulpahte solution (0.01N) consumed for sample (ml)

N = Normality of sodium thiosulphate solution

K = 32000 miliequivalent Wt. of SO2/µg

V = Volume of Sulphite Solutions (25ml)

$$C = \frac{(39.39 - 7.5) \times 0.01 \times 32000}{25} = 414.72 \text{ µg/ml}$$

(4) Working sulphite solution (For SO_2 calibration Curve)

Take 2.0 ml Stock Sulphite Solution (C µg SO2 /ml) makeup to 100 ml with TCM 0.04 Absorbing Reagent

(a) Calculate strength of working sulphite solution

$$= \frac{C \text{ X } 2}{100} = CW \text{ µg } SO_2/ml$$

= 414.72 x 2/100 = 8.29 µg SO2/ml

1 ml of This solution = 8.29 µg of SO_2

Note:- This solution is stable for 30 days if keep in the refrigerator at 5oC

STEP – III

Preparation of SO_2 calibration curve

	(1)	(2)	(3)	(4)	(5)	(6)
1. Volumatric Flask (25ml) →	Blank					
2. Working Sulphite Solution → (1 ml = CW (8.29) µg SO2)	0.0ml	0.5ml	1ml	2ml	3ml	4ml
3. Absorbing Reagent (0.04 MTCM) →	10ml	9.5ml	9ml	8ml	7ml	6ml
4. Sulphamic Acid (0.6%) →	1ml	1ml	1ml	1ml	1ml	1ml
5. Farmaldehyde Solution (0.2%) →	2ml	2ml	2ml	2ml	2ml	2ml
6. Working PRA Solution →	2ml	2ml	2ml	2ml	2ml	2ml

↓

Make up to 25.0 ml with distilled water to each volumetric flask

↓

Note :- Mixed thoroughly after addition of each reagent

↓

Measure the absorbance at 560 nm wavelength after 30 min. but before 60.0 min against blank reagent by using spectrophotometer.

7. Absorbance →	0	0.039	0.068	0.133	0.202	0.257
8. Concentration (SO_2 µg in 25 ml) →	0.0 ml	4.15 ml	8.29 ml	16.0 ml	24.87. ml	33.16 ml

9. Plot absorbance versus concentration (calibration curve) on graph paper.

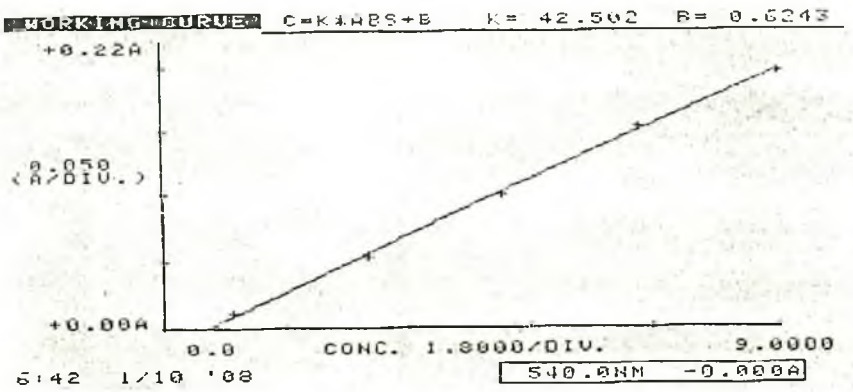

Figure 15: Calibration curve for SO_2

STEP -IV

Chemical analysis (SO_2) of sample

	(1)	(2)
1. Volumatric Flask (25ml) →	Blank	Sample
	+	+
2. Exposed Sample	0.0	10.0ml
	+	+
3. Absorbing Reagent (0.04 MTCM) →	10.ml	0.0ml
	+	+
4. Sulphamic Acid (0.6%) →	1.0ml	1.0ml
	+	+

Allow to stand for 10 min to distroy the Nitrite resulting for Oxide of Nitrogen

	+	+
5. Farmaldehyde Solution (0.2%) →	2.0ml	2.0ml
	+	+
6. Working PRA Solution →	2.0ml	2.0ml

+

Makeup to 25.0 ml with distilled water

+

Note:- Mixed thoroughly after addition of each reagent

+

Measure the absorbance at 560 nm against the blank reagent by using

spectrophotometer. After 30 min. but before 60 min

7. Absorbance ⟶	0.00	0.012
8. Curve value concentration (for µg SO_2 µg in 25 ml (C)	0.00	0.6857

(a) Total Volume of air Passed through SO_2 impingers - (lit) ---------- (V)

V (lit) = Avg. Flowrate (lpm) (Initial flow + Final follow /2) X Time (min)

V = 0.75 (1.0+0.5/2) X 492 min = 369 lit

$$\textbf{(b) } SO_2 \textbf{ concentration (µg/m3)} = \frac{C \times A \times 1000 \times D}{V \times B}$$

Where,

C = SO_2 Curve Value (µg in 25 ml)

A = Absorbing reagent Taken for Sampling (ml)

V = Volume of air Passed (lit)

B = Volume taken for sampling analysis (ml)

1000 = Conversion factor liter to m3

D = dilution factor

SO_2 (µg/m^3) =

3.6.2. Analysis of NO_2

Step – I Preparation of reagent

A) For sampling

1) Absorbing Reagent:-

Dissolved 4.0 gm Sodium Hydroxide + 1.0 gm Sodium Arsenite in 1000 ml deionized/distilled water.

Caution: Arsenic Compound are highly toxic Avoid contact with skin and especially with eyes. Wash hands after handling it, do not take internally

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B) For analysis

1) Hydrogen peroxide solution:- (0.02%)

- Dilute 0.2 ml of 30% H2O2 makeup to 250 ml Deionized Water.

Note:- Stable for one month if refrigerated and protect from light.

2) Sulphanilamide solution:-

- Dissolved 5.0 gm Sulphanilamide in 15 ml Deionized Water and add 12.5 ml Orthophospharic Acid (85%) makeup to 250 ml Deionized Water.

Note:- Store for one month

3) NEDA solution :-

- Dissolve 0.1 gm NEDA into 100 ml of Distilled Water and add 12.5 ml Orthophospharic Acid (85%) makeup to 250 ml Deionized Water.

C) For calibration curve

1) Stock sodium nitrite solution

- Dissolve 0.38265 gm of desiccated Sodium Nitrite into 250 Deionized Water.

- Amount of $NaNO_2$ (gm) (in one lit) = $\frac{\text{Gravimetric Conversion factor (1.5) x 100}}{\text{Assay Purity (\%)}}$

= 1.5 X 100/99 = 0.378 gm

Note:- This Soln. 1 ml = 1000 µg NO_2

Note:- This solution can be stored for six week if refrigerated

2) Working nitrite solution:-

a) Solution 'A' :-

- Dilute 5.0 ml of stock Nitrite Solution (1000 µg NO_2/ml) to 500ml with Deionized Water.
- This Solution 1 ml = 10 µg NO_2

b) Solution 'B' :-

- Dilute 25ml of solution 'A' (10 µg/NO_2) to 250 ml absorbing Reagent.
- This Solution 1 ml = 1 µg NO_2

Note : Prepare fresh daily

This solution used for NO_2 calibration curve preperation.

Step - II

Preparation of calibration curve (NO_2)

		1	2	3	4	5	6
1	Volumatric Flask (50ml) →						
		+	+	+	+	+	+
2	Sodium Nitrite Solution 'B' (1ml =1 µg NO2) →	0.0ml	1.0ml	3.0ml	5.0ml	7.0ml	9.0ml
		+	+	+	+	+	+
3	Absorbing Reagent →	10.ml	9.0ml	7.0ml	5.0ml	3.0ml	1.0ml
		+	+	+	+	+	+
4	Hydrogen Peroxide Solution →	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml	1.0ml
		+	+	+	+	+	+
5	Sulphanilamide Solution →	10.0ml	10.0ml	10.0ml	10.0ml	10.0ml	10.0ml
		+	+	+	+	+	+
6	NEDA Solution →	1.4ml	1.4ml	1.4ml	1.4ml	1.4ml	1.4ml

↓

Makeup to 50 ml with Deionized Water to each volumetric falsk

↓

Note:- Mixed thoroughly after reagent addition

↓

measure the absorbance at 540 nm wave length after 10 min against the blank reagent by using spectrophotometer

7	Absorbance	0.00	0.011	0.054	0.100	0.154	0.196
8	Concentration (NO_2 µg in 50ml)	0.00	1.0	3.0	5.0	7.0	9.0

9. Plot absorbance verses concentration (calibration curve on graph paper)

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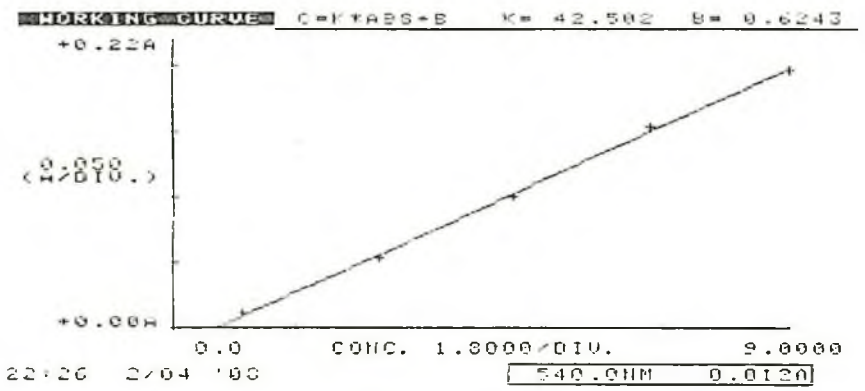

Figure 16: Calibration curve for NO_2

Step - III Chemical analysis of sample

- Replace any water lost by evaporation during by adding Deionized Water & mix thoroughly

1	Volumatric Flask (50ml)	1 Blank	2 (Sample)
		+	+
2	Sodium Nitrite Solution 'B' (1ml =1 µg NO2)	0ml	10ml
		+	+
3	Absorbing Reagent	10ml	0ml
		+	+
4	Hydrogen Peroxide Solution	1ml	1ml
		+	+
5	Sulphanilamide Solution	10ml	10ml
		+	+
6	NEDA Solution	1.4ml	1.4ml

Makeup to 50 ml with Distilled Water to each volumetric falsk

+

Mixed thorougly after addition of each reagent

+

Measure the absorbance at 540 nm after 10 min against the blank reagent by using Spectrophotometer.

7 Absorbance

8 Concentration for NOx Calibration curve (graph paper) µg in 50ml

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Step – IV : Calibration

a) Total Volume of air passed through NOx impinger = ----------lit ---------- (V)

V = Avg. flow rate (lpm) [initial flow + final flow/2] X Time (min.)

V = 1.2 (1.0 + 1.4/2) X 492 min = 590.4 lit

b) NOx Concentration ($\mu g/m^3$) = $\frac{C \times A \times 1000 \times D}{V \times B \times 0.82}$

Where,

C = NO_2 Curve value (μgNO_2 in 50 ml)

A = Sample taken for sampling (ml)

1000 = Conversion factor from litre to m^3

V = Volume of air passed (litre)

B = Sample volume taken for analysis (ml)

0.82 = Absorbing efficiency of this method

D = Dilution factor

NOx ($\mu g/m^3$) =

3.6.3. Analytical procedure for ozone (O_3)

1) Removal of SO_2

Glass Fiber Filter is impregnated with chromium Trioxide as follows

a) Cut Glass Fiber filter 200 cm^2

b) Take 1.25 gm Chromium Trioxide + 0.35 Conc. H_2SO_4 + 7.5 ml aqueous solution ‹ dropwise over 200cm^2 of () so that visually the solution is uniformaly dispersed on the filter paper. Dry in an oven at 80-90 0C for 1 hrs. Cut the paper into 6 x 12 mm strips each.

2) Absorbing reagent

Dissolve 14 gm KH_2PO_4 + 14.20 gm Na_2HPO_4 + 10 gm KI → makeup to 1000 ml deionized Water.

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3) Standard iodine solution (0.05N)

16 gm KI + 3.173 gm Iodine → make up to 500 ml Deionized Water

4) Working iodine solution (0.0025N)

Take 5.0 ml of 0.05 N I_2 solution and male up to 100 ml with Absorbing Reagent.

5) Working I_2 solution (0.0001N)

Take 5.0 ml of 0.0025 N I_2 Solution and male up to 100 ml Absorbing Reagent.

[1ml = 1 µl of O_3]

6) Calibration curve for ozone

1. Flask (10ml) →	1	2	3	4	5	6
2. 0.0001N I_2 Soln. →	0.0ml	0.1ml	0.2ml	0.5ml	1.0ml	2.0ml
3. Absorbing Reagent →	10.0ml	9.9ml	9.8ml	9.5ml	9ml	8.0ml

↓

Total Value of Solution in 10ml

↓

Mixing & Immediately read the absorbing at 352 nm

4. Absorbance	0.00	0.008	0.017	0.070	0.142	0.284
5. Concentration(in µl/25ml)	0	0.1	0.2	0.5	1	2

6. Plot absorbance versus concentration (calibration curve on graph paper

7. Analysis

Replace any water loses by evaporation during sampling by Deionized Water into initial volume & shakes it. Read Absorbance at 352 nm of Spectrophotometer.

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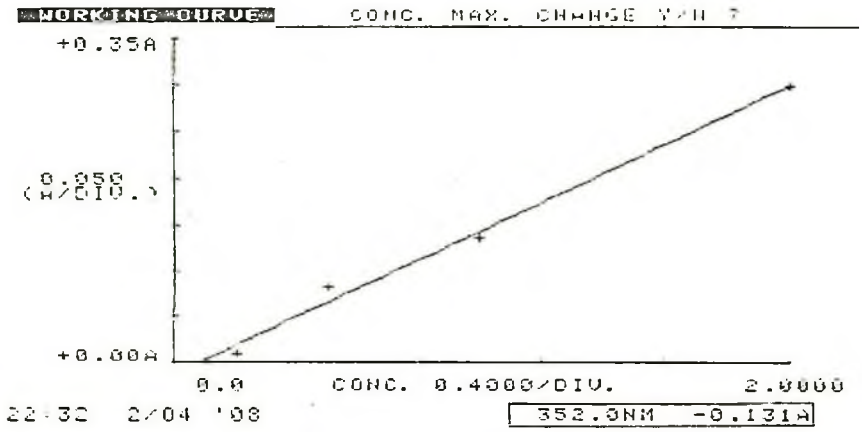

Figure 17: Calibration curve for O_3

3.6.3.1. Chemical analysis of ozone

Any water loses evaporation during sampling was replaced by de-ionized water and mixed thoroughly. The absorbance was measured at 352 nm against the blank reagent by using Spectrophotometer. From the Calibration curve, concentration of O_3 in the absorbing reagent was measured. Then the concentration of O_3 in the air was measured by using the following calculation.

3.6.3.2. Calculation

a) Total volume of Air passed through O_3 impinger = Average flow rate (lpm) X Time (min)

b) O_3 concentration in ppm $= \dfrac{C \times A \times M}{V \times B}$

Where,

C = Concentration for O_3/10ml

A = Sample taken for sampling (ml)

M= 9.6 as per method

V = Volume of air passed (litre)

B = Sample volume taken for analysis (ml)

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c) O_3 concentration ($\mu g/m^3$) = $\frac{O_3 \text{ concentration in ppm X } 48 \text{ X } 1000}{24.47}$

3.6.4. Analysis of CO

3.6.4. 1. Preparation for the analysis of CO

The CO was analyzed by Indicator tube method. The manufacture's instruments were followed carefully. The air was passed through the tube by aspirator provided. After the sampling, the color of the fixed portion of the tube was matched with the given chart value and then concentration was calculated as follows.

Total volume of Air passed through O_3 impinger = Average flow rate (lpm) X Time (min)

CO concentration ($\mu g/m^3$) = $\frac{\text{Chart Value of 1 Squeeze X } 0.75 \text{ X } 10^6}{F}$

Where,

0.75 = Factor, Density of CO

10^6 = conversion liter to m3 and mg to µg

F = Total volume of air passed (lit) through indicator tube.

3.7. Method for determination of PM_{10}, $PM_{2.5}$ and SPM

The aerosol massed for both the $PM_{2.5}$ and PM_{10} were determined by weighing the filters before and after the exposure with OHAUS analytical balance, model no. AR1140.

Particles larger than PM_{10} was determined from initial and final weight of the dust cup vial using the same balance.

Air is drawn through a size-selective inlet and through a 20.3 X 25.4 cm (8 10 inch) filter at a flow rate which is typically 1.15 to 1.20 m^3/min for PM_{10}. Particles with aerodynamic diameter less than the cut point of the inlet are collected by the filter. The mass of these particles particles is determined by the difference in filter weights prior to and after sampling. The concentration of PM10 in the designated size range is calculated by diving the weight gain of the filter by the volume of air sampled.

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3.7.1. Calculation of PM_{10}, $PM_{2.5}$ and SPM

$$PM_{10}\ (\mu g/m3) = \frac{(W_f - Wi) \times 10^6}{V}$$

Where,

PM_{10} = Mass concentration of particulate matter less than 10 micron diameter in $\mu g/m^3$

Wi = Initial weight of filter in gm

W_f = Final weight of filter in gm

V = Volume of air sample in m^3

10^6 = Conversion of gm to μg

Same formula was used for the determination of particle larger than PM_{10}. TSP was calculated from the addition of result PM_{10} and particle larger than PM_{10} which was collected in dust cup vial.

For $PM_{2.5}$ the total volume of air was calculated from the initial and final dry gas meter reading (m^3). Some formula was used for the determination of $PM_{2.5}$.

3.8. Analysis of volatile organic compounds (VOCs)

3.8.1. Sample preparation for VOCs

Active charcoal and other reagent were obtained from Merck, Germany.

The air samples were adsorbed by drawing air through active charcoal tube at a flow rate of 1-2 $Lmin^{-1}$ and then extracting these with dichloromethane (CH_2Cl_2) (10 ml) for 2 min. When all activated charcoal is transferred, the bulk containing DCM and a activated charcoal was shaken for 30minites. Extracted solvent was filtered after desorption by using 25 mm dia glass filter. 1-5 aliquot samples were injected into the GC-MS. The GC-MS operational conditions were given below:

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3.8.2. Instrument control parameters: JAS GC-MS

D:\MSDCHEM\METHODS\OPCW1

Control Information
Sample Inlet : GC
Injection Source : GC ALS
Mass Spectrometer : Enabled

.....6

890 GC METHOD

.....

OVEN
Initial temp: 40 ^{0}C (On) Maximum temp: 325 ^{0}C
Initial time : 2.00 min Equilibration time: 0.50 min
Ramps:

#	Rate	Final temp	Final time
1	10.00	280	6.00
2	0.0 (off)		

Post temp: 0 ^{0}C
Post time : 0.00 min

FRONT INLET (SPLIT/SPLITLESS) BACK INLET (UNKNOWN)
Mode: Split
Initial temp: 280 ^{0}C (On)
Pressure: 5.97 psi (On)
Split ratio: 2:1
Split flow: 1.8 ml/min
Total flow: 6.0 ml/min
Gas saver: On
Saver flow: 20.0 ml/min
Saver time: 3.00 min
Gas type: Helium

COLUMN 1
Capillary Column
Model Number: Agilent 19031s – 433
HP – SMS 5% phenyl methyl siloxane
Max temperature: 325 ^{0}C
Nominal length: 30.0 m
Nominal diameter: 250.00μm
Nominal film thickness: 0.25 μm
Mode: constant flow
Initial flow: 0.9 ml/min
Nominal init pressure: 5.98 psi
Average velocity: 34 cm/sec
Inlet: Front Inlet
Outlet: MSD
Outlet pressure: vacuum

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CHAPTER – FOUR

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1. Total suspended particulate matter (SPM)

The average concentration of total suspended particulate matter in Dhaka city ambient air is 311.05μg/m^3 (table 06), which is higher than the Bangladesh national air quality standard of 200μg/m^3 and the daily average given by WHO. PM_{10} is about 36% and $PM_{2.5}$ is about 20% of SPM mass concentration. The SPM concentrations are varying from 126.20μg/m^3 at Jahangirnagar University (JU) campus, Savar, to 636.39μg/m^3 at Uttara Model town, Uttara. The concentrations of SPM in Dhaka city air has shown in figure 18.

The cause of higher value of SPM in Dhaka city air is due to incomplete combustion of fossil fuel of vehicles included car, jeep, bus, truck, minibus, mini-truck, human holler, microbus, four stroke engine driven vehicles (auto-rickshaw, CNG, etc) and motorbikes (they emit more $PM_{2.5}$ than others). Railway engines, industrial plants, power plant, brick fields (in dry winter season), open burning incineration, solid waste disposal sites, road side dust particles, road diggings, construction and other development activities are also contributing value of SPM in Dhaka.

4.2. Particulate matters (PM_{10} & $PM_{2.5}$)

The average concentrations for PM_{10} and $PM_{2.5}$ are 112.57 and 63.56μg/m^3 respectively. These values are not much higher than the Bangladesh national air quality standard for PM_{10} & $PM_{2.5}$ which are set at 150 μg/m^3 and 65 μg/m^3 (24-hrs std) respectively and the daily average of WHO standard values also. $PM_{2.5}$ mass is about 77% of PM_{10}, which indicates the source of particulate matters are mostly from fossil fuel. Begum et al also reported that vehicles normally produce more fine particles ($PM_{2.5}$ particles) than coarse ones ($PM_{2.5-10}$ particles) which mostly originates from mechanical processes and also incomplete combustion of different types of anti-knocking agents containing fossil fuel. The concentrations of PM_{10} and $PM_{2.5}$ at different places in Dhaka city are shown in figure 19 and figure 20 respectively. The higher SPM & PM_{10} mass concentration (636.39 and 299.17μg/m^3 respectively) was found in Uttara than in other locations due to construction work, soil dust, heavy and light vehicles (local all types of Vehicles as well as inter district

heavy buses and trucks plying between Dhaka city and other districts), heavy traffic area, non-combustible materials released when burning fossil fuels (for PM_{10}), mechanical break-up of larger solid particles (for PM_{10}) as well as brick kilns (in winter season). The lowest PM_{10} concentration was found in Jahangirnagar University campus because of lowest number of motor vehicles & industries (Dade W. Moeller; Environmental health, London, 1992). The higher $PM_{2.5}$ mass concentration (80.50$\mu g/m^3$) was found in Tejgaon than in other locations due to vehicles (greater number of CNG & motor bikes plying than heavy buses and trucks) and industrial emissions. The coarse particle ($PM_{2.5-10}$) concentrations are varying from 256.10$\mu g/m^3$ to 4.95$\mu g/m^3$ and the average concentration for coarse fraction is 49.01$\mu g/m^3$ (table 06). $PM_{2.5}$ data have originated from biomass burning, while PM_{10} data have the origin in soil and other sources of dusts.

It is observed that the value of PM_{10} is higher than $PM_{2.5}$ which has been given in the line diagram (figure 21). It may state that the numbers of PM_{10} sources are always higher than the number of $PM_{2.5}$ producing sources. The $PM_{10}/PM_{2.5}$ ratio, which is a measure of relative contribution of anthropogenic (manmade) component of the pollutants compared to natural sources, shows that in Dhaka city, due to growing urbanization of the city both PM_{10} and $PM_{2.5}$ concentrations have increased compared to the previous year data (collected from DoE) but the $PM_{10}/PM_{2.5}$ ratio remain constant. PM_{10} and $PM_{2.5}$ mass concentration and $PM_{10}/PM_{2.5}$ ratio found in the study are shown in table 06.

Table 06: Particulate matter concentration of different size fraction in seven different locations in Dhaka city. (All units are in $\mu g/m^3$)

Sampling locations	SPM	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	$PM_{10}/PM_{2.5}$
Jahangirnagar University, Savar	126.20	62.05	57.10	4.95	1.09
Tower Bhaban, DU Campus	130.83	66.20	54.22	11.98	1.22
Novarties Pharmaceuticals, Tejgaon	146.97	91.23	80.50	10.73	1.13
BCLT, Hazaribagh	227.73	111.22	70.79	40.42	1.57
Medinova Hospital, Dhanmondi	386.21	73.67	63.64	10.03	1.56
BCIC Bhaban, Motijheel	523.03	84.47	75.60	8.87	1.12
Uttara Model Town, Uttara	636.39	299.17	43.07	256.10	6.95
Average (all values for 8 hrs)	**311.05**	**112.57**	**63.56**	**49.01**	**2.09**
Maximum	**636.39**	**299.17**	**80.50**	**256.10**	**6.95**
Minimum	**126.20**	**62.05**	**43.07**	**4.95**	**1.09**
Standard deviation (SD)	**206.94**	**83.95**	**13.12**	**92.08**	**2.15**

Note:

1. $\mu g/m^3$ – Microgram per cubic meter
2. ppm – Parts per million
3. SPM – Suspended particulate matter
4. $PM_{2.5}$ – Particulate matter at 2.5 micrometer
5. PM_{10} – Particulate matter at 10 micrometer

SPM levels at different locations in air of Dhaka city

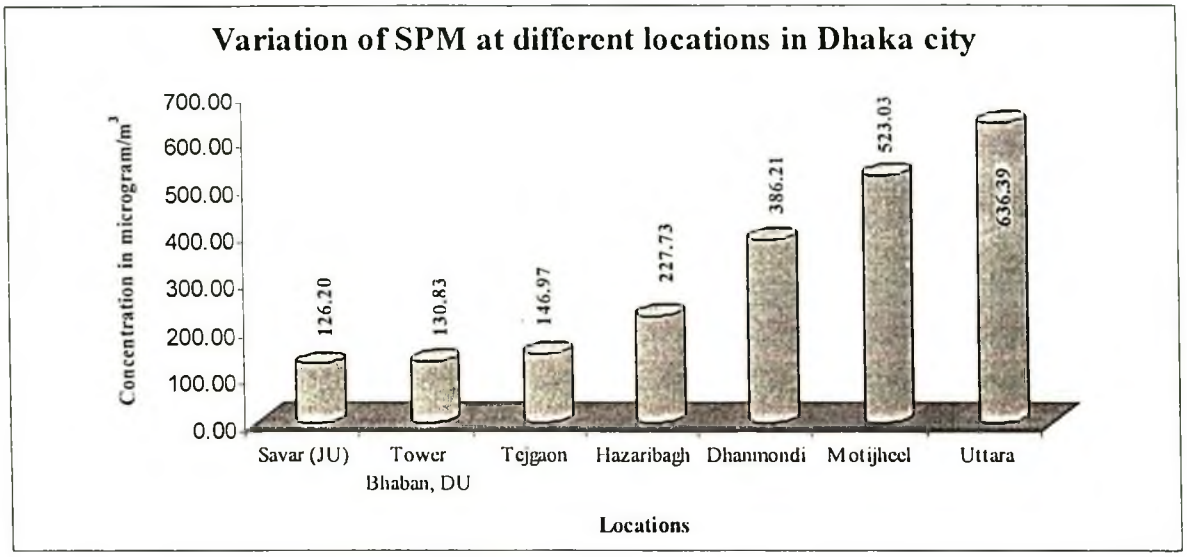

Figure 18: SPM concentration at different places in air of Dhaka city.

PM_{10} at different locations in air of Dhaka city

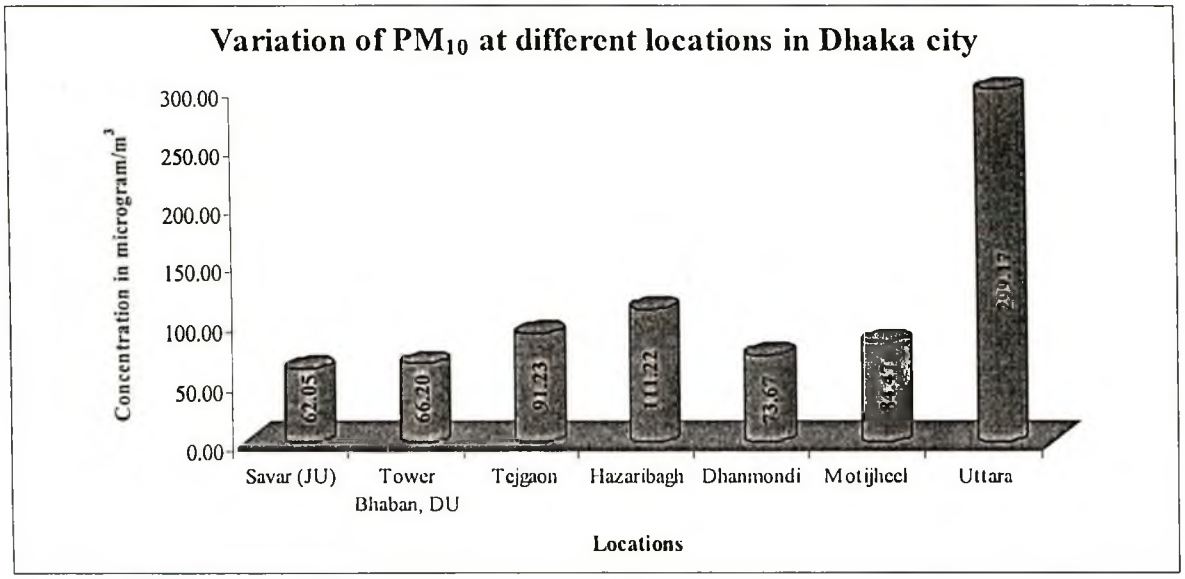

Figure 19: Respirable particulate matter PM_{10} concentration in different Locations in Dhaka city.

$PM_{2.5}$ at different Locations in air of Dhaka city

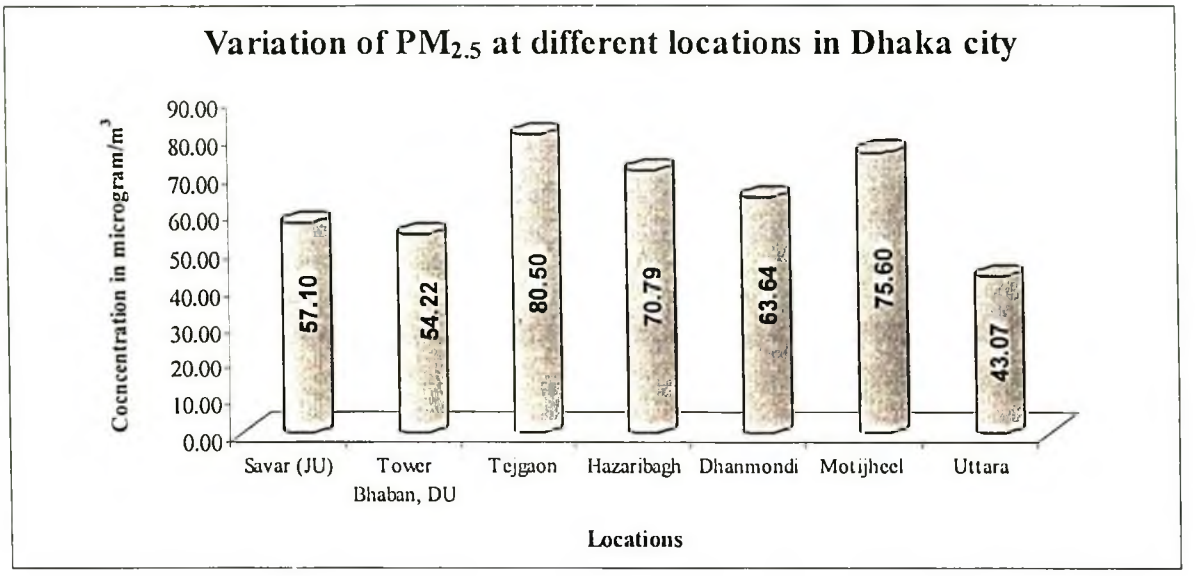

Figure 20 : $PM_{2.5}$ concentration in Dhaka city ambient air

Comparison of PM_{10} & $PM_{2.5}$ in Dhaka city ambient air

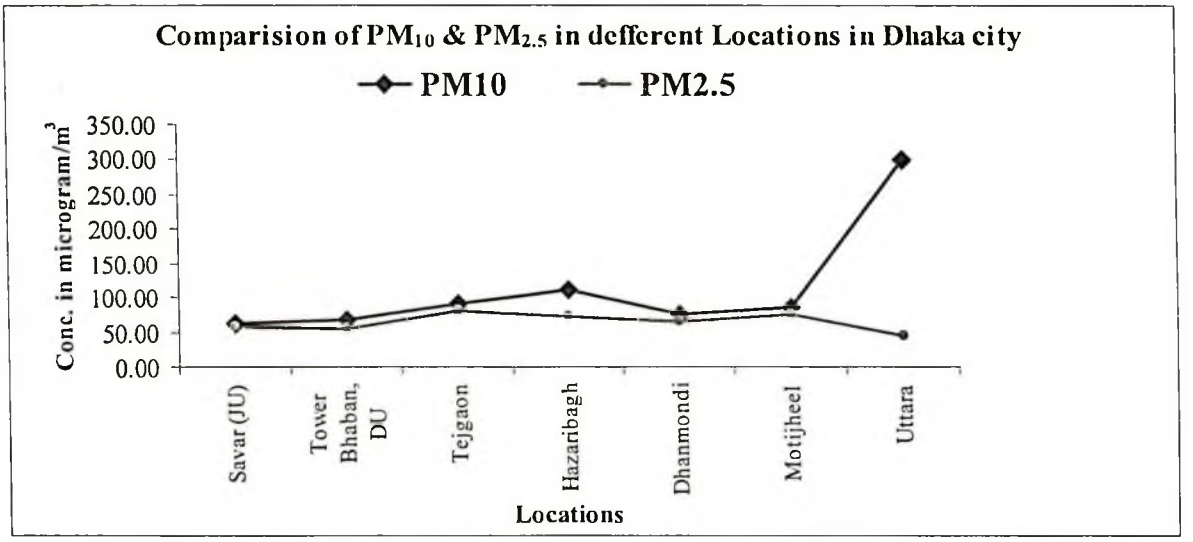

Figure 21: Variation of PM_{10} & $PM_{2.5}$ in ambient air of Dhaka city.

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Table 07: Atmospheric gaseous pollutants at Different Locations in Dhaka City. (All units are in $\mu g/m^3$)

Sampling locations	Average time	CO $\mu g/m^3$	NO_2 $\mu g/m^3$	SO_2 $\mu g/m^3$	O_3 ppm
Jahangirnagar University, Savar	1-hour	41.67	-	-	
	8-hours	-	5.53	20.74	76.47
Tower Bhaban, DU Campus	1-hour	90.81	-	-	
	8-hours	-	24.98	30.53	9.80
Noverties Pharmaceutical, Tejgaon	1-hour	334.23	-	-	
	8-hours	-	23.64	64.27	3.92
BCLT, Hazaribagh	1 hour	607.68	-	-	
	8 hrs	-	16.22	7.45	12.02
Medinova Hospital, Dhanmondi	1-hour	125.00	-	-	
	8-hours	-	40.50	49.06	29.41
BCIC Bhaban, Motijheel	1-hour	238.23	-	-	
	8-hours	-	10.27	76.82	19.60
Uttara Model town, Uttara	1 hour	560.46	-	-	
	8 hrs	-	56.22	28.21	38.14
Average		**285.44**	**25.33**	**39.59**	**27.05**
Maximum		**607.68**	**56.22**	**76.82**	**76.47**
Minimum		**41.67**	**5.53**	**7.45**	**3.92**
Standard deviation (SD)		**226.25**	**17.74**	**24.78**	**24.78**

Note:

1. CO - Carbon monoxide
2. NO_2 - Nitrogen dioxide
3. SO_2 - Sulfur dioxide
4. O_3 - Ozone
5. ppm – Parts per million
6. – No data

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4.3. Gaseous pollutants in Dhaka city air

The ambient air quality standard fixed for Bangladesh is higher than the standards of WHO. Alarmingly, the air quality of Dhaka is even higher than those levels (the values of BD air quality standard, WHO standard and NAAQS). Only the concentration of gaseous pollutants (NO_2, SO_2, CO and O_3) is said to be within acceptable range. The level of ozone exceeds the Bangladesh (BD) air quality standard in summer (especially at noon). The table 07 shows a comparative picture.

4.3.1. Concentration of CO in Dhaka city Air (exposure time 1 hour)

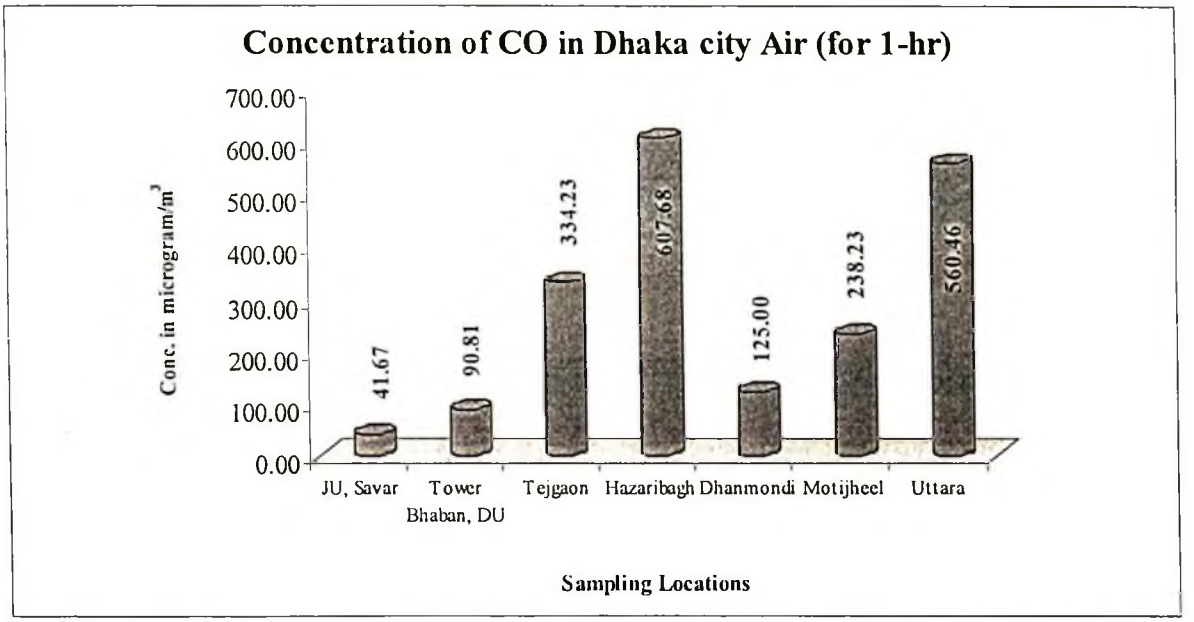

Figure 22: Variation of CO concentrations at different places in Dhaka city air

Carbon monoxide may be produced by the incomplete combustion of CNG, octane, petrol and diesel used as fuel in the vehicle. CO is released during the degradation of chlorophyll in autumn amounting perhaps as much 20% of the total annual release. Anthropogenic (manmade) sources amount for about 6% of CO emissions. The permissible limit of CO is 30 $\mu g/m^3$ for WHO, 40000 $\mu g/m^3$ (40mg/m3) for USA standard (NAAQS) and Bangladesh national air quality standard also (1-hour sampling) (table 03). Higher concentration

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(607.68μg/m^3) of CO was found Tannery area (Hazaribagh) and the lowest concentration 41.67μg/m^3 was found in Jahangirnagar University campus, Savar for 1-hour sampling (figure 22). The high concentration of CO in tannery area is due to the tannery industrial fume produced from the different tannery industries that contained CO and tanneries processing.

4.3.2. Concentration of NO_2 in Dhaka city air (exposure time 8 hours)

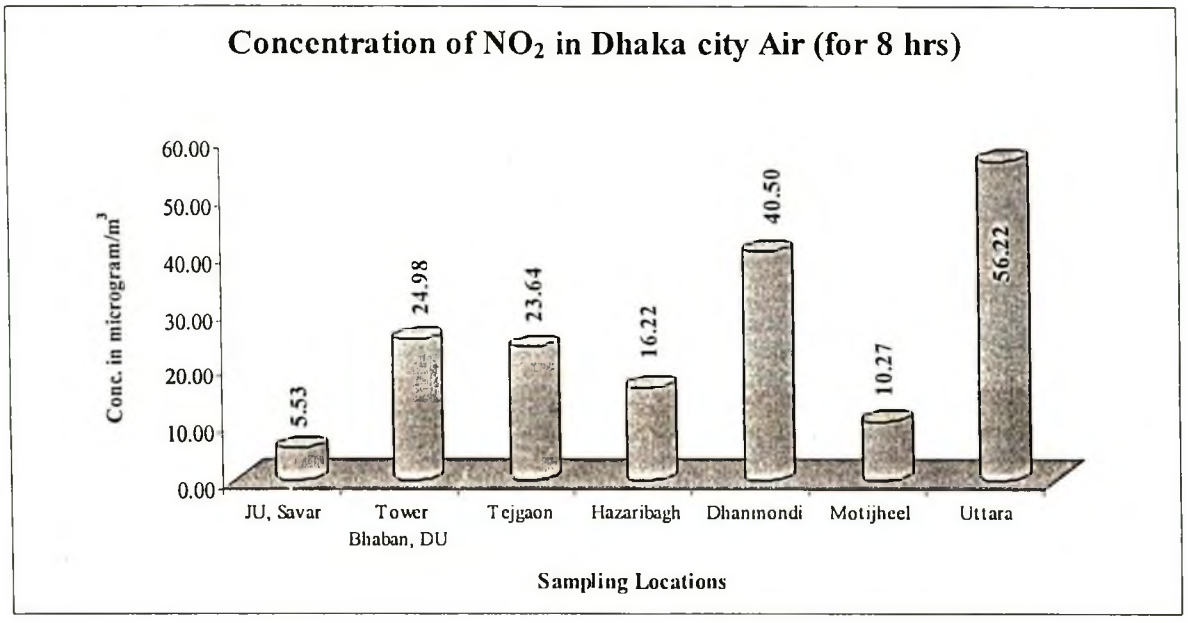

Figure 23: Variation of NO_2 concentrations at different places in Dhaka city air

The three oxides of nitrogen normally encountered in the atmosphere are nitrous oxide, nitric oxide and nitrogen dioxide. NO_2 enters the atmosphere from the natural sources included lighting, action of microorganisms on nitrogen based fertilizer and the major anthropogenic sources is the combustion of fossil fuel. The permissible limit of NO_2 is 150 μg/m^3 (24-hour samplings) for WHO, 100μg/m^3 (annual) for USA standard and Bangladesh national air quality standard also (table 03). Higher concentration (56.22μg/m^3) of NO_2 was found in heavy traffic area (Uttara) and the lower concentration (5.0μg/m^3) was found in Jahangirnagar University campus, Savar for eight hour samplings (figure 23). The higher concentrations of NO_2 was found in Uttara due to heavy traffic zone movement

of inter district buses and trucks, all types of vehicles and power generators (due to electricity gone). It is to be noted that the concentrations of NO_2 found in different locations are much lower than the guideline values of WHO and USEPA standard.

4.3.3. Concentration of O_3 in Dhaka city Air (exposure time 8 hours)

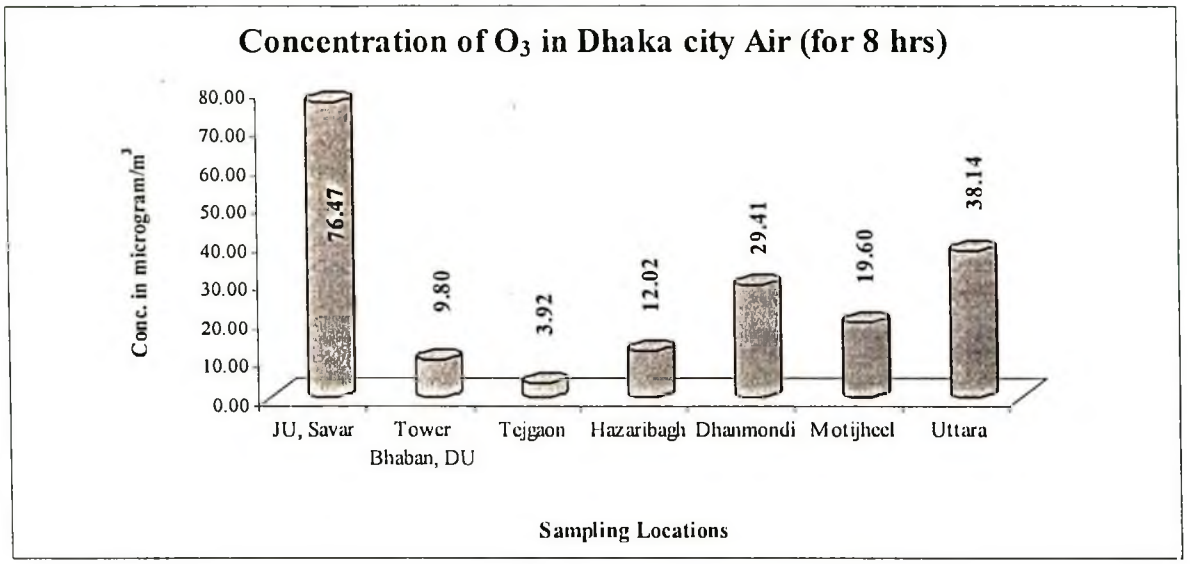

Figure 24: Variation of O_3 concentration at different places in Dhaka city air

Ozone is one of the most ubiquitous and toxic pollutants found in ambient air. Ciliated cells in respiratory airways as well as squamous cells in alveoli are injured or killed by ozone. Ozone may injure tissue membrane by oxidizing the amino acid, sulfhydryl (SH) groups of enzyme and other proteins and polyunsaturated fatty acids (lipids). The permissible limit of O_3 is 150-200 $\mu g/m^3$ (1-hour sampling) for WHO, 0.08 ppm or 157 $\mu g/m^3$ for USEPA standard and Bangladesh air quality standard also (table 03). Higher concentration (76.47$\mu g/m^3$) of O_3 was found in Janhangirnagar University campus and the lowest concentration (3.92$\mu g/m^3$) was found in industrial area (Noverties pharmaceutical, Tejgaon) for 8-hour sampling (figure 24).

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4.3.4. Concentration of SO_2 in Dhaka city air (exposure time hours)

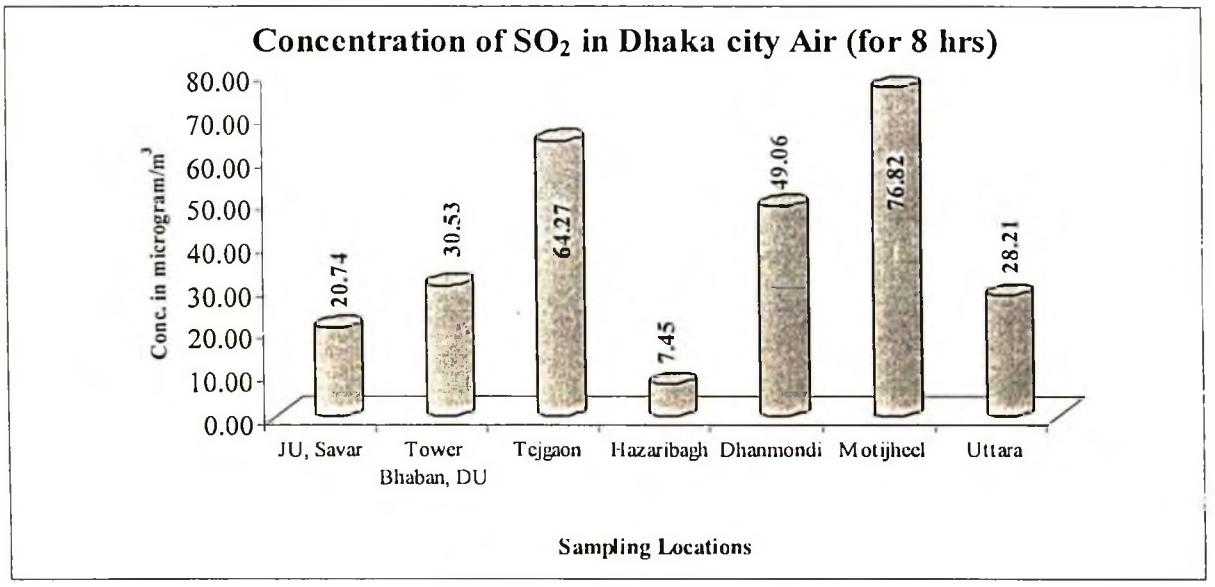

Figure 25: Variation of SO_2 concentration at different places in Dhaka city air

The permissible limit of SO_x is 40-60 $\mu g/m^3$ (annual) for WHO, 365 $\mu g/m^3$ (24-hour)) for Bangladesh (BD) air quality standard and USEPA (NAAQS) standard also (table 03). Higher concentration (76.82$\mu g/m^3$) of SO_2 was found in commercial and heavy traffic area (BCIC Bhaban, Motijhil) and the lowest concentration (20.74$\mu g/m^3$) was found in Jahangirnagar University campus for 8-hour sampling (figure 25). Higher concentration of SO_2 in Dhaka city air is due to the higher sulfur content in our imported vehicles oil. Higher concentration of SO_2 in Motijheel is due to heavy traffic zone.

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4.4. Trace metals

The arbitrary concentrations of the trace metals obtained in the samples collected at Tongi (industrial area, is heavily traveled by trucks and buses), Lalbagh (historical place, old city, residential area and high populated, congested & business area), Continuous air quality monitoring station (CAMS) (located at Sangsad Bhaban's MP hostel, representative of city wide background conditions and Tejgaon (light industrial and heavy traffic area) in Dhaka city are summarized in table 09. Iron (Fe), Zinc (Zn), Chromium (Cr), Nickel (Ni), Manganese (Mn), Copper (Cu), Cadmium (Cd), Lead (Pb), Arsenic (As), Silver (Ag) concentrations were determined with atomic absorption spectrophotometer (AAS) for the size fraction of PM10 & $PM_{2.5}$. The average concentrations of Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, Ag are 4.717, 2.467, 2.111, 1.744, 1.256, 0.824, 0.424, 2.080, 0.105 & 1.403$\mu g/m^3$ in PM_{10} and 2.618, 1.468, 1.279, 1.019, 0.911, 0.432, 0.246, 1.618, 0.050, 0.734$\mu g/m^3$ in $PM_{2.5}$ respectively (table 09 & 10).

The concentrations of iron and lead are much higher than the previous study by Salam et al[101]. The reflections of the results have also been summarized in figure (26-37).

4.4.1. Iron (Fe)

Iron concentrations were determined in PM_{10} glassy micro fibre filter paper from sampling sites Tongi, Lalbagh, Tejgaon and CAMS (sangsad bhaban area) also. The Fe concentrations were found 8.514μg/m3 and 1.292$\mu g/m^3$ in Lalbagh area and Tejgaon respectively. The PM_{10} mass in Lalbagh and Tejgaon were measured 461 μg/m3 and 63$\mu g/m^3$ respectively rather than other locations (table 09). From the figure 26, maximum Fe concentration in PM_{10} was found in Lalbagh and minimum in Tejgaon. It is evident that the highest Fe (table 09) contributions usually formed when the PM_{10} mass concentration was high. Fe concentration was found low when PM_{10} mass was low. The Fe concentration in PM_{10} of different locations in Dhaka city is higher than the Fe concentration in Vienna, Austria (table 08).

The iron concentration in $PM_{2.5}$ size fraction at Tejgaon, industrial area was varied from 4.458$\mu g/m^3$ to 1.736$\mu g/m^3$. Lower concentration of iron in CAMS is due to restricted and

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residential area. Iron content in particles size 10 μm was comparatively higher than the particles size 2.5μm i.e more iron content in PM_{10}. It might be observed that organic particles remain in $PM_{2.5}$ and inorganic particles in PM_{10}.

The same trend of variation of other metals (Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, Ag) as like as iron in all locations were observed in figures 27-35.

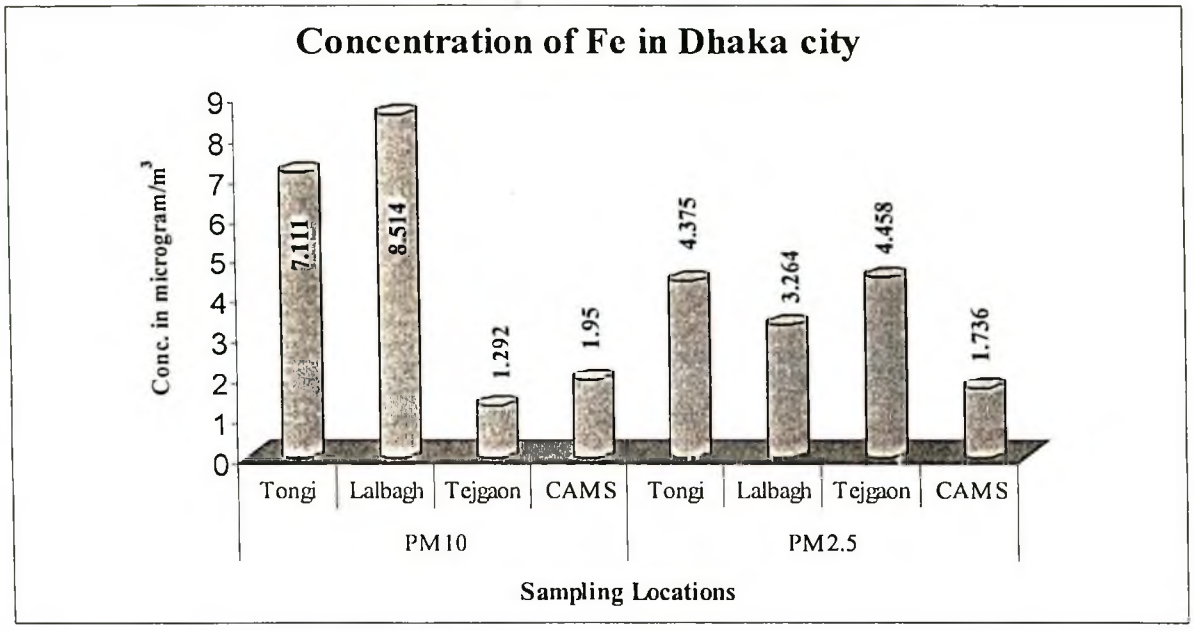

Figure 26: Variation of iron (Fe) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

4.4.2. Zinc (Zn)

The zinc concentrations in PM_{10} were varied from 4.236 to 0.917$\mu m/m^3$, which found at Lalbagh and Tejgaon respectively. The higher value of zinc in PM_{10} at Lalbagh is due to the soil dust, sea salt, and municipal waste incineration and at Tongi due to the industrial and heavy traffic area and soil dust.

The zinc concentrations in $PM_{2.5}$ were varied from 2.431 to 1.0813$\mu m/m^3$, which found at Tejgaon. The higher value of zinc in $PM_{2.5}$ at Lalbagh is due to the soil dust and municipal

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waste incineration. The variation of zinc concentrations at different locations has been given in figure 27.

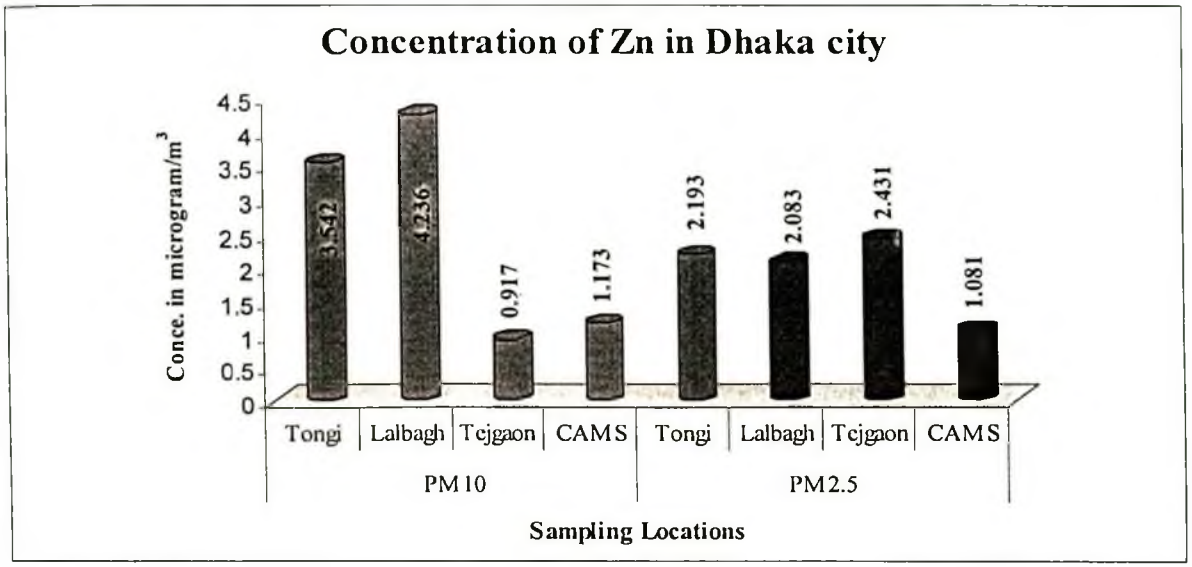

Figure 27: Variation of trace zinc (Zn) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

4.4.3. Chromium (Cr)

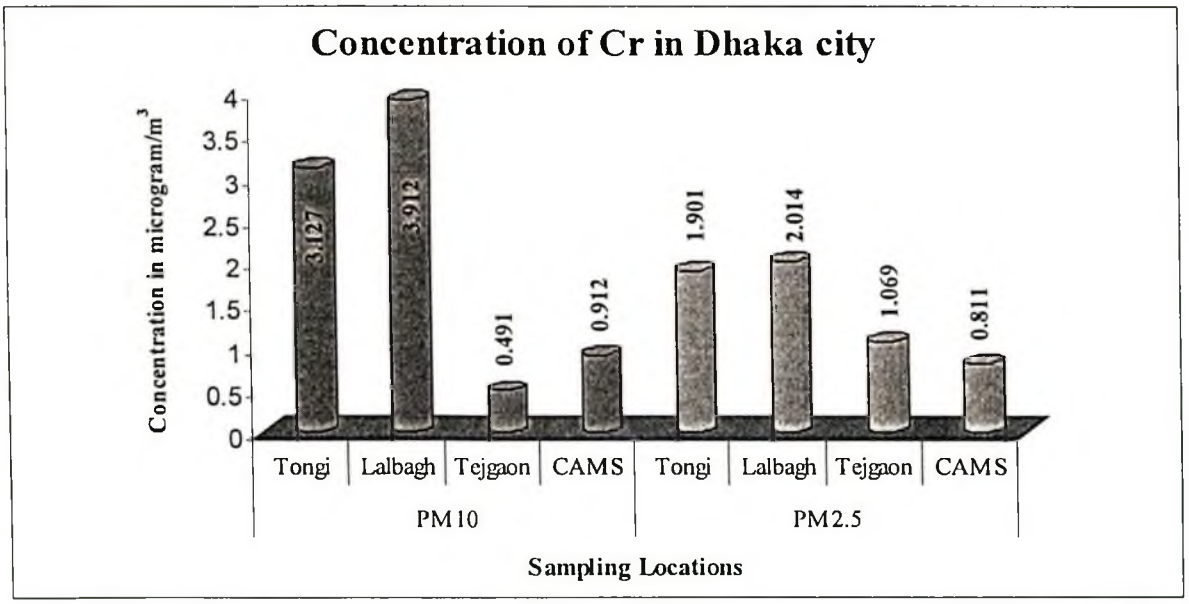

Figure 28: Variation of chromium (Cr) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

The chromium concentrations in PM_{10} were varied from 3.912 to 0.491μm/m^3, which found at Lalbagh and Tejgaon respectively. The higher value of Cr in PM_{10} at Lalbagh is due to the soil dust, sea salt, municipal waste incineration and at Tongi due to the Industrial and heavy traffic area and soil dust.

The chromium concentrations in $PM_{2.5}$ were varied from 2.014 to 0.8111μm/m^3, which found at Lalbagh and CAMS respectively. The higher value of chromium in $PM_{2.5}$ at Lalbagh is due to the soil dust and municipal waste incineration and at Tongi is due to the industrial and heavy traffic area and soil dust. The variation of chromium concentrations at different locations has been given in figure 28.

4.4.4. Nickel (Ni)

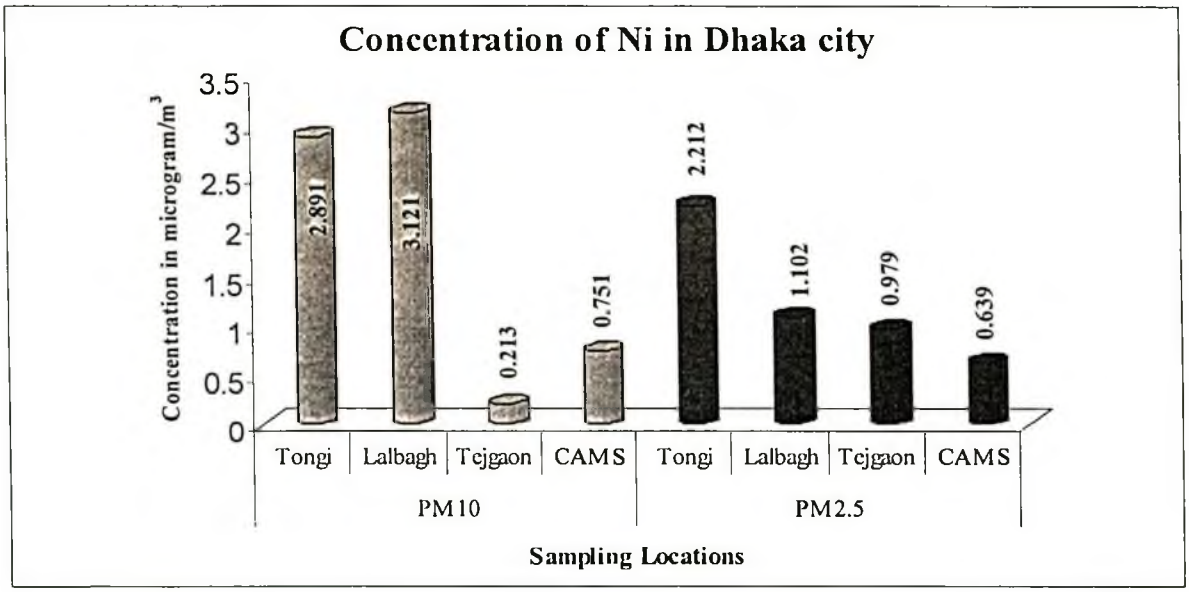

Figure 29: Variation of nickel (Ni) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in μm/m^3)

The nichel concentrations in PM_{10} were varied from 3.121 to 0.213μm/m^3, which found at Lalbagh and Tejgaon respectively. The higher value of Ni in PM_{10} at Lalbagh is due to the

soil dust, sea salt, municipal waste incineration and at Tongi (2.891μm/m^3) is due to the industrial and heavy traffic area and soil dust.

The nichel concentrations in $PM_{2.5}$ were varied from 2.212 to 0.639μm/m^3, which found at Tongi and CAMS respectively. The higher value of nichel in $PM_{2.5}$ at Tongi is due to the industrial and heavy traffic area, the soil dust, metallurgical operations and municipal waste incineration and soil dust also. The lower value of nickel at CAMS is due to restricted and residential area. The variation of nickel concentrations at different locations in Dhaka city has been given in figure 29.

4.4.5. Manganese (Mn) and copper (Cu)

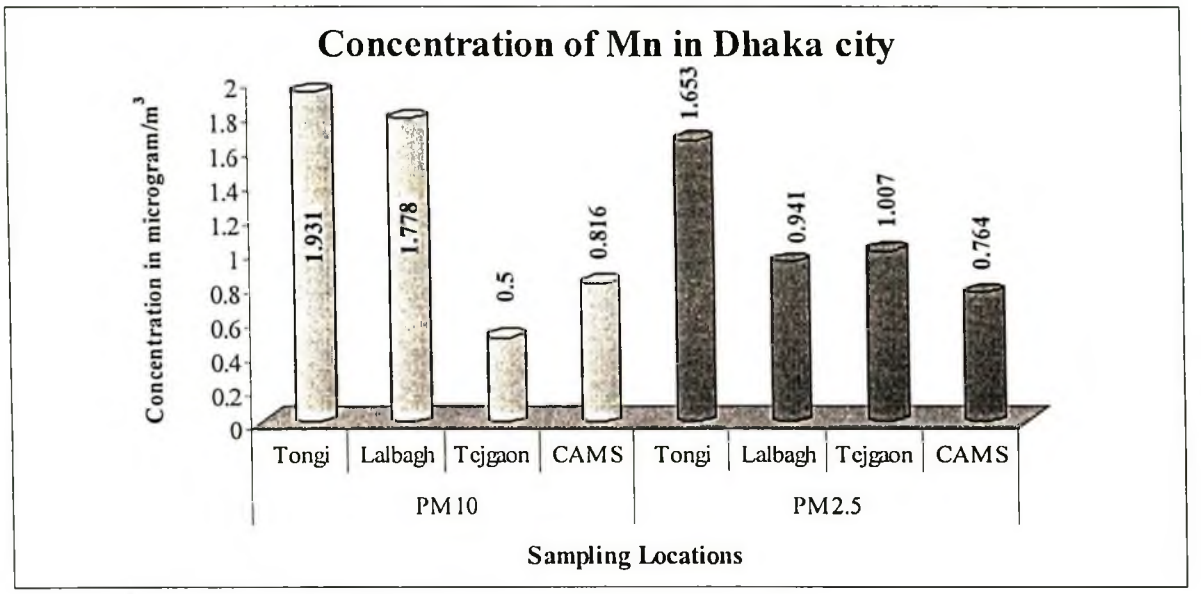

Figure 30: Variation of manganese (Mn) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in μm/m^3)

The concentrations of manganese and copper in PM_{10} were varied from 1.931 to 0.5μg/m^3 and from 1.792 to 0.05 which found at Tongi and Tejgaon respectively. The higher value of Mn and Cu in PM_{10} at Tongi are due to the Industrial and heavy traffic area, the soil dust, metallurgical operations and municipal waste incineration and soil dust.

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The concentrations of manganese and copper in $PM_{2.5}$ were varied from 1.653 to 0.764μg/m^3 and from 0.917 to 0.097μg/m^3 which found at Tongi and CAMS respectively. The higher value of Mn and Cu in $PM_{2.5}$ at Tongi are due to the industrial and heavy traffic area, the soil dust, metallurgical operations and municipal waste incineration and soil dust. The variation of Mn & Cu concentrations at different locations in Dhaka city has been given in figure (30 & 31).

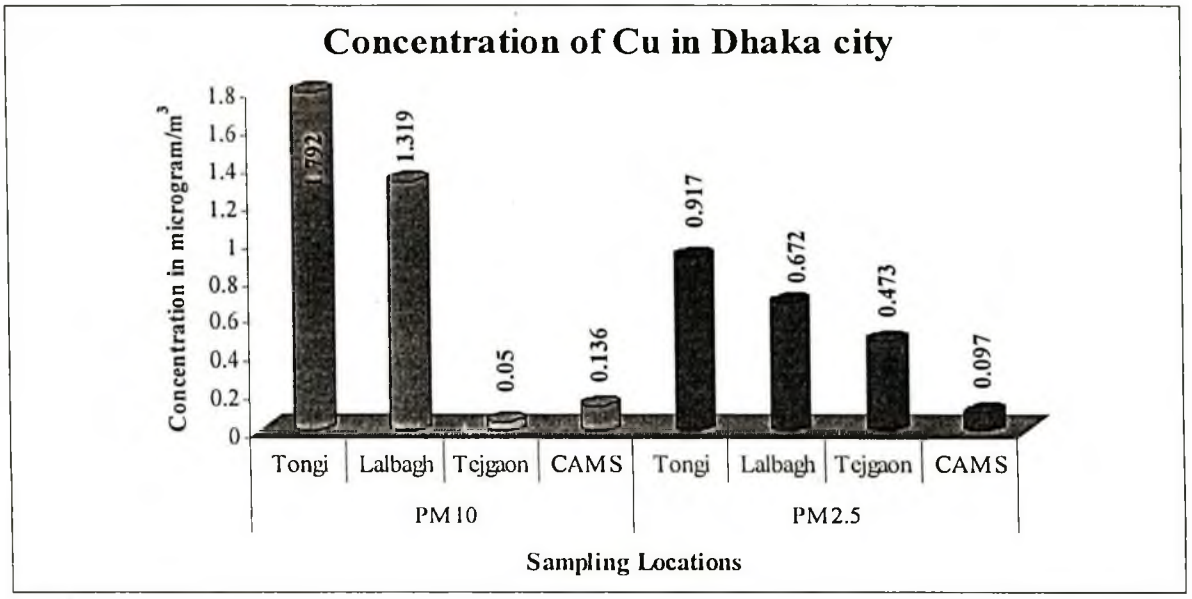

Figure 31: Variation of copper (Cu) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in μm/m^3)

4.4.6. Cadmium (Cd)

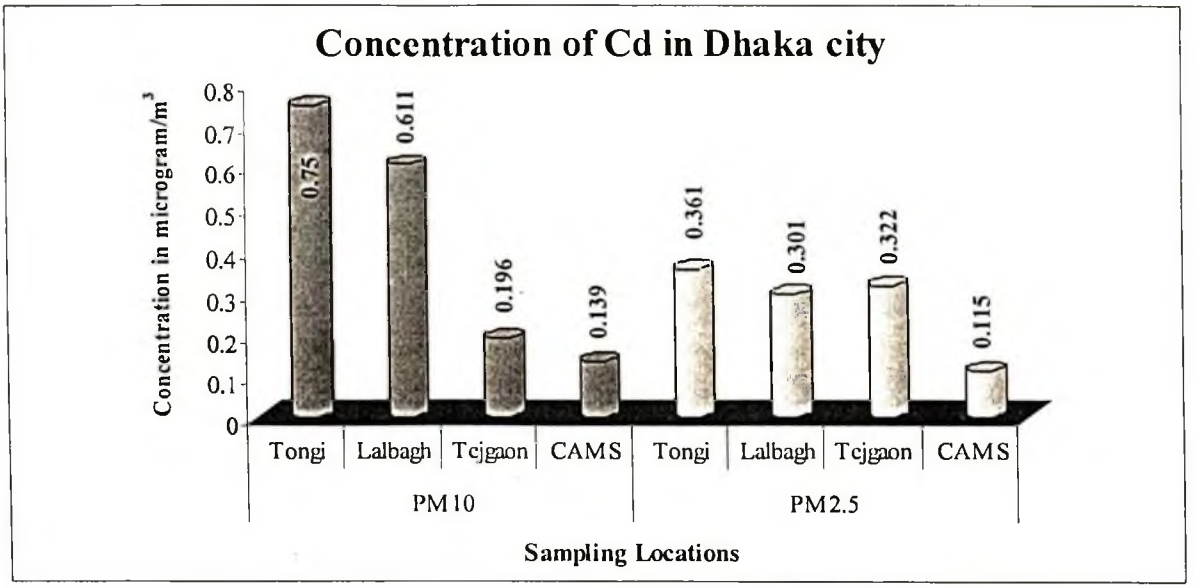

Figure 32: Variation of cadmium (Cd) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

The cadmium concentrations in PM_{10} were varied from 0.75 to 0.139$\mu g/m^3$, which found at Tongi and CAMS respectively. The higher value of Cd in PM_{10} at Tongi (0.75$\mu g/m^3$) is due to the soil dust, industrial and heavy traffic area, sea salt, and municipal waste incineration. On the other hands, the lower value of Cd in PM_{10} at CAMS is due to the residential area.

The cadmium concentrations in $PM_{2.5}$ were varied from 0.361 to 0.115$\mu g/m^3$, which found at Tongi and CAMS respectively. The higher value of Cd (0.361$\mu g/m^3$) in $PM_{2.5}$ at Tongi is due to the soil dust, industrial and heavy traffic area, sea salt and municipal waste incineration. On the other hands, the lower value of Cd (0.115$\mu g/m^3$) in PM_{10} at CAMS is due to the residential and restricted area.

The variation of cadmium concentrations at different locations in Dhaka city has been given in figure 32.

4.4.7. Lead (Pb)

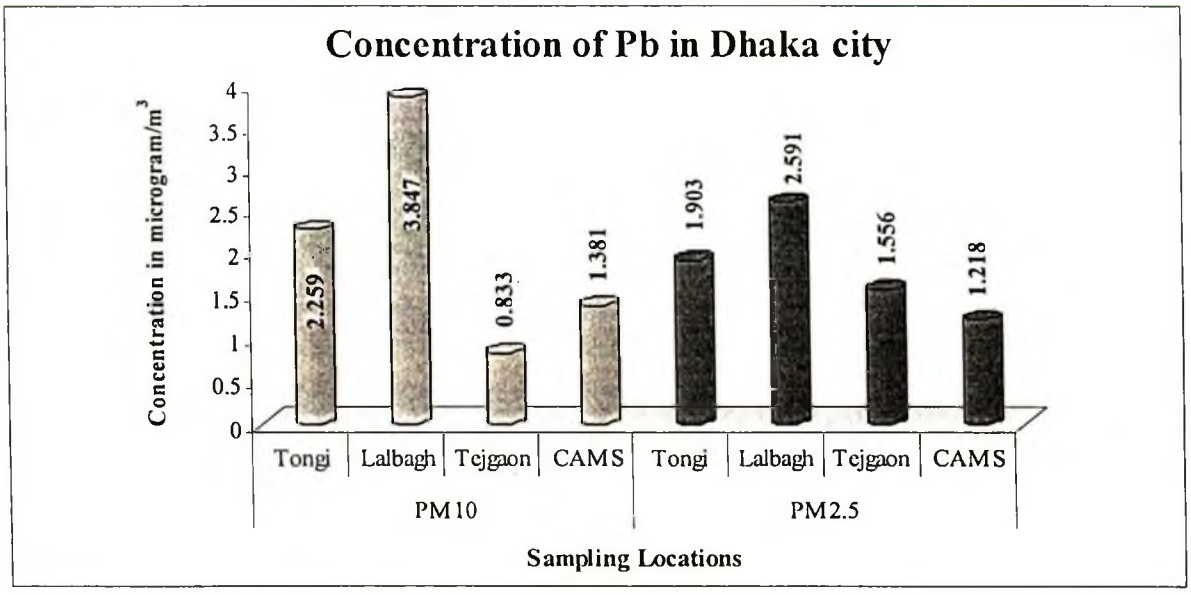

Figure 33: Variation of lead (Pb) concentrations of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

The maximum permissible limit of lead in air is 0.5 $\mu g/m^3$ which designed by DoE, Government of the People's Republic of Bangladesh. Lead concentration was higher in every location beyond the acceptable limit. The Pb concentrations in both PM_{10} & $PM_{2.5}$ were varied from 3.847 to 0.833$\mu g/m^3$ and from 2.591 to 1.218$\mu g/m^3$ respectively (figure 32) among the above locations. The maximum concentration (in both PM_{10} & $PM_{2.5}$) was found in Lalbagh and lower in Tejgaon (for PM_{10}) and in CAMS (for $PM_{2.5}$). The higher value of lead in Lalbagh is due to the soil dust, dry season and wind blow, small size industries, business area and light vehicles. The maximum values of Pb are higher than the concentration found in Los Angels, USA and Vienna, Austria (table 08). The variation of lead concentration at different locations in Dhaka city has been given in figure 33. It is reported that lead level in the rural in Bangladesh was beyond the detection limit [102]

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4.4.8. Arsenic (As)

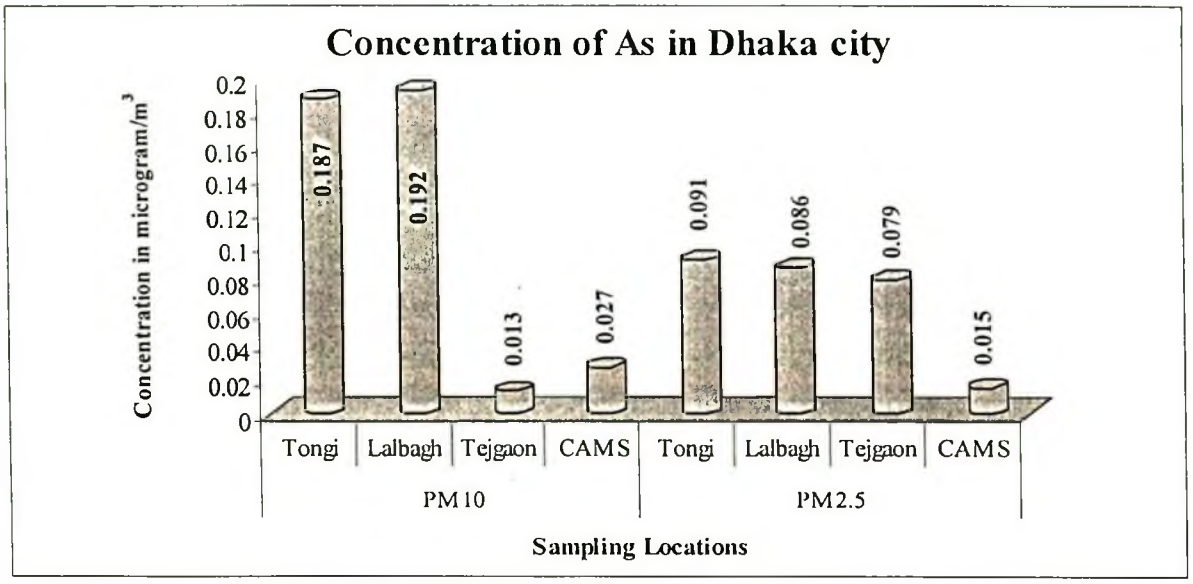

Figure 34: Variation of arsenic (As) concentrations of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

The arsenic concentrations in PM_{10} were varied from 0.192 to 0.013$\mu g/m^3$, which found at Lalbagh and Tejgaon respectively. The higher value of As (0.192$\mu g/m^3$) in PM_{10} at Lalbagh is due to the soil dust, small size industry, business area, municipal waste incineration and at Tongi (0.187$\mu g/m^3$) due to the industrial, and heavy traffic area, soil dust, sea salt, municipal waste incineration. On the other hands, the lower value of As in PM_{10} at Tejgaon is due to the light industrial and traffic area.

The arsenic concentrations in $PM_{2.5}$ were varied from 0.091 to 0.015$\mu g/m^3$, which found at Tongi and CAMS respectively. The higher value of As (0.09$\mu g/m^3$) in $PM_{2.5}$ at Tongi is due to the industrial and heavy traffic area, soil dust, sea salt, municipal waste incineration. On the other hands, the lower value of As in $PM_{2.5}$ at CAMS is due to the restricted and residential area.

Lower value of arsenic was found compare to the other metals because of its availability in the ground water in stead of air.

The variation of arsenic concentrations at different locations in Dhaka city has been given in figure 34.

4.4.9. Silver (Ag)

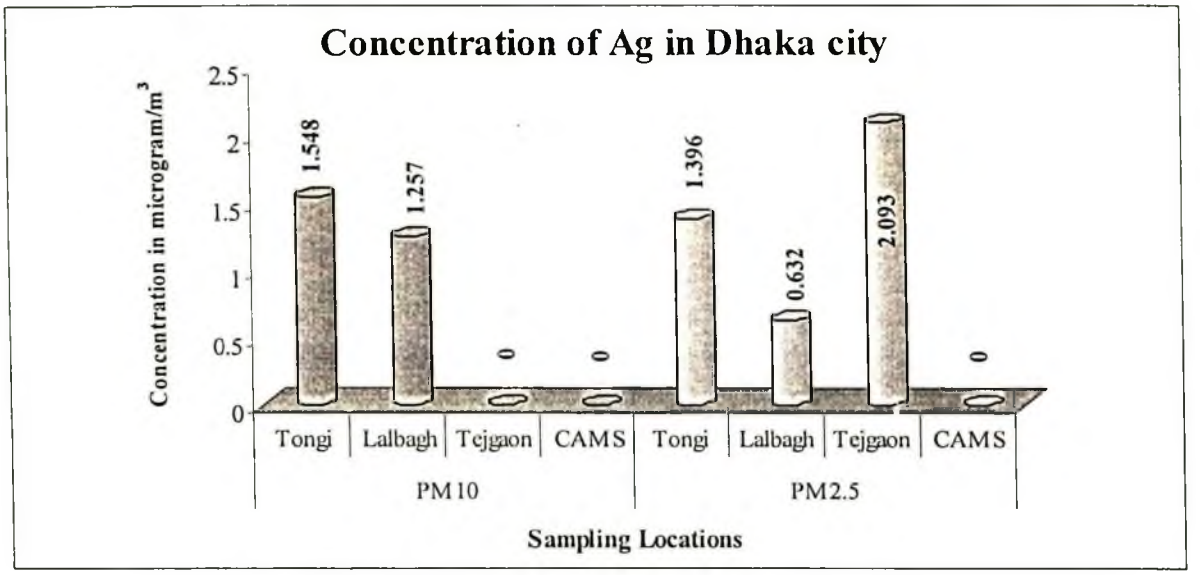

Figure 35: Variation of silver (Ag) concentration of the size fraction of PM_{10} & $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu m/m^3$)

The silver concentrations in PM_{10} were varied from 1.548 to 1.257$\mu g/m^3$, which found at Tongi and Lalbagh respectively. The higher value of Ag in PM_{10} at Tongi (1.548$\mu g/m^3$) is due the industrial and heavy traffic area, soil dust, sea salt, municipal waste incineration, paint and municipal waste incineration. On the other hands, the lower value of As in PM_{10} at Lalbagh is due to the residential area.

The higher value of Ag (2.093$\mu g/m^3$) in $PM_{2.5}$ found at Tejgaon is due to the industrial and traffic area, soil dust, paint, municipal waste incineration. The value of Ag at CAMS is Lower detection limit (LDL).

The variation of silver concentrations at different locations in Dhaka city has been given in figure 35.

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4.5. Percentage of trace elements in Dhaka city (in PM_{10} size)

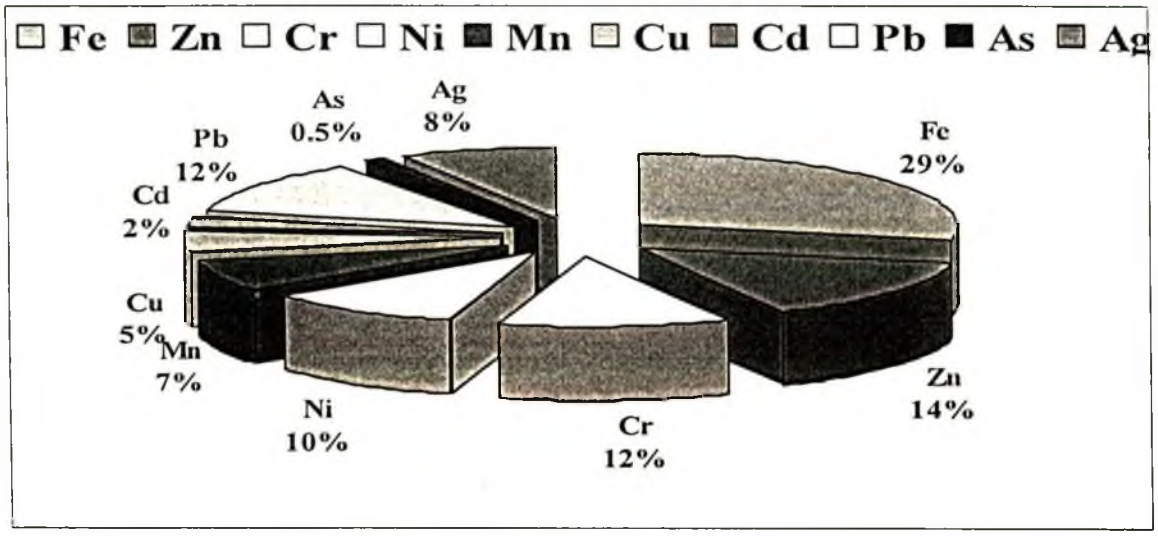

Figure 36: Percentage of determined atmospheric trace elements in PM_{10} at all locations

4.6. Percentage of trace elements in Dhaka city (in $PM_{2.5}$ size)

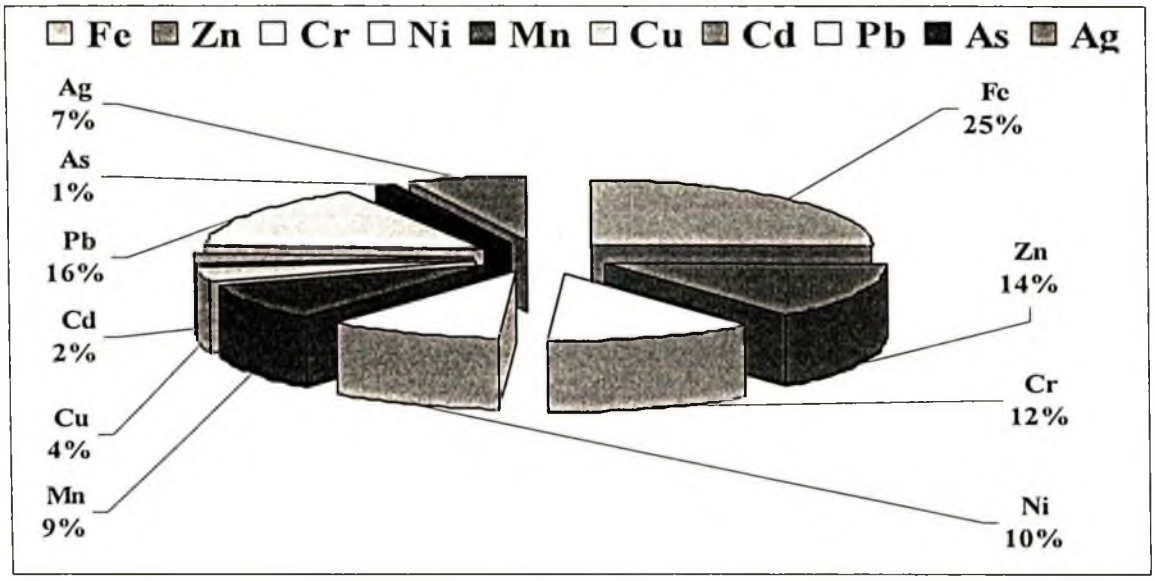

Figure 37: Percentage of determined atmospheric trace Elements in $PM_{2.5}$ at all Locations.

The percentage of the measured trace metals concentrations in the size fraction of PM_{10} and $PM_{2.5}$ at all sampling locations has been given in figure 36 and 37 respectively. The percentage results (higher to lower) of trace elements follow the sequence Fe> Zn> Pb> Cr> Ni> Ag> Mn> Cu> Cd> As in PM_{10} and Fe>Pb> Zn> Cr> Ni> Mn>Ag> Cu> Cd> As in $PM_{2.5}$ respectively. The highest percentages in both PM_{10} & $PM_{2.5}$ were observed for Fe and Zn whereas the lowest percentages were for As and Cd (figure 36& 37). The highest percentage of Fe and Zn indicate that the aerosol in Dhaka is mostly from soil dust. The relatively higher percentages of Ni and Cr were also observed. Lead is atmospheric pollutant and in spite of the banning of lead fuel in Bangladesh, the value of lead is comparatively higher. However, the percentage composition of the measured trace elements in Dhaka indicated that the particulate matter aerosol is a complex mixture of various sources like soil dust, sea salt, varieties of industries, biomass burning and fossil of fuel.

4.7. Comparison of metal concentration of Dhaka with other cities of the World.

The elemental composition of atmosphere aerosols has been determined in several cities around the world; obviously the composition is influenced mainly by local sources, distribution and meteorological conditions. Source of the characteristic standard will be in this section.

The quantitative relationship among trace elements over industrialized N. W. Indiana U. S. A. has been standard by Dams et at (1970). They showed that some elements show only minor variations over the area, while other show marked concentration increase near large industrial complexes – pollution sources.

Table 08: Mean trace metal concentration levels versus counterpart data for other sites around the world. (All units are in µg/m3)

Site		Cu	Fe	Pb	Mn	Ni	Reference
Islamabad, Pakistan (TSP)		-	0.584	0.214	0.059	0.009	N. Shaheen et al (2005)
Tehran, Iran (TSP)		-	2.23	1.02	0.078	0.037	Sohrabpour et al (1999)
Los Angels, USA (PM10)		0.017	0.45	0.13	-	-	Singha et al (2002)
Mumbai, India (PM10)		-	-	-	-	-	Venkataraman et al (2002)
Orgori, Japan (PM10)		-	-	-	-	-	Wakamatsu (1996)[I]
Beijing, China (TSP)		-	51	0.046	1.21	0.051	Mori et al (2003)
Vienna, Austria (PM10)		0.013	0.21	0.025		-	Puxbaun et al (2004)
Yamaguchi, Japan (TSP)		-	9	0.173	0.21	0.016	Mori et al (2003)
Current Study, Dhaka	CAMS	0.136	1.95	1.381	0.816	0.751	
	Lalbagh	3.912	8.514	3.847	1.778	3.121	
	Tongi	1.792	7.111	2.259	1.931	2.891	
	Tejgaon	0.05	1.292	0.833	0.5	0.213	

Elements in atmosphere aerosol may be due to natural processes and / or to human activities. It is not easy to identify the process and therefore one can not always distinguish between a pollutant and a natural component of atmosphere. A very important factor for the discussion of the origin of the various trace elements in atmosphere aerosol is their chemical form. However, this is not easy to measure for the wide variety of elements in the aerosol. In the study of the element concentrations in aerosols from the San Francisco Bay area it was assumed that all the Fe observed was soil derived. Starting with this assumption, the authors have calculated the soil and sea derived concentrations of all the other elements based on this known relative elemental abundances in the soil and seas. It is concluded that the inorganic reaction of the particulate matter is largely soil derived. The element concentration is aerosols in several populated areas in the world are shown in Table 08.

The higher concentration of Fe, Zn and Pb content was found in the aerosols of Dhaka city. Because of less iron, zinc or Lead based over-bridge, underpass, lampposts, billboards constructed in Dhaka city compare to the other urban areas in the world. These iron or zinc or copper based infrastructure mixed with soil by self erosion. Finally, these metals go to air. Moreover, still there is much lead in air because Bangladesh may be used leaded gasoline. This might be another reason which increasing the lead in the Dhaka air.

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Table 09: Trace metals (Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, Ag) concentration of the size fraction of PM_{10} at different locations in Dhaka city. (All units are in $\mu g/m^3$)

Date	Loction	PM size	Concentration of elements in $\mu g/m^3$										PM_{10} ($\mu g/m^3$)
			Fe	Zn	Cr	Ni	Mn	Cu	Cd	Pb	As	Ag	
7/2/2006	Tongi	PM_{10}	7.111	3.542	3.127	2.891	1.931	1.792	0.75	2.259	0.187	1.548	347
12/2/2006	Lalbagh	PM_{10}	8.514	4.236	3.912	3.121	1.778	1.319	0.611	3.847	0.192	1.257	461
11/7/2006	Tejgaon	PM_{10}	1.292	0.917	0.491	0.213	0.5	0.05	0.196	0.833	0.013	BDL	63
2/11/2006	CAMS	PM_{10}	1.95	1.173	0.912	0.751	0.816	0.136	0.139	1.381	0.027	BDL	186
Average			**4.717**	**2.467**	**2.111**	**1.744**	**1.256**	**0.824**	**0.424**	**2.080**	**0.105**	**1.403**	**264**
Maximum			8.514	4.236	3.912	3.121	1.931	1.792	0.75	3.847	0.192	1.548	347
Minimum			1.95	0.917	0.491	0.213	0.5	0.05	0.139	0.833	0.013	1.257	63
SD			3.630	1.670	1.667	1.477	0.706	0.867	0.302	1.316	0.098	0.206	175

Table 10: Trace metals (Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, Ag) concentration of the size fraction of $PM_{2.5}$ at different locations in Dhaka city. (All units are in $\mu g/m^3$)

Date	Loction	PM size	Concentration of elements in $\mu g/m^3$										$PM_{2.5}$ ($\mu g/m^3$)
			Fe	Zn	Cr	Ni	Mn	Cu	Cd	Pb	As	Ag	
7/2/2006	Tongi	PM2.5	4.375	2.193	1.901	2.212	1.653	0.917	0.361	1.903	0.091	1.396	232
12/2/2006	Lalbagh	PM2.5	3.264	2.083	2.014	1.102	0.941	0.672	0.301	2.591	0.086	0.632	219
9/7/2006	Tejgaon	PM2.5	1.097	0.513	0.389	0.122	0.286	0.042	0.208	0.761	0.009	0.173	49
2/11/2006	CAMS	PM2.5	1.736	1.081	0.811	0.639	0.764	0.097	0.115	1.218	0.015	BDL	131
Average			**2.618**	**1.468**	**1.279**	**1.019**	**0.911**	**0.432**	**0.246**	**1.618**	**0.050**	**0.734**	**158**
Maximum			4.375	2.193	2.014	2.212	1.653	0.917	0.361	2.591	0.091	1.396	232
Minimum			1.097	0.513	0.389	0.122	0.286	0.042	0.115	0.761	0.009	0.173	49
SD			1.483	0.809	0.804	0.891	0.567	0.431	0.108	0.801	0.044	0.618	85.258

4.7. Volatile Organic Compounds

By greater source of VOCs is vegetation, but the greater source from human activities is from transportation. Automobile exhaust fills the air in Dhaka city with VOCs beyond tolerable limits. Ambient air samples[103] were collected for 8-hrs by Organic vapour sampler at Mukarram Bhaban, Dhaka University. Primarily Benzene, Toluene, Chlorobenzene, Para-xylene, Ortho-xylene, Meta-xylene, Methoxy benzene, 1,2,4-trichlorobenzene were detected in the air.

These compounds were identified with known chemical structure from GC /MS library and Retention time. VOCs originating from auto exhausts containing a signature of unburned and weathered petrol, diesel, Mobile and CNG, paint, adhesive, waste incineration. The simplicity of the method can be utilized to measure VOCs in many developing countries where air pollution is becoming a serious national problem. Except from a few studies on the measurement of airborne particulate matter[104] there is no sufficient record on other air pollutants in Bangladesh. Further study of VOCs will be under taken in the future. The spectrum of VOCs has been given in figure 37.

The sources of benzene is petrol, gasoline, automobile exhaust fumes, cigarette smoke, emissions from coke ovens and others industrial process, and waste water from certain industries. Areas of heavy vehicular traffic, gasoline stations, and areas near industrial sources may have higher air levels. Some consumer house hold products such as glues, cleaning products, detergents, art supplies and paint strippers, contain benzene. The above mentioned sources are available in Dhaka city for the production of benzene in air.

The main source of chlorinated HC is pesticide, crude petroleum and natural gas extraction, plastic materials and synthetics manufacturing, and petroleum refining. The presence of Chlorobenzene, 1,2,4-trichlorobenzene in air that indicate the some industries might be eliminated the above HC also found in Dhaka city.

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File        :D:\MSDchem\1\DATA\Training\VOC\voc-06.D   (split method)
Operator    : MS
Acquired    : 21 Mar 2008  13:13     using AcqMethod OPCW1-SPLIT.M
Instrument :    JAS GC-MS
Sample Name: 0.4micgm-new
Misc Info   :
Vial Number: 16
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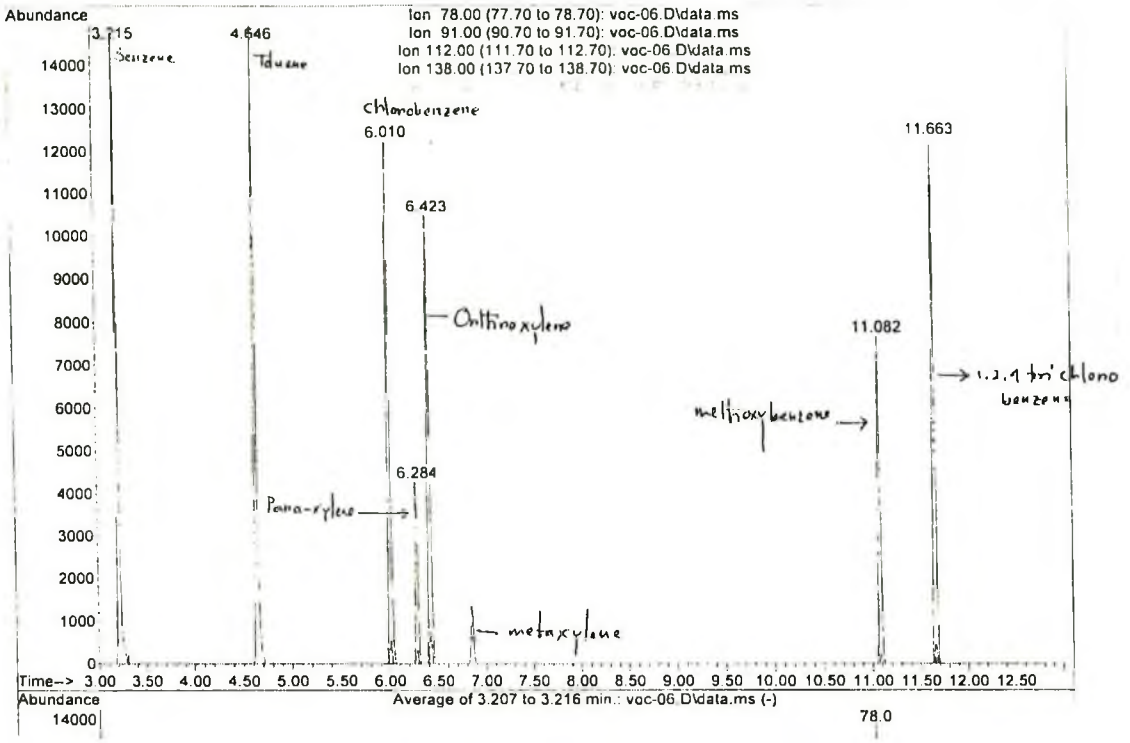

Figure 38: GC/MS – Chromatogram of Dhaka city air.

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The sources of toluene and xylene are paints, paint thinners, adhesives, fingernail polish, and gasoline petrol and petroleum – product components. Toluene and xylene are present in Dhaka city that represent the above sources. The above mentioned VOCs were identified qualitatively and Bangladesh has no standard value. Further study of VOCs will be needed in future.

ঢাকা বিশ্ববিদ্যালয় গ্রন্থাগার

4.9. Case study

New Colony, Agargaon

4.9.1. Particulate matters (SPM, PM_{10} and $PM_{2.5}$)

The concentrations of SPM, PM_{10} and $PM_{2.5}$ were measured during morning to afternoon (6AM- 2PM), afternoon to night (2PM-10PM) and night to morning (10PM-6AM) (table 11). Maximum concentration of SPM, PM_{10} and $PM_{2.5}$ were found in evening due to all kind of activities such as construction work, road repairing and PM producing work are done in the day time as well as all kinds of vehicles (except heavy trucks and buses) ply on city. The temperature at day time is slightly higher than at night. So particulate matter concentrations (as SPM, PM_{10} and $PM_{2.5}$) on day time in the city of Dhaka indicate a slightly increasing tendency. Both PM_{10} and $PM_{2.5}$ mass concentrations (especially dry season) exhibit levels exceeding more than twice the Bangladesh National Air Quality Standards of 24-hr PM_{10} (150 $\mu g/m^3$) and $PM_{2.5}$ (150 $\mu g/m^3$) and the USEPA standard (NAAQS). SPM concentrations also exceed the Bangladesh National Air Quality Standards and USEPA standard of 200$\mu g/m^3$ (table 03). Minimum concentrations were found at night time. As very few vehicles ply comparatively on the city at night as day time. The variation of SPM, PM_{10} and $PM_{2.5}$ concentration in New Colony has been given in figure 39, 40, 41 and 42 with date and time.

The highest concentrations of SPM, PM_{10} and $PM_{2.5}$ recorded in the month of January and November (dry season) in table 12. Because weather remains dry and cold during the month from November to February. On the other hand, the lowest concentration of SPM, PM_{10} and $PM_{2.5}$ are in the month of July and August (rainy season/wet season) (table 12) due to large amount of water vapour, enormous amount of rainfall, high wind speed as well as well disperse pollutant within the higher mixing height.

The figure 43 shows that the particulate matters (SPM, PM_{10} and $PM_{2.5}$) are quite less in the rainy season/wet season than the dry season.

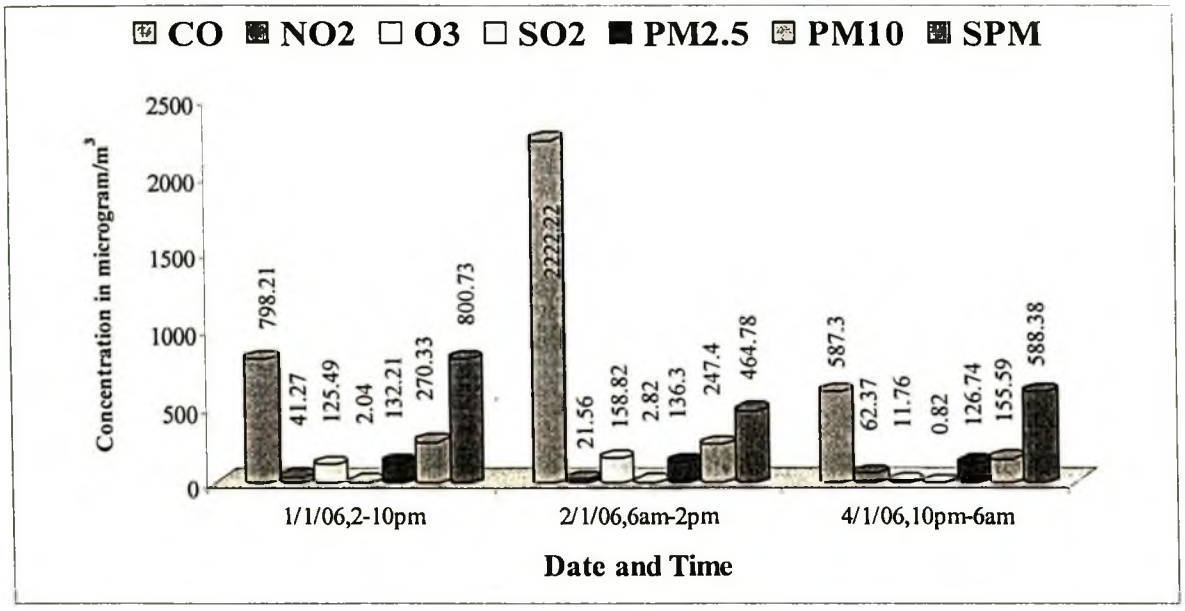

Figure 39: Variation of concentration of air pollutants (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3) for 1/1/06, 2/1/06 and 4/1/06 at New Colony, Agargaon. (All units are in $\mu g/m^3$)

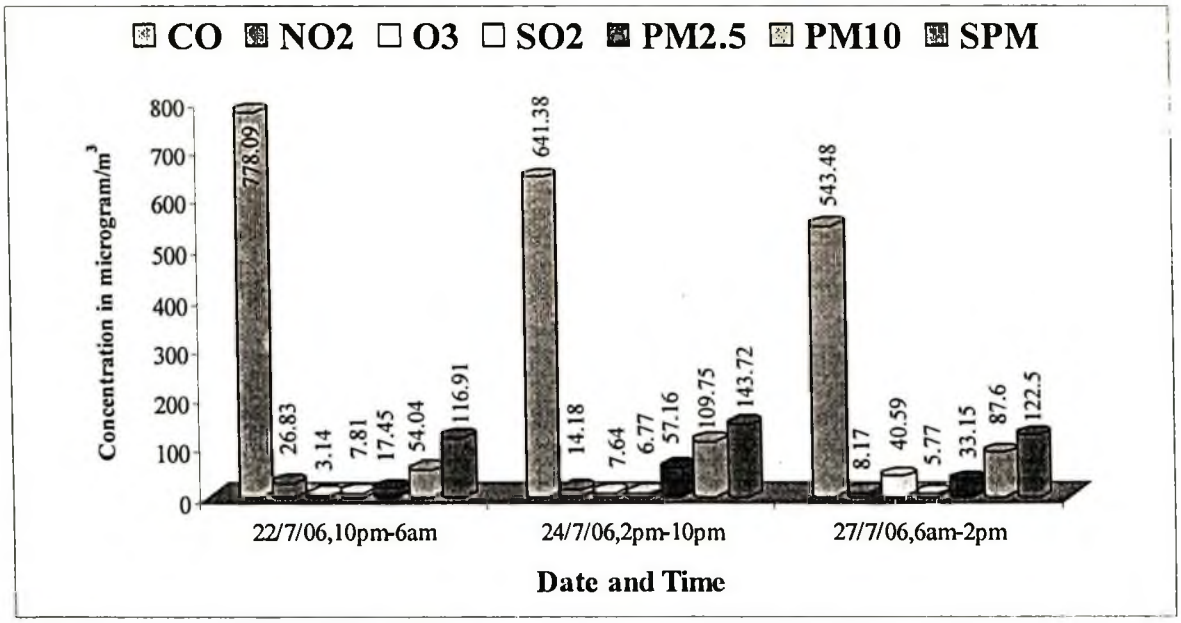

Figure 40: Variation of concentration of air pollutants (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3) for 22/7/06, 24/7/06 and 27/7/06 at New Colony, Agargaon. (All units are in $\mu g/m^3$)

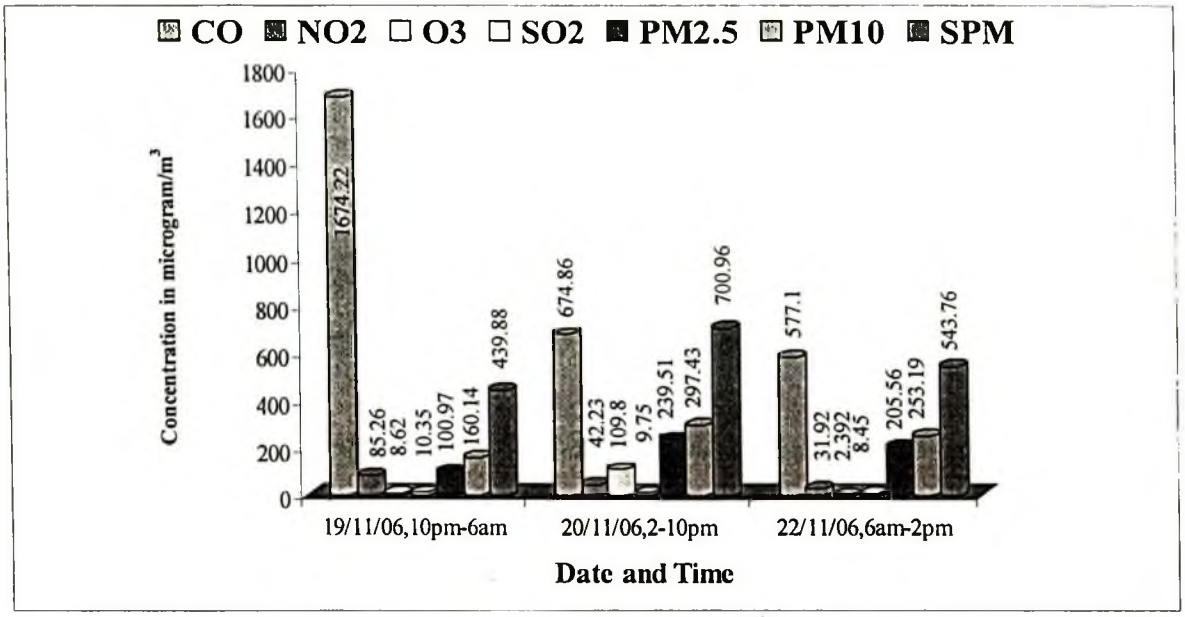

Figure 41. Variation of concentration of air pollutants (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3) for 19/11/06, 20/11/06 and 22/11/06 at New Colony, Agargaon. (All units are in $\mu g/m^3$)

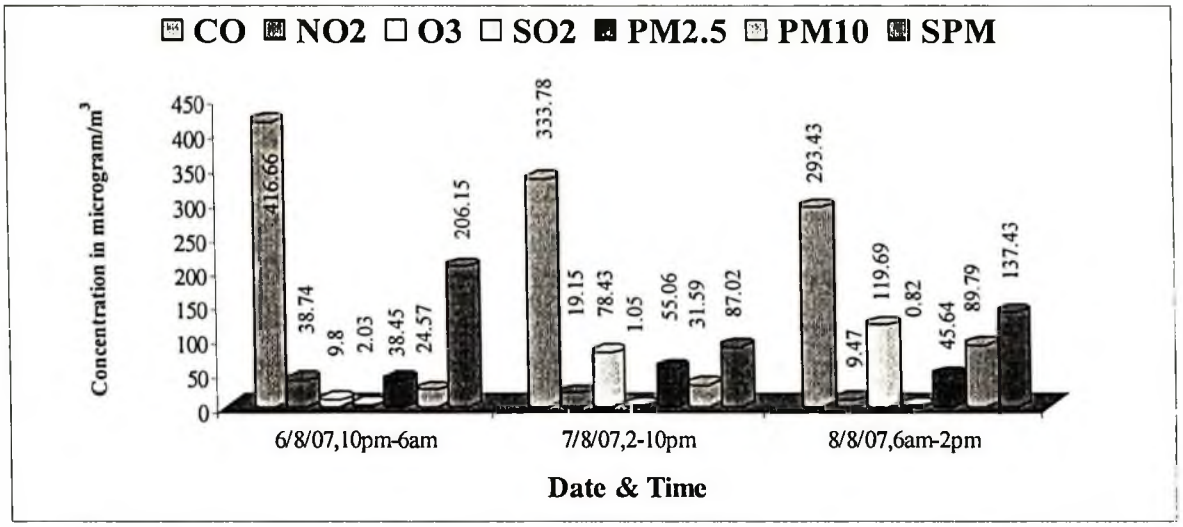

Figure 42: Variation of Concentration of air pollutants (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3) for 6/8/07, 7/8/07 and 8/8/07 at New Colony, Agargaon. (All units are in $\mu g/m^3$)

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4.9.2. Gaseous pollutants

4.9.2.1. Nitrogen dioxide (NO_2), Carbon monoxide (CO) and Sulfur dioxide (SO_2)

The concentrations of NO_2, CO and SO_2 were measured during morning to afternoon (6AM- 2PM), afternoon to night (2PM-10PM) and night to morning (10PM-6AM) (table 11). Maximum concentrations of NO_2, CO and SO_2 were found in night to morning due to old heavy trucks & buses, which produces hues amount of gaseous pollutants. Some of gross emitting NO_2, CO and SO_2 vehicles are only allowed to run at night within city. They are responsible for incomplete combustion of gasoline. When fuel is not completely burn, heavy trucks and buses emit high concentration of CO & NO_2. At night NO_2 & VOCs do not produce ozone because of sunlight absence. NO_2, CO and SO_2 concentrations exhibit levels lowering more than thrice the Bangladesh National Air Quality Standards of NO_2 (100 $\mu g/m^3$), CO (40000 $\mu g/m^3$) and SO_2 (365$\mu g/m^3$) and the USEPA standards (NAAQS). Minimum concentrations were found from morning to evening. Elevated mixing length during day time under unstable atmospheric condition leads the NO_2, CO and SO_2 concentrations lower where as at night time in absence of solar heating stable boundary layer caps the emitted NO_2 and CO adjacent to the surface, the concentrations become higher. The variation of NO_2 and CO concentration in New Colony has been given in figure 39, 40, 41 and 42 respectively.

The highest concentrations of NO_2, CO and SO_2 recorded in the month of January and November (dry season) in table 12. Because the weather remains dry and cold during the month from November to February. On the other hand, the lowest concentration of NO_2, CO and SO_2 are in the month of July and August (rainy season/wet season) (table 12) due to large amount of water vapour, hues amount of rainfall, high wind speed as well as well disperse pollutant within the higher mixing height.

The figure 43 shows that the gaseous air pollutants (NO_2, CO and SO_2) are quite less in the rainy season/wet season than the dry season.

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4.9.2.3. Ozone (O_3)

The concentrations of O_3 were measured during morning to afternoon (6AM- 2PM), afternoon to night (2PM-10PM) and night to morning (10PM-6AM) (table 11). The condition of O_3 concentration is the just the opposition of NO_2. Maximum concentration of O_3 was found in morning to evening due to intense solar heating. The concentrations of O_3 were found low with comparing the Bangladesh National Air Quality and USEPA 8-hr standard of 157μg/m^3 (stand.table 03). Some times especially in dry season, the O_3 concentration 158.82μg/m^3 of dated 2/1/06 exceeds the standard value. The Minimum concentration was found in night time. Ozone is not created directly, but is formed when nitrogen oxide and volatile organic compounds (VOCs) mix in sunlight. Ozone levels increase in cities when the air is still, the sun is bright and the temperature is warm. That is why ozone is mostly found in the summer/dry season. The variation of O_3 at New Colony has been given in figures 39, 40, 41 and 42 respectively.

The highest concentrations of O_3, recorded in the month of January and November (dry season) in table 12. Because weather remains dry and cold during the month from November to February. On the other hand, the lowest concentration of O_3 are in the month of July and August (rainy season/wet season) (table 12) due to large amount of water vapour, enormous amount of rainfall, high wind speed as well as well disperse pollutant within the higher mixing height.

The figure 43 shows that ozone is quite less in the rainy season/wet season than the dry season.

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4.9.4. Seasonal variation of air pollutants in Dhaka city

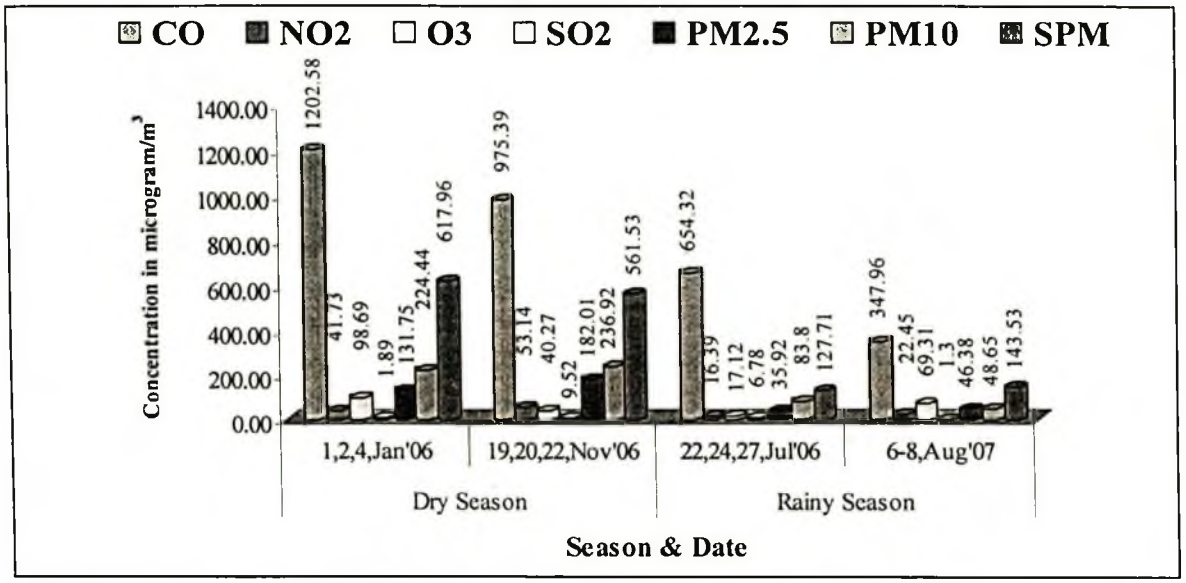

Figure 43: Seasonal variation of average concentration of air pollutants (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, and O_3) at New Colony, Agargaon. (All units are in $\mu g/m^3$)

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Table 11: 8-hour average (except CO for 1-hr) concentration of air pollutants and standard deviation (SD). (All units are in μg/m^3)

Date & Time	CO	NO_2	O_3	SO_2	$PM_{2.5}$	PM_{10}	SPM
1/1/06,2-10pm	798.21	41.27	125.49	2.04	132.21	270.33	800.73
2/1/06,6am-2pm	2222.22	21.56	158.82	2.82	136.3	247.4	464.73
4/1/06,10pm-6am	587.3	62.37	11.76	0.82	126.74	155.59	588.38
Average	**1202.58**	**41.73**	**98.69**	**1.89**	**131.75**	**224.44**	**617.96**
Std	**889.31**	**20.41**	**77.11**	**1.01**	**4.80**	**60.72**	**169.92**
Date & Time	**CO**	**NO_2**	**O_3**	**SO_2**	**$PM_{2.5}$**	**PM_{10}**	**SPM**
22/7/06,10pm-6am	778.09	26.83	3.14	7.81	17.45	54.04	116.91
24/7/06,2pm-10pm	641.38	14.18	7.64	6.77	57.16	109.75	143.72
27/7/06,6am-2pm	543.48	8.17	40.59	5.77	33.15	87.6	122.5
Average	**654.32**	**16.39**	**17.12**	**6.78**	**35.92**	**83.80**	**127.71**
SD	**117.84**	**9.52**	**20.45**	**1.02**	**20.00**	**28.05**	**14.14**
Date & Time	**CO**	**NO_2**	**O_3**	**SO_2**	**$PM_{2.5}$**	**PM_{10}**	**SPM**
19/11/06,10pm-6am	1674.22	85.26	8.62	10.35	100.97	160.14	439.88
20/11/06,2-10pm	674.86	42.23	109.8	9.75	239.51	297.43	700.96
22/11/06,6am-2pm	577.1	31.92	2.392	8.45	205.56	253.19	543.76
Average	**975.39**	**53.14**	**40.27**	**9.52**	**182.01**	**236.92**	**561.53**
SD	**607.17**	**28.29**	**60.29**	**0.97**	**72.21**	**70.08**	**131.44**
Date & Time	**CO**	**NO_2**	**O_3**	**SO_2**	**$PM_{2.5}$**	**PM_{10}**	**SPM**
6/8/07,10pm-6am	416.66	38.74	9.8	2.03	38.45	24.57	206.15
7/8/07,2-10pm	333.78	19.15	78.43	1.05	55.06	31.59	87.02
8/8/07,10am-6pm	293.43	9.47	119.69	0.82	45.64	89.79	137.43
Average	**347.96**	**22.45**	**69.31**	**1.30**	**46.38**	**48.65**	**143.53**
SD	**62.83**	**14.91**	**55.51**	**0.64**	**8.33**	**35.80**	**59.80**

Table 12: Comparison of ambient air quality parameters at Agargaon New Colony between dry and rainy season. (All units are in μg/m^3)

Season	Date	CO	NO_2	O_3	SO_2	$PM_{2.5}$	PM_{10}	SPM
Dry Season	1,2,4,Jan'06	1202.58	41.73	98.69	1.89	131.75	224.44	617.96
	19,20,22,Nov'06	975.39	53.14	40.27	9.52	182.01	236.92	561.53
Rainy Season	22,24,27,Jul'06	654.32	16.39	17.12	6.78	35.92	83.8	127.71
	6-8,Aug'07	347.96	22.45	69.31	1.3	46.38	48.65	143.53
Average		**795.06**	**33.43**	**56.35**	**4.87**	**99.02**	**148.45**	**362.68**

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CHAPTER – FIVE

CONCLUSION AND SUMMARY

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CONCLUSION

Air Pollution is a fate of man made Environmental disasters that are taking place all over the world which may be defined as an atmospheric condition in which various substances are present at concentration high enough above their ambient levels to produce measurable effect on people, animal, vegetation or materials. Among the mega cities of the world, Dhaka is one of the more polluting city.

Before 2003, when two strokes and leaded gasoline engine were moving in Dhaka city, most of the pollutants were quite higher than Bangladesh standard. Now the populations of Dhaka city are facing suspended particulate matters including PM2.5, PM10 and dust (>10 micron) problem in air. As a result, respiratory diseases such as asthma, bronchitis etc is common for the people of Dhaka city. Other pollutants such as NO_2, O_3, SO_2 and CO in Dhaka city are beyond the Bangladesh acceptable limit.

The results of the air pollutants in New Colony was varied with different months which indicates higher amount of pollutants is found in the month of January, March and September. The air pollutants were low in the month of July which indicates Dhaka city is free from pollutants in the rainy season.

The source of metals in air is corrosion, erosion and environmental effect of metal surface. The metals are associated with different size of particulate matters. Among all the trace metals, lead is very toxic to human brain. Although Bangladesh imported leaded free gasoline, but the limit of lead concentration in Dhaka city is beyond the acceptable limit. Because of lead is atmospheric pollutant and release it to air from the different metallic sources.

One of the sources of SPM in Dhaka city might be incomplete combustion of different anti -knocking agent which remains in gasoline. Hydrocarbon, chlorinated hydrocarbon, aromatic compound and its derivatives will be used as an anti-knock agent in gasoline. The combustion process is depended on the conditions of engine. The oldest and recondition engines might be produced a lot of SPM and trace amount of un-combustion anti-knock agent that is VOCs.

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The results of the above finding which indicates if GOB takes the necessary steps to remove the air pollution.

To take necessary action to control air pollution, one has to know the existing level of pollutants in the atmosphere. To do this a long time program should be adopted to study the elemental content of aerosols. As a first step in our country in this direction air samples collected from March' 05 to May' 2005, September' 2007, January' 2008 from different areas of the metropolitan city of Dhaka were analyzed. To have correct picture of the existing level of aerosols and the sources, monthly even weekly data should be collected from different stations. However, air samples were collected at different locations and analyzed them by using flame. SPM, PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3 and ten elements (Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, Ag) were quantitatively determined and identified VOCs in this study. A case study was undertaken at New Colony, Agargaon.

The particulate matters (specially dry season), elemental concentration of ambient air that collected at different locations in Dhaka city is exceeded the threshold limit and as a result the air of Dhaka city is polluted. So government of Bangladesh should take proper steps to have clean air.

Gaseous Pollutants (CO, NO_2 and SO_2) concentrations were below the Bangladesh National Air Quality and USEPA standard and sometimes O_3 exceed this standard.

Aerosol particulate samples were collected with Envirotech samplers during the period of March' 05 to May' 2005, September' 2007, January' 2008 in Dhaka. The average concentrations were 311.05 $\mu g/m^3$ for SPM, 112.57$\mu g/m^3$ for PM_{10} and 63.56$\mu g/m^3$ for $PM_{2.5}$ (Table 03). The aerosol particulate mass was dominated by fine particles (about 77% of PM_{10}), which indicates the fossil fuel burning was the main sources of Dhaka city air pollution.

CO concentration at Hazaribagh was found 607.66$\mu g/m^3$ which is the largest value than CO value of other all sampling Locations.

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Dhaka city is undergoing increasing transformation in industrialization, vehicles and urbanization; the country average urbanization rate is about 21% [130]. AQ monitoring results in the concentrations of criteria air pollutants as mentioned above, are now available for Dhaka city, collected for last four years (2005 -2007). But results from other divisional cities on AQ are very limited to any quantitative judgment about the Air Quality situation. Monitoring activities in these cities should start collecting data. From the available air quality data and the assessment of their impact on human health, it is realized that a countrywide AQM system should be established in Bangladesh, where the economy is at the threshold of transition state and undergoing increasing urbanization and industrialization. With such data, it would be possible to address AQ issues related to mobile sources, fixed point sources, revision of national air quality standards that still remain in a weak state. From this research, it indicates that criteria pollutants, particularly $PM_{2.5}$ data have originated from biomass burning, while PM_{10} data have the origin in soil and other sources of dusts.

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Summery

The quality of air in the metropolitan cities of the country has become a major concern of the people. Among the cities, Dhaka is the worst affected and air pollution is threatening environment and city-dwellers. Dhaka is one of the most densely populated cities in the world and facing a high level of air pollution due to the existence of particulate matter (i.e. fine particle ($PM_{2.5}$) and respirable dust particle (PM_{10})), some gaseous pollutants (like CO, SO_2, NOx, O_3) and Volatile Organic Compounds.

There are two major sources of air pollution in Dhaka, vehicular emissions and industrial emissions. Dhaka, the capital of Bangladesh, is congested with a large number of motor vehicles, including both public and private transportation vehicles. Gasoline engines (especially two-stroke engines) contribute to air pollution by emitting high levels of PM, carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs) and trace heavy metals. Diesel engines also emit high levels of PM, NOx, VOCs, and sulfur oxide (sulfur in diesel fuel is high). A major cause behind the release of a large amount of these pollutants is the exhaust fumes released from faulty engines, old engines especially those run on diesel. A large number of pedestrians, drivers, passengers, traffic policemen, street vendors and other groups undoubtedly suffer from significant health damage as a result of exposure to emissions from a large variety of motorized vehicles including trucks, buses, cars and tow-wheelers. They are responsible for 25% of the particulate matter and 60% of the toxic and smog-forming hydrocarbons contributed by all motor vehicles.

The objective of the study was to determine the concentrations of gaseous pollutants (NO_2, SO_2, CO, O_3) and particulate matters (SPM, PM_{10} & $PM_{2.5}$) to find out the variation of air pollutants in different locations of Dhaka city. The heavy metals Fe, As, Cd, Cu, Ag, Mn, Zn, Cr, Pb, Ni in PM_{10} & $PM_{2.5}$ were determined at different locations of Dhaka city. The lead is higher ($0.5\mu g/m^3$) than Bangladesh standard in particulate matter. Volatile organic compounds (Benzene, Toluene, Chlorobenzene, Para-xylene, Ortho-xylene, Meta-xylene, Methoxy benzene, 1,2,4-trichlorobenzene) were detected in air of Dhaka city.

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A case study was undertaken at New Colony of Agargaon to observe morning to afternoon (PAM-2PM), afternoon to night (2PM-10PM) and night to morning (10PM – 6AM) variation of particulate matter and gaseous pollutants in a day and seasonal variation.

The sampling locations were selected to reflect different influences from industrial and mobile sources in the highly populated center part of Dhaka. Samplings were done on March, April and May' 2005, September 2007 and January from different areas of the metropolitan city of Dhaka (Dhaka University Campus, Dhanmondi, Tejgaon, Motijhil, Jahangirnagar University Campus, Uttara and Hazaribagh). Air sample has also been collected for determination of trace elements form Tongi, Tejgaon, Lalbagh and Sangsad Bhaban Campus.

The aerosol masses of both coarse particle (PM_{10}) and fine particles ($PM_{2.5}$) were determined by the weighing (Gravimetric measurement) (after moisture equilibration at 22 degree temperature and 50% moisture) the filter papers before and after the exposure. For weighing, a four decimal OHAUS analytical balance, model AR 1140 was used.

The gaseous air pollutants (NO_2, SO_2, and O_3) were collected by passing the air through particular absorbent solutions in individual impingers attached by the side of respirable dust sampler at a constant flow rate (100 to 200 ml/min). The absorbent solutions finally analyzed and determined in UV-visible recording double beam spectrophotometer (A Shimadzu UV visible model UV-160A). Individual wavelength was used as a UV source for NO_2, SO_2 and O_3. 560 nm wavelength passed through absorbent reagent for SO_2, 540 nm wavelength for NO_2 and 352 nm wavelength for O_3. The parameters SPM, SO_2 and NO_2 are expressed in microgram/m^3.

For the determination of CO, Envirotech Organic Vapour Sampler APM 850 was used and value is expressed in ppm. CO detector/indicator tube was connected to Teflon nozzle by silicon tube. A measured volume of air is passed at the flow rate of 100 to 200ml/min for 1 to 8 hrs and colour change (yellow to green) in indicating gel of detector tube is matched

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with the colour chart provided with detector tubes for finding out carbon monoxide (CO) concentration.

A known volume of air is passed through activated charcoal tube connected to teflon nozzle by silicon tube with Envirotech Organic Vapour Sampler APM 850 at a constant flow rate (100 to 200 ml/min) with minimum pressure drop (10-15 mmHg). Volatile Organic Compounds (VOCs) was adsorbed on activated charcoal which was later desorbed/extracted using a suitable organic solvent. Extracted/desorbed solvent was used for quantifying the organic compounds with the help of GC-MS.
The heavy metals were also determined through Atomic Absorption Spectrophotometer (Shimadzu, Model: AA-680).

The average concentrations were 311.05μg/m^3, 112.57μg/m^3 and 63.56μg/m^3 for SPM, PM_{10} & $PM_{2.5}$ respectively. The higher SPM & PM_{10} mass concentration (636.39 and 299.17μg/m^3 respectively) was found in Uttara than in other locations due to construction work, soil dust, heavy and light vehicles (including inter district connecting heavy bus and truck with Dhaka), heavy traffic area, non-combustible materials released when burning fossil fuels (for PM_{10}), mechanical break-up of larger solid particles (for PM_{10}) as well as brick kilns (in winter season). The lowest PM10 concentration was found in Jahangirnagar University campus because of lowest number of motor vehicles & industries. The higher $PM_{2.5}$ mass concentration (80.50μg/m^3) was found in Tejgaon than in other locations due to greater number of vehicles ply than heavy bus and trucks. Average concentrations of gaseous pollutants were 285.44μg/m^3, 25.33μg/m^3, 39.59μg/m^3 and 27.05μg/m^3 for CO, NO_2, SO_2 and O_3 respectively. Gaseous pollutant concentration has lower limit than Bangladesh national air quality and USEPA standard value except Ozone. Emission and airborne concentrations of CO, NOx and SO_2 are higher in Dhaka city than Jahangirnagar University campus because of the greater number of motor vehicles and industrial combustion and fuel combustion. CO concentration at Hazaribagh was found 607.66μg/m^3 which is the largest value than CO value of other all sampling locations. The average concentrations were found 4.717, 2.467, 2.111, 1.744, 1.256, 0.824, 0.424, 2.080, 0.105 and 1.403μg/m^3 for Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, and Ag respectively in PM_{10} and

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2.618, 1.468, 1.279, 1.019, 0.911, 0.432, 0.246, 1.618, 0.050, 0.734μg/m^3 for Fe, Zn, Cr, Ni, Mn, Cu, Cd, Pb, As, and Ag respectively in $PM_{2.5}$. The higher concentrations of Fe, Zn, Cr, Ni, Mn for PM_{10} and $PM_{2.5}$ are observed in roads dust samples compared to the other urban areas.

The elemental concentration of ambient air that collected at different locations in Dhaka city is exceeded the threshold limit and as a result the air of Dhaka city is polluted. Therefore, Government of Bangladesh will take proper steps to have clean air.

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CHAPTER – SIX

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CHAPTER – SEVEN

APPENDIXES

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Appendix -A

SAMPLE CALCULATION FOR SULPHUR DIOXIDE, NITROGEN DIOXIDE. OZONE, RESPIRABLE DUST AND TOTAL SUSPENDED PARTICULATE MATTER USING ENVIROTECH RESPIRABLE DUST SAMPLER APM- 460NL				
SL. No.	**Following recorded data**	**Calculated data**		
A. (i)	Initial Manometer Reding (m^3/min)			
(ii)	Fianal Manometer Reding (m^3/min)			
B. (i)	Initial Filter Paper Weight (gm)			
(ii)	Final Filter Paper Weight (gm)			
C. (i)	Initial Time Totalizer Reading (Hrs.)			
(ii)	Final Time Totalizer Reading (Hrs.)			
D. (i)	Initial Dust Cup Weight (gm)			
(ii)	Final Dust Cup Weight (gm)			
E. (i)	Initial Rotameter Reading (lpm)	SO_2	NOx	O_3
(ii)	Final Rotameter Reading (lpm)	SO_2	NOx	O_3
F. (i)	Initial Absorbing Reagent taken for Sampling (ml)	SO_2	NOx	O_3
(ii)	Loss of water due to evaporation (ml)	SO_2	NOx	O_3
G.	Average Flow rate (m3/min.) =[{(A (i) + A (ii))/2}=---------]			
H.	Total on time of Machine (min) = [{C(ii) - C(i) X 60} = ---]			
I.	Dust Accumulated on Filter Paper (gm) = [{B(ii) - B (i)} = --]			
J.	Dust Accumulated on Dust Cup Vail (gm) = [{D(ii) - D (i)} = ----------]			
K.	Total Volume of Air Passed through Cyclone/filter Paper (m^3) = [G x H = ----------]			
L.	Respirable Particulate Matter Concentratin (µg/m^3) = [(I X 10^6)/K =----------]			
M.	Non-Respirable Particulate Matter Concentration (µg/m^3) = [(J X 10^6)/K = ----------]			
N.	Suspended Particulate Matter Concentration (µg/m^3) = [L + M =----------]			
O (i)	Average Flow rate SO_2 (lpm) =[{(E (i) + E (ii))/2}=--------]			
(ii)	Average Flow rate NOx (lpm) =[{(E (i) + E (ii))/2}=-------]			
(iii)	Average Flow rate NOx (lpm) =[{(E (i) + E (ii))/2}=------]			
P (i)	Total Volume of Passed SO2 (lit) = [O (i) x H = ----------]			

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(ii)	Total Volume of Passed NOx (lit) = [O (ii) x H = ----------]		
(iii)	Total Volume of Passed O3 (lit) = [O (iii) x H = ----------]		
Q.	Absorbance	(a) Blank	Concentration
		(b) SO_2	(e) SO_2
		(c) NOx	(f) NOx
		(d) O_3	(g) O_3/10ml
R.	Sample taken for Analysis (ml)	(i) SO_2	
		(ii) NOx	
		(iii) O_3	
S.	Sulphur Dioxide Concentration ($\mu g/m^3$) = [{Q(e) X F(i) X10^3 X D}/{P(i) X R(i)} =----------] Where, 10^3 = Conversion liter to cubic meter, D = Dilution factor		
T.	Nitrogen Dioxide Concentration ($\mu g/m^3$) = [{Q(f) X F(i) X10^3 X D}/{P(ii) X R(i) X 0.82} =----------] Where, 10^3 = Conversion liter to cubic meter, 0.82 = Sampling effiiency D = Dilution factor		
U.	Concentration for O^3/10 ml		
V.	Ozone Concentration (ppm) = [{M X Y F(i)}/{P(iii) X R(i)}] =----------] Where, M = 9.6 as per method O_3 ($\mu g/m^3$) = [{V X 48 X 10^3}/24.47] =----------]		

Note : Initial Reading = Reading taken at time of starting the Sample

Final Reading=Reading taken before switching of the sampler after sampling

Date:……..
Location:……
Time (ON)……
Time (OFF)……

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Appendix -B

SAMPLE CALCULATION FOR $PM_{2.5}$ & PM_{10} USING ENVIROTECH FINE PARTICULATE SAMPLER-APM 550		
1. Location Name : 2. Parameter Monitoring : 3. Date of Monitoring : 4. Time (On) : 5. Time (Off) :		
SL. No.	Following recorded data	Calculated data
A. (1)	Initial filter Paper Weight (gm)	
A. (2)	Final filter Paper Weight (gm)	
B. (1)	Initial Dry gas Meter Reading (m^3)	
B. (2)	Final Dry gas Meter Reading (m^3)	
C. (1)	Initial Time Totalizer Reading (hrs)	
C. (2)	Final Time Totalizer Reading (hrs)	
D.	Total Volume of Air Passed through filter paper (m^3) =[B (2) - B (1) = ...]	
E.	Dust Accumulated on filter paper (gm) = [A (2) - A (1) =……..…..]	
F.	Total Run Time (hrs) = [C (2) - C (1) = ……]	
G.	Particulate Matter Concentration (µg/m3) [$PM_{2.5}$/PM_{10}] =[Ex10^6/D = ….]	
Note :	Initial Reading = Reading taken at the time of starting the sample Final Reading = Reading taken before switching off the sampler after sampling	

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Appendix -C

SAMPLE CALCUALTION FOR CARBON MONOXIDE USING ENVIROTECH ORGANIC VAPOUR APM-850		
SL. No.	**Following recorded data**	**Calculated data**
A. (1)	Initial Time Totalizer Reading (hrs)	
A. (2)	Final Time Totalizer Reading (hrs)	
B. (1)	Initial Flow rate (lpm)	
B. (2)	Final Flow rate (lpm)	
C.	Colour cahrt reading for 1 squeze (%)	
D.	Average Flow Rate (lpm) = [B (1)+B (2)/2] = ...]	
E.	Total Run Time (min) = [A (2) - A(1) X 6 = ...]	
F.	Total Volume Passed (lit) = [D X E = ...]	
G.	CO conecentration ($\mu g/m^3$) = [Cahrt Value of 1 Squeze x 0.75 x 106/F =.....]	

Note : 1 Squeze - 60 CC
Date :
Location :